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DEPARTMENT OF THE INTERIOR

BULLETINS

OF THE

UNITED STATES

GEOLOGICAL SURVEY

VOL. VI

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[Bnlletin No. 37.]

The publications of the United States Geological Survey are issued in accordance with the statute approved March 3, 1879, which declares that—

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

On July 7, 1882, the following joint resolution, referring to all Government publications, was passed by Congress:

"That whenever any document or report shall be ordered printed by Congress, there shall be printed, in addition to the number in each case stated, the 'usual number' (1,900) of copies for binding and distribution among those entitled to receive them."

Except in those cases in which an extra number of any publication has been supplied to the Survey by special resolution of Congress or has been ordered by the Secretary of the Interior, this Office has no copies for gratuitous distribution.

ANNUAL REPORTS.

Of the Annual Reports there have been already published:

I. First Annual Report to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Report of the Director of the United States Geological Survey for 1880-'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 61 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881-'82, by J. W. Powell. 1883. 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882-'83, by J. W. Powell. 1884. 8°. xxxii, 473 pp. 85 pl. and maps.

V. Fifth Annual Report of the United States Geological Survey, 1883-'84, by J. W. Powell. 1885. 8°. xxxvi, 469 pp. 58 pl. and maps.

The Sixth and Seventh Annual Reports are in press.

MONOGRAPHS.

Of the Monographs, Nos. II, III, IV, V, VI, VII, VIII, IX, X, and XI are now published, viz:

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt. U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp 3 pl Price $1.50.

V. Copper-bearing Rocks of Lake Superior, by Roland D. Irving. 1883. 4°. xvi, 464 pp. 15 l. 29 pl. Price $1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price $1.05.

VII. Silver-Lead Deposits of Eureka, Nevada, by Joseph S. Curtis. 1884. 4°. xiii, 200 pp. 16 pl. Price $1.20.

VIII. Paleontology of the Eureka District, by Charles D. Walcott. 1884. 4°. xiii, 298 pp. 24 l. 24 pl. Price $1.10.

IX. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. 1885. 4°. xx, 338 pp. 35 pl. Price $1.15.

X. Dinocerata. A Monograph of an Extinct Order of Gigantic Mammals, by Othniel Charles Marsh. 1885. 4°. xviii, 243 pp. 56 l. 56 pl. Price $2.70.

XI. Geological History of Lake Lahontan, a Quaternary Lake of Northwestern Nevada, by Israel Cook Russell. 1885. 4°. xiv, 288 pp. 46 pl. Price $1.75.

ADVERTISEMENT.

The following is in press, viz:

XII. Geology and Mining Industry of Leadville, with atlas, by S. F. Emmons. 1886. 4°. xxix, 770 pp. 45 pl. and atlas of 35 sheets folio.

The following are in preparation, viz:

I. The Precious Metals, by Clarence King.

— Gasteropoda of the New Jersey Cretaceous and Eocene Marls, by R. P. Whitfield.

— Geology of the Eureka Mining District, Nevada, with atlas, by Arnold Hague.

— Lake Bonneville, by G. K. Gilbert.

— Sauropoda, by Prof. O. C. Marsh

— Stegosauria, by Prof. O. C. Marsh.

— Brontotheridæ, by Prof. O. C. Marsh.

— Geology of the Quicksilver Deposits of the Pacific Slope, with atlas, by George F. Becker.

— The Penokee-Gogebic Iron-Bearing Series of North Wisconsin and Michigan, by Roland D. Irving.

— Younger Mesozoic Flora of Virginia, by William M. Fontaine.

— Description of New Fossil Plants from the Dakota Group, by Leo Lesquereux.

— Report on the Denver Coal Basin, by S. F. Emmons.

— Report on Ten-Mile Mining District, Colorado, by S. F. Emmons.

— Report on Silver Cliff Mining District, by S. F. Emmons.

— Flora of the Dakota Group, by J. S. Newberry.

BULLETINS.

The Bulletins of the Survey will contain such papers relating to the general purpose of its work as do not properly come under the heads of Annual Reports or Monographs.

Each of these Bulletins contains but one paper and is complete in itself. They are, however, numbered in a continuous series, and may be united into volumes of convenient size. To facilitate this, each Bulletin has two paginations, one proper to itself and another which belongs to it as part of the volume

Of this series of Bulletins Nos. 1 to 37 are already published, viz:

1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross, with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons. 1883. 8°. 42 pp. 2 pl. Price 10 cents.

2. Gold and Silver Conversion Tables, giving the coining values of troy ounces of fine metal. etc., by Albert Williams, jr. 1883. 8°. 8 pp. Price 5 cents.

3. On the Fossil Faunas of the Upper Devonian, along the meridian of 76° 30′, from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams. 1884. 8°. 36 pp. Price 5 cents.

4. On Mesozoic Fossils, by Charles A. White. 1884. 8°. 36 pp. 9 pl. Price 5 cents.

5. A Dictionary of Altitudes in the United States, compiled by Henry Gannett. 1884. 8°. 325 pp. Price 20 cents.

6. Elevations in the Dominion of Canada, by J. W. Spencer. 1884. 8°. 43 pp. Price 5 cents.

7. Mapoteca Geologica Americana. A catalogue of geological maps of America (North and South), 1752–1881, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.

8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Van Hise. 1884. 8°. 56 pp. 6 pl. Price 10 cents.

9. Report of work done in the Washington Laboratory during the fiscal year 1883–'84. F. W. Clarke, chief chemist; T. M. Chatard, assistant. 1884. 8°. 40 pp. Price 5 cents.

10. On the Cambrian Faunas of North America. Preliminary studies, by Charles D. Walcott. 1884. 8°. 74 pp. 10 pl. Price 5 cents.

11. On the Quaternary and Recent Mollusca of the Great Basin; with Descriptions of New Forms, by R. Ellsworth Call; introduced by a sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert. 1884. 8°. 66 pp. 6 pl. Price 5 cents.

12. A Crystallographic Study of the Thinolite of Lake Lahontan, by Edward S. Dana 1884. 8°. 34 pp. 3 pl. Price 5 cents.

13. Boundaries of the United States and of the several States and Territories, by Henry Gannett, 1885. 8°. 135 pp. Price 10 cents.

14. The Electrical and Magnetic Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1885. 8°. 238 pp. Price 15 cents.

15. On the Mesozoic and Cenozoic Paleontology of California, by Charles A. White. 1885. 8°. 33 pp. Price 5 cents.

16. On the higher Devonian Faunas of Ontario County, New York, by John M. Clarke. 1885. 8°. 86 pp. 3 pl. Price 5 cents.

17. On the Development of Crystallization in the Igneous Rocks of Washoe, Nevada, by Arnold Hague and Joseph P. Iddings. 1885. 8°. 44 pp. Price 5 cents.

18. On Marine Eocene, Fresh-water Miocene, and other Fossil Mollusca of Western North America, by Charles A. White. 1885. 8°. 26 pp. 3 pl. Price 5 cents.

19. Notes on the Stratigraphy of California, by George F. Becker. 1885. 8°. 28 pp. Price 5 cents.

20. Contributions to the Mineralogy of the Rocky Mountains, by Whitman Cross and W. F. Hillebrand. 1885. 8°. 114 pp. 1 pl. Price 10 cents.

ADVERTISEMENT.

21. The Lignites of the Great Sioux Reservation, by Bailey Willis. 1885. 8°. 16 pp. 5 pl. Price 5 cents.

22. On New Cretaceous Fossils from California, by Charles A. White. 1885. 8°. 25 pp. 5 pl. Price 5 cents.

23. Observations on the Junction between the Eastern Sandstone and the Keweenaw Series on Keweenaw Point, Lake Superior, by R. D. Irving and T. C. Chamberlin. 1885. 8°. 124 pp. 17 pl. Price 15 cents.

24. List of Marine Mollusca, comprising the Quaternary fossils and recent forms from American localities between Cape Hatteras and Cape Roque, including the Bermudas, by William H. Dall. 1885. 8°. 336 pp. Price 25 cents.

25. The Present Technical Condition of the Steel Industry of the United States, by Phineas Barnes. 1885. 8°. 85 pp. Price 10 cents.

26. Copper Smelting, by Henry M. Howe. 1885. 8°. 107 pp. Price 10 cents.

27. Report of work done in the division of Chemistry and Physics, mainly during the fiscal year 1884–'85. 1886. 8°. 80 pp. Price 10 cents.

28. The Gabbros and Associated Hornblende Rocks occurring in the neighborhood of Baltimore, Md., by George H. Williams. 1886. 8°. 78 pp. 4 pl. Price 10 cents.

29. On the Fresh-water Invertebrates of the North American Jurassic, by Charles A. White. 1886. 8°. 41 pp. 4 pl. Price 5 cents.

30. Second contribution to the studies on the Cambrian Faunas of North America, by Charles D. Walcott. 1886. 8°. 369 pp. 33 pl. Price 25 cents.

31. A systematic review of our present knowledge of Fossil Insects, including Myriapods and Arachnids, by Samuel H. Scudder. 1886. 8°. 128 pp. Price 15 cents.

32. Lists and Analyses of the Mineral Springs of the United States; a preliminary study, by Albert C. Peale. 1886. 8°. 235 pp. Price 20 cents.

33. Notes on the Geology of Northern California, by Joseph S. Diller. 1886. 8°. 23 pp. Price 5 cents.

34. On the relation of the Laramie Molluscan Fauna to that of the succeeding Fresh-water Eocene and other groups, by Charles A. White. 1886. 8°. 54 pp. 5 pl. Price 10 cents.

35. The Physical Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1886. 8°. 62 pp. Price 10 cents.

36. Subsidence of fine Solid particles in Liquids, by Carl Barus. 1887. 8°. 58 pp. Price 10 cents.

37. Types of the Laramie Flora, by Lester F. Ward. 1887. 8°. 354 pp. 57 pl. Price 25 cents.

38. Peridotite of Elliott County, Kentucky, by Joseph S. Diller. 1887. 8°. 31 pp. 1 pl. Price 5 cents.

Numbers 1 to 6 of the Bulletins form Volume I; Numbers 7 to 14, Volume II; Numbers 15 to 23, Volume III; Numbers 24 to 30, Volume IV; Numbers 31 to 36, Volume V. Volume VI is not yet complete.

The following are in press, viz:

39. The Upper Beaches and Deltas of the Glacial Lake Agassiz, by Warren Upham.

40. Changes in River Courses in Washington Territory due to Glaciation, by Bailey Willis.

41. Fossil Faunas of the Upper Devonian—the Genesee Section, by Henry S. Williams.

42. Report of work done in the division of Chemistry and Physics, mainly during the fiscal year 1885–'86. F. W. Clarke, chief chemist.

43. On the Tertiary and Cretaceous Strata of the Tuscaloosa, Tombigbee, and Alabama Rivers, by Eugene A. Smith and Lawrence C. Johnson.

In preparation:

44. Historic statement respecting geologic work in Texas, by R. T. Hill.

45. The Nature and Origin of Deposits of Phosphates of Lime, by R. A. F. Penrose, jr.

46. Bibliography of North American Crustacea, by A. W. Vogdes.

— The Gabbros and associated rocks in Delaware, by F. D. Chester.

— Report on Louisiana and Texas, by Lawrence C. Johnson.

STATISTICAL PAPERS.

A fourth series of publications, having special reference to the mineral resources of the United States, has been undertaken.

Of that series the following have been published, viz:

Mineral Resources of the United States [1882], by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1883 and 1884, by Albert Williams, jr. 1885. 8°. xiv, 1016 pp. Price 60 cents.

Mineral Resources of the United States, 1885. Division of Mining Statistics and Technology. 1886. 8°. vii, 576 pp. Price 40 cents.

Correspondence relating to the publications of the Survey, and all remittances, which must be by POSTAL NOTE OR MONEY ORDER (not stamps), should be addressed

TO THE DIRECTOR OF THE
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

WASHINGTON, D. C., *April* 15, 1887.

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[illegible] Ferns and Fern Allies [illegible], by Lawrence C. Johnson [illegible]

STATISTICAL PAPERS

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[illegible] of the United States, 1880 and 1884, by Albert Williams [illegible]

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DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 37

WASHINGTON
GOVERNMENT PRINTING OFFICE
1887

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

TYPES

OF THE

LARAMIE FLORA

BY

LESTER F. WARD

WASHINGTON
GOVERNMENT PRINTING OFFICE
1887

CONTENTS.

ILLUSTRATIONS.

TYPES OF THE LARAMIE FLORA.

By Lester F. Ward.

EXPLANATORY REMARKS.

I have in preparation a work on the flora of the Laramie group, in which will be described and figured a very large number of fossil plants, most of which were collected by myself in the seasons of 1881 and 1883 and the elaboration of which has occupied most of my time since the latter date. The work of illustrating this material has progressed slowly and cannot be completed earlier than the end of the present year (1887), after which much will still remain to be done before the volume can be ready for publication. Realizing this, and also the fact that the illustrated monographs of the Geological Survey are usually long delayed in printing, and feeling the importance of making known the general character of these additions to the Laramie flora at an earlier date, I thought best to prepare and publish as a preliminary sketch some of the more striking types from among the collections. Accordingly, in July, 1885, there were submitted for publication in the Sixth Annual Report of the Survey, at the close of my paper entitled "Synopsis of the Flora of the Laramie Group," thirty-five double plates, containing one hundred and thirty-nine figures, accompanied by a list of the provisional names which my studies up to that time had enabled me to assign.

In that paper, a portion of which was devoted to a description of the localities at which the material was collected, it was explained that the selections were not made altogether from the best or most instructive specimens, but consisted rather of the more representative types of such as were then ready, and that it was expected that further research would elucidate many obscure points and suggest important modifications.

It was no part of my purpose in that paper to furnish descriptions of the species regarded as new and lack of space debarred me from introducing critical comments upon any of the forms figured. As, however, such descriptions and discussions are necessary to the proper understanding of the figures and of the nature of the flora under treatment, I commenced to characterize these forms on my return from the field in September, 1885, and to append such explanatory notes as were necessary to render this part of the work intelligible and available to scientific men. The present bulletin is the result. I had originally intended to publish it merely as a text to the figures in the Sixth Annual Report, but it was finally decided to rearrange the figures on plates of smaller size, adapted to the bulletins, and thus render the work complete in itself.

No changes have been made in the names given to the species in the previous paper, but wherever, as has sometimes occurred, later investigations have led me to modified conclusions relative to the proper affinities of the forms described, the changes thus proposed are mentioned in the discussions.

The following table will show the corresponding figures in the two sets of plates:

Table to facilitate cross-reference between the plates and figures in this bulletin and the same figures as published in the Sixth Annual Report of the U. S. Geological Survey, Plates XXXI to LXV.

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	2		2		6		9		2		5
	3		3	VIII	1		10	XIII	1	XXXIX	1
	3a		3a		2		11		2		2
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	9		9		5		8		5		3
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	4		2		2		13		3		8
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XXV	1		4		4		15		5		10
	2		5		5	LII	1	XLI	1	LVI	1

Table to facilitate cross-reference between plates and figures in this bulletin, &c.—Cont'd.

Bulletin.		Annual Report.		Bulletin.		Annual Report.		Bulletin.		Annual Report.	
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	5		5		3		6		3		7
	6		6		4		7		4		8
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	4		4		2		10		2		5
XLVIII	1		5		3	LXIII	1		3		6
	2	LX	1		4		2		4		7
	3		2		5		3		5		8

DESCRIPTION OF THE SPECIES.

CRYPTOGAMS.

ALGÆ.

FUCUS L.

This genus as now restricted is almost exclusively confined to the northern hemisphere, the sea-weeds of the southern hemisphere going by different names. It is a tidal form and not found in deep water. About a dozen species are known, which, however, gives no idea of their vast abundance upon the rocky shores where they grow. They are mostly high northern, and the greater part of the species are common to both the Old and the New World. Until recently the only fossil species recognized were those described by Watelet from the Paris Basin, six of which were considered sufficiently reliable to be accepted by Schimper in his Paléontologie végétale. Since the appearance of the latter work Heer has detected the remains of one of the living species (*F. caniculatus* L.) in the Quaternary deposits of Spitzbergen. Lesquereux and myself have found the species mentioned below in two different localities belonging to the Laramie group, and Pilar thinks he recognizes two species of Fucus in the Miocene deposits of Sused.

Fucus lignitum Lx.

FUCUS LIGNITUM Lx., Bulletin U. S. Geol. Survey of the Territories, Vol. I, No. 5, p. 364; Annual Report do., 1874, p. 296; Tert. Fl., p. 42, pl. lxi, figs. 24, 24*a*.

Plate I, Figs. 1, 2.—Point of Rocks, Wyoming; white sandstone bed east of station (Fig. 1). Burns's Ranch, Montana (Fig. 2).

The specimen represented by Fig. 1 comes from the same bed at Point of Rocks as that collected by Dr. F. V. Hayden and figured by Prof. Leo Lesquereux. It is a somewhat fuller specimen and shows more of the branches. The other specimen (Fig. 2) was found at Burns's Ranch, on the Yellowstone, and has already been referred to as part of the evidence of partial synchronism of the two beds. Though an inferior specimen it seems to belong to the same species. Prof. Lesquereux refers to its resemblance to *Sphærococcites crispiformis* Schloth.; and *S. Schambelinus* Heer (Urwelt der Schweiz, pl. iv, fig. 1) may also be profitably compared. In its external character, at least, it closely resembles forms of Gelidium (see Saporta, Algues Fossiles, pl. iii, figs. 1*b*, 3), and also some forms of Chondrites.

SPIRAXIS Newberry.

A genus recently created, as mentioned below. It seems to be one of the ancient forms of fossil kelp, the more recent representatives of which go by the name of Halymenites.

Spiraxis bivalvis, n. sp.

Plate I, Fig. 3.—Head of Clear Creek, Montana.

Body cylindrical or fusiform, often tapering toward both ends, traversed by numerous fine spiral ridges at an angle of 60° to the axis, slightly verrucose, minutely fistulose at the center, cleft through longitudinally by a plane that generally passes a little to one side of the center and is either strictly tangential or slightly curved, the larger segment often cleft also through its center, or sometimes the cylinder divided by three planes of cleavage into three nearly equal segments uniting at the center.

This is the peculiar fucoid found near the head of Clear Creek, to which reference was made when treating of that locality. It certainly bears a strong general resemblance to some of the "screw-like fossils from the Chemung rocks" recently made known by Dr. J. S. Newberry (Annals N. Y. Acad. Sciences, Vol. III, pp. 217–220, pl. xviii) under the name of Spiraxis, and although his specimens came from a very much lower horizon his theory of their fucoidal character is doubtless correct and the present specimens from the Fort Union group probably belong to the same form of life. I have therefore ventured to refer them to the same genus, although this may extend its geological range more widely than the author intended.

The specific name is based upon the tendency, already referred to, which this particular form exhibits, to split into two valves or halves by a longitudinal cleavage which passes across the spiral striæ upon the surface without being in the least affected by them.

PHANEROGAMS.

GYMNOSPERMS.

CONIFERÆ.

GINKGO L.

The sole living representative of this once abundant genus is thought to have been confined to China prior to the advent of man, but now it is not only widely distributed throughout eastern Asia and Japan, but also throughout the western world as an ornamental tree. In the fossil state it ranges from the Permian to the Miocene. Two of the twenty-five fossil species have already been described from the Laramie group, to which two more are here added.

Ginkgo Laramiensis Ward.

GINKGO LARAMIENSIS Ward, Science, Vol. V, June 19, 1885, p. 496, fig. 7.

Plate I, Fig. 4.—Point of Rocks, Wyoming; gray sandstone bed north of station.

Leaves small (3 to 5 cm. in width), narrowed to the petiole, the margin undulate, sinuate, or somewhat lobate; nerves flabellate-divergent, many times dichotomous.

The occurrence of sinuses of variable depth at irregular intervals around the margins of the leaves is the chief distinction which separates this form from both *G. adiantoides* and *G. biloba*, between which it clearly holds an intermediate position.

Twelve fragments of this leaf were collected at Point of Rocks in the sandstone bed north of the station, the one figured here being perhaps the most perfect. At the request of Dr. Newberry, who saw them at the National Museum, they were sent to him at the School of Mines, New York, and subsequently returned by him with the remark that he could find no sufficient characters to justify a specific distinction between them and leaves of the living species, *G. biloba.* There certainly is very little difference, except in size, but between *G. adiantoides* Ung. and the living species there is not even that difference. I have therefore thought best to commemorate this small form by a separate name and retain Unger's name for the next. Should intermediate forms be subsequently discovered, all might perhaps be referred to *G. biloba.*

Ginkgo adiantoides (Ung.) Heer.

GINKGO ADIANTOIDES (Ung.) Heer, Fl. Foss. Arct., Vol. V, Pt. III (Prim. Fl. Foss. Sachal.), p. 21, pl. ii, figs. 7–10.

SALISBURIA ADIANTOIDES Ung., Synops., p. 211; Gen. et Spec., p. 392. Massal. & Scarab., Fl. Foss. del Senigal., p. 163, pl. i, fig. 1; pl. vi, fig. 18; pl. vii, fig. 2. Heer, Fl. Foss. Arct., Vol. I, p. 183, pl. xlvii, fig. 14; Vol. II, Pt. IV (Foss. Fl. N. Greenland), p. 465, pl. xliv, fig. 1.

Plate I, Figs. 5, 6.—Seven Mile Creek, Montana; Sparganium bed.

The discovery of these interesting leaf impressions in the Sparganium bed at Seven Mile Creek was mentioned in the Sixth Annual Report (p. 545). They have nearly the size of the leaves of the living species and do not appreciably differ from the non-lobate forms of it which frequently occur (some trees having nearly all their leaves without lobes and others having them nearly all lobed). The lobes also differ greatly in depth and the Fort Union leaves sometimes have shallow sinuses.

SEQUOIA Endl.

Like Ginkgo, this genus represents a waning type of plant life, only the two well known Californian species remaining of the forty or more that are described in the fossil state. These latter range from the base of the Cretaceous, or even from the upper Jurassic, to the Pliocene. Six belong to the Laramie group, of which two are from the northern district.

Sequoia biformis Lx.

SEQUOIA BIFORMIS Lx., Bulletin U. S. Geol. Surv. Terr., Vol. I, p. 366; Ann. Rep. do., 1874, p. 298; Tert. Fl., p. 80, pl. lxii, figs. 15–18, 18*a*.

Plate II, Figs. 1–6.—Point of Rocks, Wyoming; white sandstone bed east of station (Figs. 1, 2); white marl bed northwest of station (Figs. 3, 6).

The two specimens, Figs. 1 and 2, are from the original fine white sandstone bed at Point of Rocks, long since explored by Dr. Hayden and Mr. William Cleburne; but they differ from the specimens collected by Hayden and figured by Lesquereux in having the shorter leaves more densely packed together and especially in exhibiting rhombic scars at the points where the leaves have fallen away. In this latter character they resemble more closely the forms called Araucarites. I do not, however, consider it probable that my specimens from that bed represent a different species from that formerly collected there, and the differences are probably due to accidents of preservation.

The special interest attaching to them is in the fact that all the other specimens, which agree more closely with those formerly collected, come from the white arenaceous marl bed at the base of the cliff to the northwest of the station. They greatly strengthen the presumption which I entertained at that time that these beds might be the equivalent of the others and be in their observed position by virtue of either a strong westerly dip or a fault in the intermediate region. It is important to know this, since by such knowledge the relative position of the more important bed, some 300 feet almost directly over this one, could be determined.

ANGIOSPERMS.

MONOCOTYLEDONS.

GRAMINEÆ.

PHRAGMITES Trin.

The two living species of Phragmites are very widely diffused throughout temperate and tropical regions of the globe. Four or five times as many species are described in the fossil state, chiefly from the Miocene; but three are found in Laramie strata. The reference of some of these forms to this genus is very doubtful.

Phragmites Alaskana Heer.

PHRAGMITES ALASKANA Heer, Fl. Foss. Arct., Vol. II, Pt. II (Fl. Foss. Alask.), p. 24, pl. i, figs. 12, 12 *b*. Lesquereux, Ann. Rep. U. S. Geol. Surv. Terr., 1871, p. 296; Tert. Fl., p. 90, pl. viii, figs. 10–12, 12*a*; Cret. and Tert. Fl., p. 141. Schimper, Pal. Vég., Vol. II, p. 398.

Plate III, Figs. 1–3.— Burns's Ranch, Montana.

There can be no doubt that these specimens represent the same plant that is figured by Lesquereux (Tert. Fl., pl. viii, fig. 10), collected 6 miles above Spring Cañon, near Fort Ellis, Mont., and it is a form that seems to be confined to the Fort Union group. It is probably not Phragmites, and may be profitably compared with *Bambusa Lugdunensis*. (See Saporta, Vég. Foss. de Meximieux, pl. xxiii, figs. 8–16.)

LEMNACEÆ.

LEMNA L.

Seven species of this genus are found inhabiting the fresh waters of temperate and tropical parts of the world. Besides the one named below, only two species are known in the fossil state. One of these is from the Green River shales at Florissant, Colo.

Lemna scutata Dawson.

LEMNA SCUTATA Dawson, Report on the Geology of the 49th Parallel, Appendix A, p. 329, pl. xvi, figs. 5, 6; Trans. Roy. Soc. Can., Sec. IV, 1882, p. 32. Lesquereux, Ann. Rep. Geol. Surv. Terr., 1874, p. 300; Tert. Fl., p. 102, pl. lxi, figs. 2–5.

Plate III, Figs. 4, 5.—Burns's Ranch, Montana.

I have concluded to refer these forms to *Lemna scutata* rather than to *Pistia corrugata* because none of them have the obovate shape characteristic of the mature leaves found at Point of Rocks and because, if there is any difference between the Point of Rocks specimens and those from British America, the probabilities are in favor of the identity of our plant with the latter, which doubtless belongs to the Fort Union group. But I quite agree with Prof. Lesquereux that the two are one and that all the specimens from Point of Rocks beds, which I also carefully examined while there, belong to a single species. All the specimens figured are from Burns's Ranch, but faint impressions (showing no nervation) of what I have little doubt is the same plant are visible upon some of the Iron Bluff shales.

TYPHACEÆ.

SPARGANIUM L.

This is rather a northern type occupying temperate and subfrigid regions, but representatives are found in Australia. There are in all half a dozen living species and about ten fossil ones, of which *S. Stygium* Heer is by far the best known.

Sparganium Stygium Heer.

SPARGANIUM STYGIUM Heer, Fl. Tert. Helv., Vol. I, p. 101, pl. xlv, figs. 1–4; Fl. Foss. Arct., Vol. I, p. 97, pl. xlv, figs. 2*a*, 13*d*; Vol. II, Pt. IV (Foss. Fl. N. Greenland), p. 467, pl. xlii, figs. 4*b*, 5, 5*b*. Schimper, Pal. Vég., Vol. II, p. 473.

Plate III, Figs. 6, 7.—Seven Mile Creek, Montana.

The single heads, which occur in masses on the rocks of the next highest beds of the Seven Mile Creek series, agree almost absolutely with the one figured by Heer in the Arctic Flora last cited, and this alone has determined me to refer our plant to that species. But the special interest in the case is the occurrence of about complete racemes, bearing single heads at the extremities of peduncles nearly an inch long. Two such racemes were obtained, one of which is figured (Fig. 7). These heads are smaller than those found separate and the fruits are less acuminate. I presume they represent an earlier stage in the development of the plant. At least, as all were found at one place, there seems no good reason for supposing that they represent two species.

DICOTYLEDONS.

APETALÆ.

SALICINEÆ.

POPULUS L.

The Fort Union group seems to be exceedingly rich in forms of Populus, which are probably the ancestors of the forms that still constitute almost the only arboreous vegetation of the region embraced by that extensive deposit. But it is remarkable, if such be the case, that the existing forms, *P. monilifera*, *P. balsamifera* (with its willow shaped variety, *angustifolia*) and also, to some extent, *P. tremuloides* have a much more pinnate nervation, and where tending to be palmate it never possesses the decidedly acrodrome character which belongs to nearly all the fossil forms, not only of western America but of the Arctic regions. It is only in the fossil floras of Europe that the pinnately nerved forms occur (cf. *P. latior*, *P. balsamoides*). It would seem that the Old World forms, after having been distributed over both hemispheres, proved fittest to survive in the struggle for existence with glacial agencies.

Dr. Newberry, in his Later Extinct Floras of North America, describes eight species of Populus from the Fort Union group, and in the great profusion of forms which I found, and which are represented so abundantly in my collections, I certainly expected that the most of those figured by him would be represented. But, unless we allow a much greater range of variation both in general form and in nervation than ever occurs with living species, only one of his species can be with certainty identified in my collections, and only two of my forms can, without such undue expansion of the characters, be referred to any species hitherto described. On the other hand, there are some eight or ten forms which, after examining all the species of Populus, both fossil and living, to which I have access through either specimens or figures, I am compelled to record as new and distinct from one another. It is true that great liberty has been taken by certain authors in referring forms differing entirely in their nervation to the same species, but if they have examined living specimens they must have found that they agree in nervation even where they differ in nearly all other respects.

Populus glandulifera Heer.

POPULUS GLANDULIFERA Heer, Fl. Tert. Helv., Vol. II, p. 17, pl. lviii, figs. 5–11; pl. lxiii, fig. 7; Fl. Foss. Arct., Vol. II, Pt. II (Fl. Foss. Alask.), p. 26, pl. ii, figs. 1, 2; Vol. V, Pt. III (Prim. Fl. Foss Sachal.), p. 25, pl. iii, fig. 4; Pt. IV (Mioc. Pfl. v. Sachal.), p. 5, pl. ii, figs. 7*a*, *b*; Fl. Foss. du Portugal, p. 25, pl. xxi, figs. 5, 6*a*. Ludwig, Palæontogr., Vol. VIII, p. 91, pl. xxvi, fig. 10. Schimper, Pal. Vég., Vol. II, p. 690. Lesquereux, Cret. and Tert. Fl., p. 226, pl. xlviA, figs. 3, 4.

Plate IV, Figs. 1–4, Fig. 3*a* enlarged.—Burns's Ranch, Montana.

The forms referred to this species are all alike in nervation and in form and all come from the carbonaceous shale at Burns's Ranch, where the fine grained character of the rock brings out the nervation in a very perfect manner. They do not agree well enough with the originals figured by Heer (Fl. Tert. Helv., pl. lviii) to have suggested their identity, but they are substantially identical with the forms figured by Lesquereux from the Bad Lands of Dakota (belonging to the Fort Union group), in his Cretaceous and Tertiary Floras (pl. xlviA, figs. 3, 4), Fig. 2 agreeing entirely with his fig. 4. The rest of the specimens have a somewhat more irregular outline, but this and all other peculiarities are seen in Heer's fig. 7, pl. lxiii, of the Tertiary Flora of Switzerland, quoted above. Baron von Ettingshausen, to whom the figures have been sent, regards this as a distinct species.

Populus cuneata Newberry.

POPULUS CUNEATA Newberry, Later Extinct Floras, pp. 31, 64; Illustr. of Cret. and Tert. Plants, pl. xiv, figs. 1–4. Lesquereux, Cret. and Tert. Fl., p. 225, pl. xlviA, fig. 5. Dawson, Cret. and Tert. Fl. Brit. Col. and N. W. Terr., Trans. Roy. Soc. Can., Sec. IV, 1882, p. 32.

Plate IV, Figs. 5–8; Plate V, Figs. 1–3.—Seven Mile Creek, Montana, Sparganium bed (Plate IV, Figs. 5–8; Plate V, Figs. 1, 2). Clear Creek, Montana (Plate V, Fig. 3).

All but the last of the specimens of this form figured here came from the Sparganium bed of the Seven Mile Creek system and are perfectly normal in all respects; the last (Plate V, Fig. 3) presents some differences and was collected at Clear Creek. It may be a form of *Populus arctica* Heer and has its nearest analogue in the specimen from Siberia figured by Heer in the Arctic Flora (Vol. V, Pt. II, Foss. Fl. Sibir., pl xv, fig. 3). The species occurred at Cracker Box Creek and in other beds, but the specimens are less perfect.

Populus speciosa, n. sp.

Plate V, Figs. 4–7.—Clear Creek, Montana.

Leaves long petioled, 5 to 7cm. wide, the blade but little longer rounded sinuate or crenate except the nearly horizontal base, palmate nerved; midrib strong; lateral primaries three pairs, all uniting with the midrib at the summit of the petiole, the innermost pair much the strongest, acrodrome, outer pair basal and delicate; tertiary nerves distinct, often terminating directly in the blunt teeth, frequently anastomosing and forming arches from which finer ones proceed to the margin

These fine specimens from the Clear Creek beds probably most closely resemble *P. arctica* Heer, but there are some constant differences, such as the rounded teeth, which seem to be essential. It is also a larger and in every way handsomer form. The five principal nerves always unite at the summit of the petiole, and in most of the specimens the base is nearly or quite horizontal without being cordate.

Populus amblyrhyncha, n. sp.

Plate VI, Figs. 1–8; Plate VII, Figs. 1–3.—Seven Mile Creek, Montana; white marl bed.

Leaves long petioled, 3.5 to 8.5cm. broad, the blade considerably longer than broad, varying from cordate to wedge shaped at the base, entire to near the widest part, rounded sinuate or crenate above, somewhat irregular in outline, the apex prolonged into a blunt point; midrib strong; lateral nerves one to three pairs, the inner pair much the strongest, uniting with the midrib some distance above the summit of the petiole, somewhat alternate, erect, sending out strong tertiaries which branch and anastomose, sometimes reaching the margin and terminating in blunt teeth which project beyond the others; lower lateral primaries light, alternate, or of unequal number on the two sides of the midrib; nervilles faint, percurrent or broken.

These constant forms are all from one bed, viz, the highest at Seven Mile Creek, and seem distinct from all others I have examined. They all agree in having the two or three principal nerves unite with the midrib a short distance above the base of the leaf, below which the thin basilar nerves proceed. The rounded teeth are somewhat irregular toward the summit, and the terminal one is usually produced into a conspicuous blunt snout, which gives a distinct character to this species and from which I have given it its name.

Populus daphnogenoides, n. sp.

Plate VII, Figs. 4–6.—Seven Mile Creek, Montana; white marl bed.

Leaves ovate in outline, entire near the wedge shaped base, rounded-sinuate or somewhat sharply toothed above, terminating in a long, entire, often curved, blunt point; petiole divided a little above the base of the blade into three strong, nearly equal, primary nerves, the two lateral ones distinctly acrodrome and very erect, terminating near the apex, giving off strong tertiaries which branch and terminate in the teeth; basal nerves light or indistinguishable; nervilles irregular, branched, often percurrent.

In searching for the analogues of this form they are chiefly found, so far as the size, shape, and general nervation are concerned, among other genera than Populus, for example, Zizyphus, Paliurus, Daphnogene, and Cinnamomum, but upon closer scrutiny they fail to convince me that these leaves are not those of a true Populus and one not widely distinct from that last mentioned, from which they differ in their smaller size, more narrowed and elongated form, and in having somewhat sharper teeth.

Populus oxyrhyncha, n. sp.

Plate VIII, Figs. 1, 2. - Seven Mile Creek, Montana; white marl bed.

Leaves broader than long, 4.5 to 6cm. in width, entire or slightly undulate to the middle, irregularly rounded-dentate and somewhat three-lobed above, terminating in an acute or slightly obtuse point, horizontal or slightly wedge shaped at the base; palmately nerved, the inner lateral primaries nearly equaling the midrib, erect and curving inward, giving off strong tertiaries from near the base which often reach the margin, uniting near the summit with tertiaries from the midrib; nervilles distinct, flexed in the middle and united by others running parallel to the tertiaries, forming quadrate or trapezoidal meshes.

I at first thought it would be necessary to separate these two forms, but upon further study I conclude to unite them. They have some resemblance to the specimens which I have designated as *P. amblyrhyncha*, but the mode of union of the primary nerves with the midrib is different and one of the specimens (Fig. 2) has the point decidedly acute. This resembles in general character Unger's figure of *P. attenuata* Al. Br., published in his Sylloge (III, pl. xxii, fig. 15), but there the lateral primaries rise from some distance above the base of the leaf and send out secondaries in a very different manner.

The other specimen (Fig. 1) resembles very closely Saporta's *P. Euboica* (Monde des Plantes, p. 285, fig. 80, No. 1), but is considerably larger. It differs from most of the other specimens from this locality in exhibiting a much larger amount of detailed nervation, but whether this indicates a leaf of different texture or merely an accident of preservation it is impossible to say.

Populus craspedodroma, n. sp.

Plate VIII, Fig. 3.—Burns's Ranch, Montana.

Leaf small for the genus, ovate in outline, somewhat lobed, slightly heart shaped, toothed all round, the teeth prominent, unequal, obtuse, or rounded, the terminal tooth prolonged; nervation craspedodrome; midrib much stronger than the lateral nerves, these in two pairs rising from the summit of the petiole, the basal pair very light, terminating in the first teeth, second pair proceeding from the midrib at an angle of 60° to the margin at the widest part of the leaf and terminating in a strong tooth or lobe, the upper pair strongest, erect, and dichotomously branching, the ultimate ramifications ending in the teeth; nervilles few and faint, often ending blind, forming near the midrib irregular meshes.

It is with grave doubts that I refer this beautiful impression to the genus Populus rather than to Hedera or Vitis. It has, however, all the essential characters of the genus, even to the basilar nerves, and yet the principal nerves pass directly into the teeth, which have the peculiar narrow but blunt form characteristic of the Vitaceæ.

Populus Whitei, n. sp.

Plate VIII, Fig. 4.—Burns's Ranch, Montana; collected by Dr. C. A. White in 1882 and named in his honor.

Leaf long petioled, subrhombic in outline, three lobed, unequally toothed to near the base, terminating in a prominent, slightly recurved point; nervation craspedodrome; lateral primary nerves in two pairs, upper pair nearly equal to the midrib, arising from above the base of the blade, erect and acrodrome, sending out strong secondary nerves to the lobes and teeth; lower pair short, rising midway between these and the base; nervilles percurrent, more or less curved, flexed in the middle, sometimes forking.

This specimen occurs in the collection of Dr. C. A. White from the lower Yellowstone district, made in 1882, and was collected at Burns's Ranch. My collection from that locality contains nothing that resembles it, unless the species last named may be said to do so. For a long time I supposed this form to be the same as that figured by Newberry on plate xiii, fig. 5, of the Illustrations of Cretaceous and Tertiary Plants, under the name of *Populus acerifolia*, although that figure bears almost no resemblance to the others under the same name. But a careful comparison convinces me that the two forms are distinct, and the strongly craspedodrome character of the nervation makes it somewhat doubtful whether our specimen represents a true Populus.

Populus hederoides, n. sp.

Plate VIII, Fig. 5.—Seven Mile Creek, Montana; white marl bed.

Leaf long petioled, large, (7.5cm. wide), coarsely sinuate-toothed to belowthe middle, entire at the base; midrib flexuous, divided at considerable distance above the base of the blade into three equal branches, the lateral branches curving upward and inward toward the apex and giving off three or four secondaries, which go to the margin; lower pair of lateral primary nerves arising from a point lower down and near the base, light, simple, and parallel to the margin, terminating in the first or second tooth; nervilles faint, straight, percurrent.

That this impression represents a true Populus I am quite certain, although the nervation is wholly anomalous and the general form more nearly approaches some species of Hedera. Only one specimen accompanies the collection, and of this the summit is wanting. It is from the highest beds of the Seven Mile Creek series.

Populus Richardsoni Heer.

POPULUS RICHARDSONI Heer, Fl. Foss. Arct., Vol. I, p. 98, pl. iv, figs. 1–5, 6*b*; pl. vi, figs. 7, 8; pl. xv, fig. 1*c*; p. 137, pl. xxiii, figs. 2*a*, 3; p. 158, pl. xxxi, figs. 1*a*, 2; Vol. II, Pt. III (Mioc. Fl. Spitzbergens), p. 54, pl. x, figs. 8–12; Pt. IV (Foss. Fl. N. Greenland), p. 468, pl. xliv, figs. 7, 8, 9*a*; pl. lv, fig. 3*b*; Vol. IV, Pt. I (Foss. Fl. Spitzbergens), p. 68, pl. xi, fig, 7*e*; pl. xiv, fig. 4; pl. xxxii, figs. 1, 2; Vol. V, Pt. II (Foss. Fl. Sibiriens), p. 49, pl. xv, fig. 7. Lesquereux, Tert. Fl., p. 177, pl. xxii, figs. 10–12. Schimper, Pal. Vég., Vol. II, p. 688.

Plate VIII, Fig. 6.—Burns's Ranch, Montana.

Although only a single fragment, this specimen differs from all the rest in the collections and agrees in all respects with the characters of *P. Richardsoni.* I have therefore no alternative but to refer it to that species.

Populus anomala, n. sp.

Plate VIII, Fig. 7.—Burns's Ranch, Montana.

Leaf long petioled (4cm.), 4.5cm. wide, roundish-ovate, strongly and somewhat sharply toothed to below the middle, entire and rounded at the base; nervation pinnate, craspedodrome; midrib thick, dichotomous above; secondaries two or three on each side below the forks of the midrib, strong, parallel to one another, curving upward, the upper forking, the lower giving off tertiaries from the under side; nervilles distinct, close together, somewhat curved, mostly percurrent, often bent in the middle, forked or joined by cross nerves.

This very anomalous form, of which the immediate base and the summit are unfortunately wanting, accompanied Dr. White's collection from Burns's Ranch and was not duplicated by my researches. The form is somewhat similar to that of *Populus subrotundata* Lx. (Tert. Fl., pl. xxiv, figs. 6–8), but the nervation is more pinnate and craspedodrome. Its place may be in another genus, but the petiole, which is long and preserved entire, is that of a Populus.

Populus Grewiopsis, n. sp.

Plate IX, Fig. 1.—Seven Mile Creek, Montana; white marl bed.

Leaf large (8cm. broad), long petioled (6cm.), roundish in outline, toothed to near the base, teeth unequal, obtuse or acute; nervation subpalmate, craspedodrome; midrib strong and straight, passing through the center of the leaf; lateral nerves 6 to 8 on each side, alternate, the lowest basilar and slight, the third above the base on each side much the strongest, all except the lowest nearly straight, terminating in the teeth and giving off tertiaries that pass directly to other teeth; nervilles few, straight, percurrent, at right-angles to the nerves.

I was long undecided whether to refer this nearly perfect and very distinct impression to Populus, Viburnum, or Grewiopsis. To some specimens which I refer to the last named of these genera it has a decided resemblance (cf. *infra*, pp. 89–90, Pl. XL, Figs. 2–5). But the very well marked basilar nerves seem to decide the case, and the plant resembles quite closely the part that is shown of one of Heer's figures of *Populus Richardsoni* (Fl. Foss. Arct., Vol. IV, Pt. I, Foss. Fl. Spitzbergens, pl. xiv, fig. 4). The long petiole is also that of a Populus, and here we will leave it, for the present at least.

The specific name should be written with a capital initial to indicate its affinities with Grewiopsis and not with Grewia.

Populus inæqualis, n. sp.

Plate IX, Fig. 2.—Burns's Ranch, Montana.

Leaf roundish in outline, sharply and irregularly toothed above the middle, entire or undulate-margined below, abruptly narrowed at the uneven base to the distinctly wing-margined petiole; nervation pinnate, mixed (craspedo-camptodrome); midrib far to one side, curved, forked near the summit; secondary nerves six on each side, nearly equally prominent except the one or two lowest, passing out to near the margin, where they fork or are joined by arches, the ultimate ramifications proceeding into the teeth; nervilles few and irregular, forking or joined.

This is perhaps the most anomalous form of all, but there is less doubt than in some of the previous cases as to its generic affinities. Its sharp teeth turned forward, pinnate nervation, numerous secondaries and general asymmetry distinguish it from all the forms I have been able to compare with it.

CUPULIFERÆ.

QUERCUS L.

Very few forms clearly referable to Quercus occur in the collection, and these come chiefly from the lower districts. The only one figured here from the Fort Union group is of doubtful generic affinity.

Quercus bicornis, n. sp.

Plate IX, Fig. 3.—Seven Mile Creek, Montana; bed below the ironstone.

Leaf obovate-oblong, 2.6cm. broad, 6.5cm. long inclusive of the petiole which is 1.5cm. long, entire below, tricuspidate at the summit, the terminal cusp long and recurved, the two lateral shorter, unequal, sharp, and curved inward, separated from the terminal by rounded sinuses; nervation pinnate; midrib straight, except the curved summit; secondaries numerous (about twelve on each side) and hence close together, subopposite, proceeding from the midrib at an angle of 40° to 50°, curving upward near the margin, to which they become tangential, nearly simple, two of them running out into the tips of the cusps, otherwise camptodrome, one on each side forking and striding the sinuses; nervilles faint, percurrent, at right angles to the secondaries.

I have been unable to find anything with which the leaf can be compared. Distant resemblances may be seen in *Quercus troglodytes* (Fl. Foss. Arct., Vol. VI, Abth. II, Foss. Fl. Gröuld., pl. xxix, fig. 14), *Q. Mediterranea* Ung., and *Q. Zoroastri* Ung. (Foss. Fl. v. Kumi, Denkschr. Wien. Akad., Vol. XXVII, pl. vi, figs. 1–28), as well as in some living species, as, for example, *Q. Ilex* (cf. Saporta, Vég. Foss. be Meximieux, pl. xxiv, fig. *a*). Analogues also occur in other genera (cf. *Myrica latiloba acutiloba* Lx., Tert. Fl., pl. xvii, fig. 13), and the specimen, though nearly perfect, is doubtfully referred to Quercus.

.Quercus Doljensis Pilar.

QUERCUS DOLJENSIS Pilar, Flora fossilis Susedana, p. 37, pl. vii, fig. 14.

Plate IX, Figs. 4, 5.—Black Buttes Station, Wyoming.

The remarkable similarity of form and nervation between these specinens and those figured by Pilar from Dolje in Sused justify their reference to that species, notwithstanding the improbability that the same species should flourish in the American Laramie and the Miocene of southeastern Europe. Still, Baron von Ettingshausen is probably correct in presuming that the American form is a nearly related species rather than identical with the Croatian.

Quercus Carbonensis, n. sp.

Plate IX, Fig. 6.—Carbon Station, Wyoming.

Leaf 8cm. broad, rounded at the base, slightly sinuate-margined between the distant sharp, cuspidate, or spinulose teeth; petiole 6cm. long, thick and flexuous; midrib thick and straight, giving off strong secondaries at short ntervals, which are slightly curved outward and upward and pass out toward the margins parallel to one another; nervilles few, straight or flexed near the middle, percurrent, forked or obliquely joined; nervation chiefly camptodrome.

The entire upper portion of this leaf is wanting, but the lower half, including the petiole, is highly distinctive. The nervation and the spinous teeth, or lobes, strongly suggest its affinity to Quercus, but the petiole is too long and flexuous for most species of that genus. Better material will be necessary to decide the question.

Quercus Dentoni Lx.

QUERCUS DENTONI Lx., Cret. & Tert. Fl., p. 224, pl. xlviii, figs. 1, 11.

Plate X, Fig. 1. Point of Rocks, Wyoming; gray sandstone bed north of station.

The close resemblance between this specimen and that figured by Lesquereux from the Bad Lands of Dakota inclines me to class them together for the present rather than to multiply species. The shape, however, is somewhat different, the Wyoming specimen being more narrowed upward and indicating a contracted apex. The petiole is also thicker and slightly inflated, recalling some species of Ficus.

DRYOPHYLLUM Debey.

I have already referred (Sixth Ann. Rep. U. S. Geol. Surv., p. 534) to the numerous forms probably referable to this genus, rather than to Quercus, which appear in my collections. A few of them are illustrated.

Dryophyllum aquamarum, n. sp.

Plate X, Figs. 2-4.—Black Buttes Station, Wyoming.

Leaves lanceolate, narrowed at both ends, broadest at or below the middle, 3 to 5 cm. broad, 10 to 15 cm. long, entire or wavy near the base, undulate or sinuate-toothed above; nervation mixed; midrib strong; secondary nerves numerous (fifteen to twenty on each side) and close together, alternate, irregular as to interval and angle, often having intercalary nerves between them, which proceed from the midrib at a wider angle and unite with the next nerve below; nervilles very prominent, joining the secondaries to one another and the midrib to the secondaries, these latter strong, curved, and often passing into intercalary nerves.

These leaves appear to belong to the subgenus Dryophanes of Debey and to have their nearest analogue in his *Dryophyllum Eodrys* (Feuilles querciformes, pp. 11, 14, fig. 19), but there is much in the nervation that reminds one of *Quercus Lucumonum* Gaud. (Contr. II, Nouv. Mém. Soc. Helv. Sci. Nat., Vol. XVII, pl. x, fig. 12). The irregular character of the secondary nerves very closely resembles some forms that have been referred to *Quercus furcinervis* (Rossm.) Ung. (cf. Lesquereux, Cret. and Tert. Fl., pl. liv, figs. 1, 2), but the camptodrome tendency as they approach the border, which is characteristic of Dryophyllum, is not found in that species. The tertiary nervation is very prominent and distinguishes these leaves from any others I have seen. The specimens figured all come from the same bed, and all the gradations between the strongly camptodrome forms (Figs. 2, 3) and the distinctly craspedodrome forms represented by Fig. 4 occur in the collection; their reference to Salix seems therefore out of the question.

Dryophyllum Bruneri, n. sp.

Plate X, Figs. 5–8.—Point of Rocks, Wyoming; gray sandstone bed (Figs. 5, 6). Hodges Pass, Wyoming (Figs. 7, 8).

Leaves lanceolate or oblong-lanceolate pointed, abruptly narrowed to a short thick petiole, coarsely and obscurely to sharply sinuate-toothed except the entire base; nervation craspedodrome; midrib strong, straight or a little curved; secondary nerves numerous (fifteen to twenty on each side) and close together, proceeding from the midrib at an angle varying from 35° to 80°, slightly curving upward, rarely forking or forming arches, the ultimate ramifications entering the teeth; nervilles faint, slender and wavy, percurrent, joining the secondaries only (except in a few cases).

I dedicate this species to Prof. Lawrence Bruner, of Nebraska, who was my companion throughout most of my campaign in Colorado and Wyoming and who rendered much valuable aid in making the collections at both the points named. The specimens closely resemble those last described, but the distinctly craspedodrome nervation and the great difference in the nervilles lead me to regard them as specifically distinct. Intercalary nerves do indeed appear in some specimens (Figs 5, 8) and nervilles occasionally proceed from the midrib (Figs. 6, 8), but these cases are rare. The arches formed by the secondaries in Figs. 7 and 8 are farther from the margin than those of *D. aquamarum* and different in character.

I have not found it possible to separate these specimens, although they come from different localities. If any separation were possible the specimens, Figs. 5 and 8, would naturally fall together, as nearer alike than they are to the other two, but some variation must be allowed, and they are probably all of one species.

Dryophyllum falcatum, n. sp.

Plate XI, Fig. 1.—Hodges Pass, Wyoming.

Leaf ovate-lanceolate, slender-pointed, and falcate at the summit, 8.5cm. long, broadest (2.5cm.) near the base, which is rapidly narrowed, obscurely sinuate-toothed above, entire at the base; midrib thick below, rapidly diminishing above; secondaries light, twelve to fourteen on a side, parallel (except the lowermost, which are more erect), unequally distant, simple or forked near their extremities, scarcely reaching the margin; nervilles indistinguishable.

This species also somewhat resembles *D. Eodrys* Deb. (Feuilles querciformes, fig. 19), but it is more falcate and pointed and the secondaries are more regular and parallel.

Dryophyllum basidentatum, n. sp.

Plate XI, Fig. 2.—Carbon Station, Wyoming.

Leaf obovate in outline, 4cm. broad above, long petioled, wedge shaped at the base, distantly and sharply sinuate-toothed, with prominent subspinulose teeth, oblique at the base; petiole very thick, especially below, 3cm. long; midrib straight, diminishing above; secondary nerves five or six on a side, close together, parallel, ascending at an angle of 30° to the midrib, curving upward and inward toward the summit, where they give off five or six tertiaries; nervilles distinct, wavy, percurrent or forked, often crossed by short veins at right angles, forming fine quadrilateral meshes.

The upper portion of this leaf is wanting, but the form and the nervation of the parts preserved indicate a rapid narrowing to the apex, which was probably more or less toothed.

I should have been disposed to regard this as a species of Quercus but for its striking resemblance to *Dryophyllum cretaceum* Deb., particularly as figured by Saporta in his Flora of Gelinden, pl. v., figs. 3, 4. The nerves in our specimen are, however, a little more erect and nearer together and the teeth near the base are decidedly more prominent and conspicuous. It may prove to be the same as *Quercus Carbonensis* (Pl. IX, Fig. 6), from which it differs chiefly in size and in its wedge shaped base.

CORYLUS Tournef.

The same forms of Corylus described by Newberry in his Later Extinct Floras recur at nearly all points in the Fort Union group. I obtained them all, unless it be his *C. orbiculata*, as I believe he now admits his *C. grandifolia* to be identical with Heer's *C. McQuarrii*. I have carefully compared my larger specimens with all the published figures of *C. McQuarrii* and also with specimens of *C. Americana*, *C. rostrata*, and *C. Avellana*, and I am compelled to conclude that there is scarcely a specific difference between *C. McQuarrii* and *C. Americana*. It is singular that Heer, in comparing his fossil forms with living ones, makes no mention of this most common American species so similar to his fossil one. He compares his *C. insignis* with *C. rostrata* and *C. McQuarrii* with *C. Avellana*, and remarks that the larger fossil species resembles the larger living one, except that the leaves rapidly grow narrower above the middle, while in the living form the broadest part is above the middle. He also mentions the resemblance in the nervation of the two more robust forms as being more prominent, with the nerves in relief. Now these are just the characters, and almost the only ones, which distinguish *C. Americana*.

Corylus Americana Walt.

CORYLUS AMERICANA Walt., Newberry, Later Extinct Floras, pp. 31, 59; Illustrations of Cret. and Tert. Plants, pl. xiv, figs. 8, 10. Schimper, Pal. Vég., Vol. II, p. 600. Dawson, Cret. and Tert. Fl. Brit. Col. and N. W. Terr., Trans. Roy. Soc. Can., Sec. IV, p. 32.

Plate XI, Figs. 3-5; Plate XII, Figs. 1, 2.—Seven Mile Creek, Montana; white marl bed.

My specimens are larger than those figured by Newberry under this name, but it is easy to find living leaves as large. The figures of *C.*

McQuarrii are also generally smaller than those here figured, but the one represented by Fig. 1 agrees in all respects with Heer's figure of *C. McQuarrii* in his Flora of Grinnell-Land (Fl. Foss. Arct., Vol. V, Pt. I, pl. vi, fig. 6). I also find leaves of the living species that exactly correspond to both these figures. Usually, however, the teeth of *C. McQuarrii* are represented as less sharp.

Corylus rostrata Ait.

CORYLUS ROSTRATA Ait., Newberry, Later Extinct Floras, pp. 31, 60; Illustrations of Cret. and Tert. Plants, pl. xv, figs, 1, 3. Schimper, Pal. Vég., Vol. II, p. 600. Dawson, Cret. and Tert. Fl. Brit. Col. and N. W. Terr., Trans. Roy. Soc. Can., Sec. IV, p. 32.

Plate XIII, Figs. 1-4.—Seven Mile Creek, Montana; white marl bed.

These specimens correspond very well with those figured by Newberry (Illustr., pl. xv, figs. 1-3), but our Fig. 4, which agrees with his fig. 3, may belong to another species.

Corylus Fosteri, n. sp.

Plate XIII, Figs. 5, 6.—Head of Clear Creek, Montana (Fig. 5); Clear Creek, Montana (Fig. 6); collected by Mr. Richard Foster, for whom it is named.

Leaves ovate, deeply heart shaped, the lobes of the base unequal, long pointed, the entire margin toothed, the unequal teeth broad at the base and somewhat obtuse; midrib strong, slightly sinuous or curved; secondary nerves seven or eight on each side, the two lowest opposite and sending out five or six strong tertiary nerves, the first of which arise from near the midrib and in turn give off quaternary nerves to the basal lobes, the next three or four secondaries supporting each a few branches toward the summit, the upper ones simple; nervilles very prominent, mostly percurrent, at right angles to the secondaries, often joined near the middle by oblique veins forming irregular meshes, sometimes forking, those connecting the midrib with the secondaries much curved, often opposite and appearing to form concentric circles.

It is fitting that I should name this handsome species of Corylus in honor of Prof. Richard Foster, now of Howard University, who collected both the specimens figured here and through whose zeal and energy the rich bed at the head of Clear Creek, where the finest specimen was found, was visited.

I formerly regarded the smaller of the two specimens which accompanied Dr. White's collection of the year previous as representing Newberry's *C. orbiculata*, but it differs from that form in having teeth of a different shape and identical with those of the larger specimen. Although the summit is wanting it is evident from the rest of the leaf that this was narrowed to a point.

? Corylus McQuarrii (Forbes) Heer.

CORYLUS MCQUARRII (Forbes) Heer, Fl. Foss. Arct., Vol. I, p. 104, pl. viii, figs. 9–12; pl. ix, figs. 1–8; pl. xvii, fig. 5*d*; pl. xix, fig. 7*c*; p. 138, pl. xxi, fig. 11*c*; pl. xxii, figs. 1–6; pl. xxiii, fig. 1; p. 149, pl. xxvi, figs. 1*a*, 2–4; p. 159, pl. xxxi, figs. 1*b*, 5, 6*a*; Vol. II, Pt. II (Fl. Foss. Alask.), p. 29, pl. iii, fig. 9; pl. iv; Pt. III (Mioc. Fl. Spitzbergens). p. 56, pl. xi, figs. 10–13; pl. xiii, fig. 35*b*; Pt. IV (Foss. Fl. Greenland), p. 469, pl. xliv, fig. 11*a*; pl. xlv, fig. 6*b*; Vol. IV, Pt. I (Foss. Fl. Spitzbergens), p. 72, pl. xv, figs. 1–4; pl. xxviii, figs. 7, 8; Vol. V, Pt. I (Mioc. Fl. Grinnell-Land.), p. 33, pl. v, fig, 9; pl. vi, figs. 3–6; pl. viii, fig. 9*a*; pl. ix, fig. 1; Pt. III (Prim. Fl. Foss. Sachal.), p. 34, pl. vii, figs. 8, 9*a*. Lesquereux, Tert. Fl., p. 144, pl. xviii, figs. 9–11; Cret. and Tert. Fl., p. 223, pl. xlix, fig. 4. Ettingshausen, Foss. Fl. v. Sagor, I (Denkschr. Wien. Acad., Vol. XXXII), p. 177, pl. iv, figs. 20, 21. Schimper, Pal. Vég., Vol. II, p. 598. Zwanziger, Mioc. Fl. v. Liescha, p. 35, pl. viii, figs. 3, 4.

ALNITES MCQUARRII Forbes, Quart Journ. Geol. Soc., Vol. VII, 1851, p. 103, pl. iv, fig. 3.

Plate XIII, Fig. 7.—Seven Mile Creek, Montana; bed below the ironstone.

This very anomalous leaf, the only one of the kind in the collection, comes from the next lowest horizon at Seven Mile Creek. Its reference to the genus Corylus is very doubtful, but it agrees tolerably well with some of the figures of Heer. The midrib, however, and the three opposite pairs of secondary nerves are unlike Corylus and resemble Alnus or Betula. That it is not a form of *Alnus Kefersteinii* I would not affirm, but the projection of the teeth at the extremities of the secondary nerves and the general form of the upper portion strongly suggest its reference to Corylus. Unwilling to make a new species on so defective material, and yet desiring the judgment of others upon it, I venture to enter it as above.

ALNUS Gärtn.

Unless the specimen last mentioned represents an Alnus only one has been selected referable to that species.

Alnus Grewiopsis, n. sp.

Plate XIV, Fig. 1.—Hodges Pass, Wyoming.

Leaf obovate, obtuse, sinuate, and somewhat doubly toothed above, entire or slightly undulate margined below, 4cm. broad, 7cm. long, exclusive of the petiole (1cm.); midrib strong, somewhat curved, rapidly diminishing toward the summit; secondary nerves about nine on each side, the strongest near the middle of the leaf, nearly parallel and straight, making an angle of about 30° with the midrib, the lower ones giving off short simple tertiaries, which usually lose themselves near the entire margin, the upper either passing directly into the teeth or curving and forming angular arches near the border, from which finer veinlets proceed to the lesser as well as to the principal teeth; nervilles faint, mostly straight and percurrent, sometimes forked.

The specific name is suggested by a peculiar character in the nervation near the upper border closely resembling that of some species of Grewiopsis, e. g., *G. Saportana* Lx. (Tert. Fl. pl. 1, fig. 11); *G. Cleburni* Lx. (op. cit., pl. lxii, fig. 12). The form and general nervation, however, are those of an Alnus.

BETULA L.

Numerous specimens belonging to this genus occur in the collections, of which the following four are figured.

Betula prisca Ett.

BETULA PRISCA Ett., Foss. Fl. v. Wien, p. 11, pl. i, figs. 15–17; Foss. Pfl. v. Heiligen Kreuz bei Kremnitz (Abh. K. K. Geol. Reichsanstalt, Vol. I), p. 5, pl. i, fig. 3; Foss. Fl. v. Bilin, I (Denkschr. Wien. Acad., Vol. XXVI), p. 121, pl. xiv, figs. 14–16; Tert. Fl. Steiermark's (Sitzb. Wien. Acad., Vol. LX, Abth. I), p. 45, pl. i, figs. 24–26. Göppert, Tert. Fl. v. Schossnitz, p. 11, pl. iii, figs. 11, 12. Massalongo, Synops. Fl. Foss. Senog., p. 24; Fl. Foss. del Senigal., p. 172, pl. xxxvi, fig. 9. Heer, Mioc. Balt. Fl., p. 70, pl. xviii, figs. 8–15; Fl. Foss. Arct., Vol. I, p. 148, pl. xxv, figs. 9*a*, 10, 20–25; pl. xxvi, figs. 1*b*, 1*c*; Vol. II, Pt. II (Fl. Foss. Alask.), p. 28, pl. v, figs. 3–7; Pt. III (Mioc. Fl. Spitzbergens), p. 55, pl. xi, figs. 3–6; Vol. IV, Pt. I (Foss. Fl. Spitzbergens), p. 70, pl. xxxi, fig. 10; Vol. V, Pt. I (Mioc. Fl. Grinnell-Land.), p. 31, pl. iii, fig. 3*h*; pl. v, figs. 2–5; Pt. III (Prim. Fl. Foss. Sachal.), p. 30, pl. v, figs. 9, 10; pl. vii, figs. 1–4; Pt. IV (Mioc. Pfl. v. Sachal.), p. 6, pl. ii, fig. 8; pl. iii, fig. 6. Gaudin, Contr. IV (Nouv. Mém. Soc. Helv., Vol. XVII), p. 20, pl. i, fig. 14; Contr. VI (op. cit., Vol. XX), p. 12, pl. ii, fig. 10. Engelhardt, Fl. d. Braunk. Sachsen, p. 16, pl. iii, figs. 19–21. Schimper, Pal. Vég., vol. ii, p. 567.

Plate XIV, Fig. 2.—Seven Mile Creek, Montana; bed below the ironstone.

The remarkable agreement between our specimen and the original figure upon which the species was founded does not permit me to hesitate in referring it to that species. The species is a widespread and variable one, but occasionally, as in Heer's Miocene Baltic Flora (pl. xviii, fig. 11), there is a return to the type, and ours seems to constitute another such case.

Betula coryloides, n. sp.

Plate XIV, Fig. 3.—Seven Mile Creek, Montana; white marl bed.

Leaf ovate-lanceolate, 2.5cm. wide, 5cm. long, irregularly doubly or trebly toothed, entire at the horizontal base, recurved pointed at the summit; petiole 12mm. long; midrib strong, nearly straight; secondary nerves eight on each side, making an angle with the midrib of about 35°, the lowest and some of the higher pairs opposite, very thick at the base, rapidly diminishing to the margin of the leaf, the lowest pair giving out each a strong horizontal tertiary nerve from near its insertion, which terminates in a slightly prolonged tooth or lobe and gives off several quaternary nerves from the lower side; lower and middle secondaries all yielding tertiaries, upper ones simple; nervilles very prominent, mostly straight, percurrent, and at right angles to the secondaries but often forking, flexed, and variously joined, forming irregular meshes.

The prominent nervilles and double dentation, and especially the pair of horizontal tertiary nerves at the base, assimilate this leaf very closely to the genus Corylus, where it would find its nearest analogue in *C. insignis* (cf. Heer, Fl. Tert. Helv., pl. lxxiii, figs. 11–17); but upon the whole the nervation perhaps agrees as well with that of Betula, while the general shape is much nearer that of most leaves of that genus. It resembles quite closely some forms of *B. prisca*, particularly the one figured by Heer in his Arctic Flora (Vol. I, pl. xxv, fig. 20), but a still nearer approach to our form is found in *B. lutea* Michx. f., of the present North American flora.

Betula basiserrata, n. sp.

Plate XIV, Fig. 4.—Seven Mile Creek, Montana; white marl bed.

Leaf roundish ovate, sharply simply serrate, 3cm. wide, 3.5 or 4cm. long; midrib straight; secondary nerves five or six on a side, making an angle of 40° with the midrib; the lowest pair opposite, arising at a less angle and curving outward, furnished with five to seven simple tertiaries, which pass into the teeth, the next one or two on each side having a few tertiaries near their extremities, the upper one simple; nervilles indistinct, curved percurrent, sometimes forked.

In this specimen the teeth approach the base of the leaf more closely than is usual with the genus. Otherwise there seems to be no reason to exclude it.

MYRICACEÆ.

MYRICA L.

Only two species of this abundant type occur in the Laramie group. The thirty-five species of the living flora are distributed throughout nearly all temperate parts of the world. Two species are very abundant in North America, either or both of which may have descended from these fossil forms.

Myrica Torreyi Lx.

MYRICA TORREYI Lx., Ann. Rep. Geol. Surv. Terr., 1872, pp. 392, 399; Tert. Fl., p. 129, pl. xvi, figs. 3–10. Schimper, Pal. Vég., Vol. III, p. 586.

Plate XIV, Fig. 5.—Black Buttes Station, Wyoming.

The specimen represents a leaf of about the maximum length (15cm.) of the plant described by Lesquereux from the same locality in 1872. It has not been found at any other place. The absence of marginal nerves is in favor of the reference of this leaf to Myrica, while their presence in the earlier described specimens points, as Baron von Ettingshausen suggests, to Lomatia as their more probable affinity.

JUGLANDACEÆ.

JUGLANS L.

Five of the eight surviving species of Juglans are North American and the Laramie group has hitherto yielded eight extinct ones. One of the following is not included in these, and if correctly referred will increase this number to nine.

? Juglans Ungeri Heer.

JUGLANS UNGERI Heer, Tert. Fl. Helv., Vol. III, p. 199, pl. clv, fig. 18; Braunk. Pfl. v. Bornstädt, p. 21, pl. iv, fig. 13. Schimper, Pal. Vég., Vol. III, p. 241. Engelhardt, Foss. Pfl. v. Tschernowitz (Nova Acta L.-C. Acad., Vol. XXXIX), p. 385, pl. xxiii, fig. 2; Foss. Pfl. v. Grasseth (op. cit., Vol. XLIII), p. 313, pl. xxi, figs. 3, 5, 6.

PHYLLITES JUGLANDOIDES Rossm., Verstein. d. Braunk. v. Altsattel, p. 29, pl. iv, fig. 16.

JUGLANS COSTATA Ung. (quoad folia), Gen. et Spec., p. 468. Heer, Fl. Tert. Helv., Vol. III, pp. 90, 199. Ludwig, Palæontogr., Vol. VIII, p. 138, pl. lvi, fig. 7; pl. lvii, figs. 6, 7.

Plate XIV, Fig. 6.—Burns's Ranch, Montana.

Our specimen closely resembles the Swiss plant and also the one from Altsattel, but finds its nearest analogue in the specimen from Tschernowitz, as figured by Engelhardt, with which it agrees in having nearly all the secondary nerves opposite.

? Juglans nigella Heer.

JUGLANS NIGELLA Heer, Fl. Foss. Arct., Vol. II, Pt. II (Fl. Foss. Alask.), p. 38, pl. ix, figs. 2–4; Vol. V, Pt. III (Prim. Fl. Foss. Sachal.), p. 41, pl. x, figs. 6, 7; pl. xi, figs. 1, 2; Pt. IV (Mioc. Pfl. v. Sachal.), p. 9, pl. iv, fig. 10. Schimper, Pal. Vég., Vol. III, p. 247, pl. cii, fig. 4. Lesquereux, Cret. and Tert. Fl., p. 235, pl. xlviA, fig. 11.

Plate XV, Fig. 1.—Burns's Ranch, Montana.

Much difficulty has been experienced in separating leaves of similar nervation to the present one into their proper genera. For a long time I had classed this with the forms referred to the Celastraceæ, and I am not yet certain that it does not belong there. Its affinities are closest with those that I have grouped under the genus Elæodendron (Pl. XXXVII, Figs. 3–5; Pl. XXXVIII, Figs. 1–7), all but one of which were collected in the same bed at Burns's Ranch. But these all show a greater tendency to form a double series of arches at a greater distance from the margin and the nerves are more regular than in this one. The teeth in this specimen are also finer and sharper. It agrees in nearly all respects with the figures of *Juglans nigella* above cited, and is as likely as they to belong to that genus. Whether this will necessarily carry some of the other leaves into Juglans remains to be seen.

CARYA Nutt.

Although the ten species of Carya are all North American, there is abundant evidence that the type played an important rôle in the Miocene epoch in Europe. About twenty species are found there and only four or five in North American strata. Only one of these latter is from the Laramie group.

Carya antiquorum Newberry.

CARYA ANTIQUORUM Newberry, Later Extinct Floras, pp. 31, 72; Illustrations of Cret. and Tert. Plants, pl. xxiii, figs. 1-4. Lesquereux, Ann. Rep. U. S. Geol. Surv. Terr., 1871, p. 294; 1872, p. 402; Tert. Fl., p. 289, pl. lvii; lviii, fig. 2. Schimper, Pal. Vég., Vol. III, p. 255. Dawson, Cret. and Tert. Fl. Brit. Col. and N. W. Terr. (Trans. Roy. Soc. Can., Sec. IV), p. 32.

Plate XV, Fig 2.—Carbon Station, Wyoming.

Less than half the leaf is preserved, but this includes the nearly complete petiole and shows the nervation very clearly. This resembles that of the Fort Union specimens less than it does those from Evanston, which is probably nearly on the same horizon with Carbon. Prof. Lesquereux's fig. 2 of pl. lvii represents a fragment very similar to this one, but the fine teeth come farther down. This specimen is not in the Museum collection, but I have examined those represented by figs. 3 and 4 of the same plate, and I have no doubt that our plant belongs to the same species.

PLATANACEÆ.

PLATANUS L.

Six species of this very ancient type survive and are confined to the northern hemisphere, two being North American. Eight fossil species have hitherto been described from the Laramie group.

Platanus Heerii Lx.

PLATANUS HEERII Lx., Ann. Rep. U. S. Geol. Surv. Terr., 1871, p. 303; 1872, p. 425; 1874, p. 341, pl. viii, fig. 5; Cret. Fl., p. 70, pl. viii, fig. 4; pl. ix, figs. 1, 2; Cret. and Tert. Fl., p. 44, pl. iii, fig. 1; pl. vii, fig. 5. Schimper, Pal. Vég., Vol. III, p. 591. Heer, Fl. Foss. Arct., Vol. VI, Abth. II (Foss. Fl. Grönlands), p. 72, pl. vii, figs. 1, 2; pl. viii, figs. 1, 2*a*; pl. ix, figs. 1-4.

Plate XV, Figs. 3, 4.—Black Buttes Station, Wyoming.

Prof. Lesquereux, to whom I have recently sent figures of this leaf, thinks that the basilar origin of the lateral primary nerves and the more strongly toothed margin are fatal to the reference of this leaf to *P. Heerii*. He considers its affinities to be rather with his *Viburnum platanoides* (Tert. Fl., p. 224, pl. xxxviii, fig. 8), or perhaps with *Platanus affinis* Lx., especially the arctic forms (Heer, Fl. Foss. Arct., Vol. VII, pl. lvii, figs. 1-6), or even with *P. Guillelmæ* (op. cit., Vol. V, Pt. II, Foss. Fl. Sibir., pl. ix, fig. 14). The general resemblance of the leaves to those figured by Heer (Fl. Foss. Arct., Vol. VI, Abth. II, pl. vii, fig. 1) as *P. Heerii*, is very striking, but here the origin of the lateral primaries is still higher than in either of my specimens.

Platanus nobilis Newberry.

PLATANUS NOBILIS Newberry, Later Extinct Floras, pp. 30, 67; Illustrations of Cret. and Tert. Plants, pl. xvii. Lesquereux, Ann. Reps. Geol. Surv. Terr., 1871, p. 295; 1872, p. 404. Schimper, Pal. Vég., Vol. II, p. 708. Dawson, Foss. Pl. of Roche Percée (Geol. Surv. Can., Rep. of Prog., 1879-'80, App. II), p. 51; Cret. and Tert. Fl. Brit. Col. and N. W. Terr. (Trans. Roy. Soc. Can., Sec. IV), p. 32.

Plate XVI, Fig. 1.—Seven Mile Creek, Montana; Sparganium bed.

This leaf is the largest collected in the Yellowstone Valley, and measures 35cm. across its broadest portion, while the midrib is preserved for about 30cm. It resembles very closely Newberry's figure (Illustr., pl. xvii), but is strictly three lobed, whereas that shows a fourth lobe of diminished length formed by a prepotent secondary nerve given off by one of the lateral primaries. The base is remarkably similar, the paranchyma not extending as far down as the origin of the principal nerves, and these in both cases are somewhat alternate. Numerous fragments in the Museum collection (No. 1070) recorded by Lesquereux in the catalogue as from Fort Clarke, but which may be the same as he mentions in the Annual Report for 1872 (p. 403) as from "Elk Creek, near Yellowstone River," agree substantially with our leaf. I should be very glad of an opportunity to examine the Evanston specimens mentioned in the Annual Report for 1871 (p. 295), as they must possess considerable interest in connection with the question of correlating the Fort Union with the Wyoming Laramie; but these are not in the Museum type series. Baron von Ettingshausen regards this species as an Aralia (in litt. 24. Aug. 1886). See, *infra*, pp. 59-61, remarks on the genus Aralia, and especially on *A. notata*.

Platanus basilobata, n. sp.

Plate XVII, Fig. 1; Plate XVIII, Figs. 1-3, 3*a*, enlarged; Plate XIX, Fig. 1.—Seven Mile Creek, Montana; Sparganium bed (Plates XVII, XVIII). Clear Creek, Montana, collected by Dr. White's party in 1882 (Plate XIX).

Leaves large (25 to 35cm. wide), with nearly entire margins, long petioled, three lobed above and provided with a three to six lobed appendage at the base; nervation strongly palmate, camptodrome, the three principal nerves all rising from the same point and near the summit of the petiole, the four to eight nerves of the basilar appendage proceeding from the same point in the opposite direction; primary nerves provided with secondaries on both sides, some of the lower secondaries giving off tertiaries from the under side; nervilles distinct, close together, mostly irregular, curved or wavy, sometimes percurrent, more frequently forked or obliquely joined near the middle, the areolæ, as also the interval between the arches and the margin, occupied by fine network of regular quadrate meshes.

This remarkable form differs specifically from *P. nobilis* in its decidedly camptodrome nervation and entire margins, but especially in the peculiar basilar appendage above described. This is not preserved with absolute completeness in any of my specimens, but in several it is nearly complete, and by comparing them all there is no difficulty in understanding its nature. It seems to consist of a miniature reflex of the leaf itself projected backward over the petiole as a lobate expansion. It is palmately nerved like the blade, the principal nerves entering the lobes. These sometimes differ in number from those of the leaf, amounting to six in two of the specimens (Pl. XVII, Fig. 1; Pl. XVIII, Fig. 1). The lobes also vary considerably in length and shape. In Fig. 3, Plate XVIII, the base is wanting, the leaf is small, and the upper lobes are quite short, but the nervation is here very distinct and is identical with that of the other specimens. The specimen from Clear Creek seems also to be identical with the others in all that is essential to the species. The basilar appendage, which is here nearly perfect, is only three-lobed, but the same is true of one of the specimens from Seven Mile Creek (Pl. XVIII, Fig. 2).

This basilar appendage is extremely interesting. It is not stipular, since it arises from the summit of a petiole of considerable length, as shown in Plate XVII, where 6cm. of it are preserved without showing the attachment. The appendage is, moreover, not bracteal, but it is a veritable part of the main blade, to which it is joined by a broad (1.5 to 2 cm.) neck of parenchymatous tissue. It has very few analogues in the living flora, but something faintly resembling it occurs in some leaves of *Platanus occidentalis*, so common in the valleys of nearly all the rivers of North America. Long before I had seen the fossil specimens I had remarked that certain very vigorous leaves of that tree, usually such as grow from young shoots about the base of stumps, exhibit a sort of basilar appendage somewhat resembling the lobed stipules of the same species, which are also most prominent on such shoots, and I had collected and preserved specimens of these leaves to illustrate this peculiarity. Upon a comparison of these appendages with those of the fossil form I find that they are clearly homologous. Since collecting the latter I have lost no opportunity to study this phenomenon in the living plant. I find various transitions from the naked leaves (resembling in this respect those of *P. orientalis*, in which I have never seen any tendency toward basilar lobation) to forms with quite large and somewhat lobed and nerved expansions, though the nervation seems here to be rather pinnate than palmate, the intermediate forms consisting of a more or less winged petiole. Certain stipular appendages occur, however, which have precisely the form and nervation of the lobes of the extinct species, including the tendency to augment the number of primary nerves and lobes. These are not always true leaf stipules, but appear lower down on the young leaf-bearing branches. In *P. appendiculata* Lx. (Foss. Pl. Aurif. Gravels, pl. iii, fig. 3) there occur large stipular appendages wholly detached from the blade, yet near to it—apparently a transition or intermediate form. Prof. Leo Lesquereux has recently figured a form from the Dakota group which still more closely resembles our plant so far as the basilar appendage is concerned. He calls it an Araliophyllum, but there seems no doubt of its genetic affinities with these forms of Platanus. The Marquis Saporta, to whom figures of *P. basilobata* were sent, suggests its affinity with Pterospermum.

In considering all these facts it becomes difficult to escape the conviction that the basilar expansions of our North American species possess a phylogenetic significance in connection with those of the fossil form, and if no other result is attained, some degree of confidence will be thereby inspired that in referring these anomalous forms (e. g., *P. nobilis*) to this genus their natural relationships have been rightly divined.

Platanus Guillelmæ Göpp.

PLATANUS GUILLELMÆ Göpp., Tert. Fl. v. Schossnitz, p. 21, pl. xi, figs. 1, 2; pl. xii, fig. 5. Schimper, Pal. Vég., Vol. II, p. 707. Heer, Fl. Foss. Arct., Vol. II, Pt. IV (Foss. Fl. N. Greenld.), p. 473, pl. xlvii–xlix, figs. 4*b*, *c*, *d*, 6*b*; Vol. V, Pt. II (Foss. Fl. Sibir.), p. 40, pl. ix, figs. 14-16; pl. x, figs. 1-4*a*; pl. xi, fig. 1; pl. xiii, figs. 5*b*, 6*b*. Lesquereux, Tert. Fl., p. 183, pl. xxv, figs. 1-3.

Plate XX, Fig. 1.—Burns's Ranch, Montana; collected by Dr. White's party in 1882.

This is one of the most perfect specimens of this species that have been figured. Its petiole is complete, and is 3cm. in length, slightly dilated at the point of attachment. The leaf is small (6.3cm. wide) and agrees better with the original figures of Göppert, especially his first one (Tert. Fl. v. Schossnitz, pl. xi, fig. 1), than any of the American or arctic forms.

Platanus Raynoldsii Newberry.

PLATANUS RAYNOLDSII Newberry, Later Extinct Floras, pp. 30, 69; Illustrations of Cret. and Tert. Plants, pl. xviii. Lesquereux, Ann. Rep. U. S. Geol. Surv. Terr., 1872, pp. 379, 399; Tert. Fl., p. 185, pl. xxvii, figs. 1-3. Schimper, Pal. Vég., Vol. II, p. 708.

Plate XX, Figs. 2, 3.—Clear Creek, Montana; collected in 1882 by Dr. White's party.

The two specimens here figured correspond well with those from Golden as represented by Lesquereux on plate xxvii of the Tertiary Flora. Like his, they want the upper portion and lateral lobes. They are less in accord with Dr. Newberry's specimen, and differ from all others in the possession of a pair of quite strong and ascending nerves arising some distance below the insertion of the principal lateral primaries and passing upward and outward, giving off a few secondaries to the lowest teeth.

URTICACEÆ.

FICUS L.

Twenty species of Ficus have thus far been reported from the Laramie group none of which have been collected in typical strata of the Fort Union group. Upon a critical examination of these species, however, as will be seen by the table in the Sixth Annual Report (p. 482), I have referred six of them to that group. Three of these are from the localities of the upper districts which Lesquereux regards as equivalent to the Laramie of Colorado, but which seem to me to form the western extension of the Lower Yellowstone beds (cf. loc. cit., p. 441); two others occur in the British American Laramie, which is without doubt a northern extension of the true Fort Union terrane, while the one remaining species (*F. artocarpoides* Lx.), as well as one of the last named class (*F. tiliæfolia* Al. Br.), is from the Bad Lands of Dakota, which Mr. Lesquereux regards as Miocene, but which seem to me to form a southern extension of the Fort Union strata.

Among my Fort Union specimens I have thus far found three species referable to that genus which, if this reference is sustained, and even if no others should be detected, will show that a climate existed in the Fort Union epoch and at the latitude of Glendive warm enough and moist enough to permit these chiefly tropical plants to thrive.

On the other hand, four species were collected by me in the lower districts in 1881, and to these one is added from the collections of Mr. C. W. Cross, from Golden, Colo.

Ficus irregularis Lx.

FICUS IRREGULARIS Lx., Ann. Rep. U. S. Geol. Surv. Terr., 1874, p. 304; Bulletin do., Vol. V, p. 368; Tert. Fl., p. 196, pl. xxxiv, figs. 4–7; pl. lxiii, fig. 9.
ULMUS IRREGULARIS Lx., Ann. Rep. U. S. Geol. Surv. Terr., 1872, p. 378.

Plate XX, Figs. 4, 5.—Golden, Colorado.

The specimens are both from the tufa beds of South Table Mountain, near Golden, Colo., the first (Fig. 4) collected by Mr. C. W. Cross, the second (Fig. 5) by myself. Mr. Cross's specimen is nearly perfect to above the middle of the leaf and adds considerably to our previous knowledge of the species; my specimen also shows the basal portion, but for a shorter distance. It is remarkable in having a slightly heart-shaped base, in so far differing from all the other specimens known, and suggesting its reference to another species (e. g., *F. artocarpoides* Lx., cf. Cret. and Tert. Fl., pl. xlvii, figs. 2, 4, 5). Otherwise, however, it has the characteristic nervation of *F. irregularis*, including the anomalous forking of some of the secondary veins. In no other specimen I have seen are the fibrillose nervilles so clearly and perfectly shown as in this fragment.

Ficus spectabilis Lx.

FICUS SPECTABILIS Lx., Ann. Rep. U. S. Geol. Surv. Terr., 1872, p. 379; Tert. Fl., p. 199, pl. xxxiii, figs. 4–6. Schimper, Pal. Vég., Vol. III, p. 595.

Plate XXI, Fig. 1.—Golden, Colorado; collected in November, 1881, by Mr. C. W. Cross for Mr. S. F. Emmons.

The more distant secondary nerves indicate the reference of this specimen to *F. spectabilis* rather than to *F. irregularis*, but the percurrent nervilles are more like those of the latter species. As the base is wanting, some doubt must remain respecting its true affinities.

Ficus Cróssii, n. sp.

Plate XXI, Fig. 2.—Golden, Colorado; collected in 1881 by Mr. C. W. Cross for Mr. S. F. Emmons.

Leaves medium size for the genus (4.5cm. wide, 8cm. long), ovate-oblong, wavy margined; midrib thick, diminishing rapidly to the summit; secondary nerves about twelve on each side, forming an angle of 60° to 70° with the midrib, curving upward near the margin, parallel and equidistant, occasionally forking at the point of curvature; nervilles percurrent, straight, forming acute angles with the under side of the secondaries, regular and parallel.

The specimen is from the coarse white sandstone beds near Golden, but is preserved with considerable fidelity. It seems to have its nearest analogue in *F. arenacea*, described by Prof. Lesquereux from some unknown locality which he vaguely surmises to have been in the Green River group (see Ann. Rep. U. S. Geol. Surv. Terr., 1871, p. 300; Tert. Fl., p. 195, pl. xxix, figs. 1–5). It may also be compared with *F. multinervis* Heer (Tert. Fl., p. 194, pl. xxviii, fig. 8, not 7), of which I have not seen any specimens. It seems, however, to differ specifically from both these forms.

Ficus speciosissima, n. sp.

Plate XXI, Fig. 3.—Point of Rocks, Wyoming; gray sandstone bed north of station.

Leaves large (16cm. wide, 18cm. long), round ovate, deeply auriculate-cordate, entire margined, strongly palmately nerved; petiole short (3 cm.), curved or hooked, projecting little below the rounded auricles of the leaf, divided at the summit into three strong primary nerves, of which the central one retains about as many fibers as the two lateral, these forming an angle with it of about 40° and proceeding nearly straight to near the margin far above the middle, sending off from their outer side about ten well developed secondaries, the lowest of which on each side supports six to eight tertiaries, and these in turn several nerves of the fourth order; upper secondaries giving off successively fewer tertiaries; midrib naked for some distance above the insertion of the lateral primaries, then bearing three or four strong, alternate, distant nerves on each side, which branch in the same manner as those of the lateral nerves; secondary and tertiary nerves arching near the margin by angular curves, from which short, straight branches go direct to the margin; nervilles very prominent, mostly percurrent and curved, often forking, or joined once or twice in their course by perpendicular or oblique veinlets, the rectangular or trapezoidal areas thus formed further subdivided into fine quadrate or somewhat polygonal meshes.

This beautiful leaf approaches most closely in form and general nervation to certain large forms of *F. tiliæfolia* (cf. Unger, Foss. Fl. v. Sotzka, Denkschr. Wien. Acad., Vol. II, pl. xlvii, fig. 2; Göppert, Palæontographica, Vol. II, pl. xxxvii, fig. 1; Heer, Tert. Fl. Helv., Vol. II, pl. lxxxiii, fig. 7; Vol. III, pl. cxlii, fig. 25; Lesquereux, Tert. Fl., pl. lxiii, fig. 8; Zwanziger, Mioc. Fl. v. Liescha, pl. xvi, xvii), and it also has analogues in some species of Dombeyopsis (cf. *D. Heufleriana* Mass., Monogr. Dombeyac. Foss., plate; *D. Decheni*, Ludw., Palæontographica, Vol. VIII, pl. xlix, fig. 1; *D. tridens*, loc. cit., figs. 2, 3); but, aside from the hooked petiole, this form is distinguished from all others I have been able to compare with it by the character of the nervation in its ultimate ramifications joining the arches directly to the margin. This character is faintly imitated in Saporta's *Populus Massiliensis* (Études, Ann. Sci. Nat., Bot., 5e Sér., Vol. IX, pl. iii, fig. 1), and still more faintly in *Tilia expansa* Sap. & Mar. (Vég. Foss. de Meximieux, pl. xxxviii, fig. 3; Monde des Plantes, p. 333, fig. 103, No. 5); but it reaches its most complete expression in certain forms of Cinnamomum, Laurus, &c. (cf. Rossmässler, Verstein., pl. i, figs. 1, 3, 4; Ettingshausen, Foss. Fl. v. Bilin, II, Denkschr. Wien. Acad., Vol. XXVIII, pl. xxxiii, figs. 4–22; Ludwig, Palæontogr., Vol. VIII, pl. xli, fig. 51). These leaves, however, differ widely in form from ours, but certain species of Cinnamomum have broad, though never heart-shaped, leaves (cf. *C. transversum* Heer, Fl. Tert. Helv., Vol. II, pl. xcv, figs. 10, 12), and at Black Buttes Station I collected some leaves (not yet fully figured), no larger than those figured by Heer, which seem to combine many of the characters of Ficus and Cinnamomum and closely to resemble this species.

Ficus tiliæfolia (Al. Br.) Heer.

FICUS TILIÆFOLIA (Al. Br.) Heer, Fl. Tert. Helv., Vol. II, p. 68, pl. lxxxiii, figs. 3–12; pl. lxxxiv, figs. 1–6; pl. lxxxv, fig. 14; Vol. III, p. 183, pl. cxlii, fig. 25; Mioc. Balt. Fl., p. 35, pl. viii, fig. 1; p. 74, pl. xxi, fig. 12. Ettingshausen, Fl. Tert. v. Bilin, I (Denkschr. Wien. Acad., Vol. XXVI), p. 156, pl. xxv, figs. 4, 5, 7, 10; Foss. Fl. Braunk. Wetterau (Sitzb. Wien. Acad., Vol. LVII, Abth. I), p. 844, pl. ii, fig. 9. Gaudin, Gisement de Feuilles de Toscane (Nouv. Mém. Soc. Helv., Vol. XVI), p. 34, pl. xii, fig 11. Unger, Syllog., I, p. 14, pl. vi, fig. 2; Foss. Fl. v. Szantó (Denkschr. Wien. Acad., Vol. XXX), p. 8, pl. ii, fig. 9. Sismonda, Pal. Tert. du Piémont (Mem. Real. Accad. Sci. di Torino, Ser. 2, Vol. XXII, 1865), p. 436, pl. xvii, fig. 5. Schimper, Pal. Vég., Vol. II, p. 746. Lesquereux, Tert. Fl., p. 203, pl. xxxii, figs. 1–3; pl. lxiii, fig. 8; Foss. Pl. Aurif. Gravels, p. 18, pl. iv, figs. 8, 9. Engelhardt, Fl. d. Braunk. Sachsen (Preisschr. Fürstl. Jabl. Ges.), p. 19, pl. v, fig. 1; Tert. Fl. v. Göhren, p. 24, pl. iv, fig. 6; Tert. Pfl. Leitmeritz. Mittelgeb. (Nov. Act. L.-C. Acad., Vol. XXXVIII), p. 378, pl. xx, fig. 18; Foss. Pfl. v. Grasseth (Nov. Act. L.-C. Acad., Vol. XLIII), p. 298, pl. xv, figs. 1, 2; Zwanziger, Mioc. Fl. v. Liescha, p. 52, pl. xvi–xviii, figs. 1–3. Pilar, Fl. Foss. Susedana, p. 54, pl. viii, fig. 5. Velenowsky, Flora Vrsovic., p. 28, pl. vi, figs. 1–4.

CORDIA? TILIÆFOLIA Al. Br., Leonh. & Bronn, N. Jahrb. f. Min., 1845, p. 170.

Plate XXII, Fig 1.—Burns's Ranch, Wyoming.

Thus far only one specimen has been found in the collections that seems to be referable with considerable certainty to this widespread and variable species, and if the genus occurs at all in the Fort Union group this species is the one that might be most naturally looked for. The leaf is a little one-sided and the midrib turned to one side near the base, like many specimens of that species, and but for the somewhat alternate character of the lower pair of nerves it would closely resemble some of the forms figured by Heer (Fl. Tert. Helv., pl. lxxxiii, lxxxiv). It also forcibly recalls Lesquereux's *F. tenuinervis* (Cret. and Tert. Fl., p. 164, pl. xliv, fig. 4) from Alkali Stage Station near Green River, but the nervation is much stronger. While I have referred it with considerable confidence to Ficus, it is proper to say that forms that have been placed in other genera have many characters in common with it. This is especially the case with certain leaves in the Leguminosæ, and notably with Saporta's *Phaseolites fraternus* (Études, Ann. Sci. Nat., Bot., 5e Sér., Vol. IV, 1865, pl. xiii, fig. 11) and Unger's *P. oligantherus* (Syllog. II, pl. vi, figs. 8, 9); also with Unger's *Dolichites maximus* (op. cit., pl. viii). Certain species of Cinnamomum also approach it very nearly in some respects, particularly *C. polymorphum transversum* (cf. Saporta, Études, op. cit., Vol. IX, pl. v, figs. 3, 4).

Ficus sinuosa, n. sp.

Plate XXII, Fig. 2.—Black Buttes Station, Wyoming.

Leaf lanceolate, oblique, and sinuate, acute at both ends, 1.5cm. wide, 5cm. long, entire; nervation distinct, pinnate, camptodrome; midrib strong, sinuate in two curves to follow the center of the leaf; secondary nerves about ten on each side, all except the short upper ones opposite, proceeding from the midrib at an angle of 45°, curving upward in passing toward the margin, near which they arch and anastomose with one another, often giving off fine veinlets from the summit of the arches, which curve close to the margin, forming a partial second row with small rhomboidal meshes, the lowest pair finer and making a less angle with the midrib; nervilles distinct, simple, straight, percurrent, joining the secondaries at right angles.

The petiole of this specimen is not preserved, but the blade has so many of the characters of Ficus that it seemed necessary to refer it to that genus. There are certain small lanceolate forms of *F. tiliæfolia* which it approaches in some respects (cf. Heer, Fl. Tert. Helv., pl. lxxxiii, fig. 5). One of the specimens referred by Lesquereux (Tert. Fl., pl. lxiii, fig. 4) to Ettingshausen's *F. Dalmatica* is somewhat sinuous and otherwise resembles ours, but in the original from Monte Promina (Denkschr. Wien. Acad., Vol. VIII, pl. vii, fig. 11) the resemblance is less marked.

Among the figures belonging to other genera which I have been able to compare the nearest analogues are: *Rhus zanthoxyloides* Ung. (Foss. Fl. v. Kumi, Denkschr. Wien. Acad., Vol. XXVII, pl. xiii, fig. 28).

Rhamnus Decheni Web. (Palæontogr., Vol. II, pl. xxiii, fig. 2*d*), and *Quercus Lamberti* Wat. (Pl. Foss. du Bassin de Paris, pl. xxxv, fig. 5). In the first two cases the finer details of the nervation are wanting, while that of our specimen does not agree with either Rhus or Rhamnus as well as with Ficus. As to the third case, where the nervilles are well shown and are characteristic of Quercus, they differ entirely from those of our specimen. The smaller angle, formed by the lowest pair of secondaries, is suggestive of the Laurineæ, but it is also a common character of Ficus, and upon the whole this seems the safest reference.

Ficus limpida, n. sp.

Plate XXII, Fig. 3.—Clear Creek, Montana.

Leaf lanceolate, pointed at both ends, falcate at the summit, dentate to near the oblique base, short petioled; nervation craspedodrome; midrib rather slender, curved in opposite directions below and above; secondary nerves, six on each side, proceeding from the midrib at an angle of 30° and gently curving upward in passing to the margin, alternate, the lowest giving off six or seven distinct tertiary nerves, which directly enter the teeth, several of the next higher ones provided with similar branches near their extremities, the uppermost simple; nervilles straight, simple, percurrent, close together and parallel, slightly tremulous-wavy, joining the secondaries to one another and also to the midrib.

On reconsidering the diagnosis made of the leaf in July, 1885, for the purpose of assigning a name to it in the list of types figured in the Sixth Annual Report, I find reason for doubting whether I should have referred it to Ficus rather than to Viburnum. Much of the margin is wanting, and it will probably be impossible to settle the question without more and better material.

Ficus viburnifolia, n. sp.

Plate XXII, Figs. 4–8.—Clear Creek, Montana.

Leaves thick and coriaceous, round-ovate, obliquely heart shaped, dentate above, with short broad teeth or nearly entire below; nervation very strong, forming deep depressions or prominent ridges in the rock, pinnate; midrib very thick below, rapidly diminishing above, usually much to one side of the middle, sometimes curved towards the narrower side; secondary nerves numerous (six or eight on each side), the lower ones very strong, several crowded together at and near the base of the leaf, the lowest passing downward and outward nearly parallel to the margin of the lobes, the others passing outward and curving upward, those on the narrower side of the leaf nearly straight, all more or less sympodially branched or forked, the ultimate ramifications entering the teeth or often curving near the margin and anastomosing with one another, forming arches from which small nerves pass into the teeth; nervilles very conspicuous (deeply furrowing the matrix, in which in some cases the silicified tissue is well preserved), close together, percurrent, straight, simple, or rarely forked, joining all the other nerves nearly at right angles.

These fine and in many respects remarkable specimens were all obtained at Clear Creek, the one represented by Fig. 4 by Dr. White in 1882, the rest by myself a year later. They occurred in immediate association with the abundant Viburnum leaves to be described later on, which, as will be seen, vary greatly among themselves and seem to approach those we are now considering in some of their extreme forms. I had been struck from the first by the peculiarity in nearly all the Clear Creek specimens, that the lower secondaries were inclined to converge and huddle together near the base, not at a single point, but along a small portion of the midrib, and as these leaves exhibited the same character I was at first disposed to class them with the rest. On finding the two very one-sided specimens, however, represented by Figs. 5 and 8, my attention was specially attracted to their marked analogy in general form to some species of Ficus (cf. *F. tiliæfolia* Unger, Foss. Fl. v. Sotzka, Denkschr. Wien. Acad., Vol. II, pl. xlvi, figs. 4, 5; Heer, Fl. Tert. Helv., Vol. II, pl. lxxxiii, figs. 4, 10, 11; pl. lxxxiv, figs. 1–3; Sismonda, Terr. Tert. du Piémont, Mem. Reale Accad. Sci. di Torino, Vol. XXII, pl. xvii, fig. 5). The last specimen (Fig. 8) is the only one which presents the under surface of the leaf, showing the nervation in relief, and along with other differences it seems to have the border entire all round, whereas the rest are clearly dentate to below the middle, and, although it has been drawn as if entire, it is fair to say that some doubt is admissible as to whether this appearance may not have been due to the margin having been somewhat recurved at the time it was imbedded and to the failure of this dentate portion to be preserved. Were I not inclined to this view, I should feel compelled to separate this specimen from the rest and refer it to *F. tiliæfolia*. But, assuming them all to have been more or less dentate, such a reference is inadmissible, while at the same time the similarity of the nervation to that of Ficus is too great to be ignored. I have therefore decided for the present to regard them as belonging to that genus and to emphasize their general resemblance to the Viburnum leaves of Clear Creek by the specific name given to the plant.

That the possession of teeth cannot be regarded as conclusive against this being a Ficus is shown by the existence of many dentate species, both living and fossil, including the best known species of all, *F. Carica*, the fig tree proper, and M. Gaudin has described a fossil state of this species from the diluvial travertines of Tuscany which presents a nervation strikingly similar, in some respects, to the leaves under consideration (cf. Contr., IV, pl. iv, figs. 1–4).

While it does not seem possible to find any forms, either living or fossil, that combine all the characters of these leaves, there are several genera outside of Ficus which sometimes exhibit some one of them. The general form, for example, is not unlike that of Grewia (cf. Heer, Fl. Tert. Helv., pl. cix, Figs. 12, 12*b*, 12*c*; pl. cx, Figs. 1–13), but here the nervation is strictly palmate and the primary nerves all proceed from one point at the summit of the petiole. The dichotomous behavior of the secondary nerves in our leaves is closely imitated by *Grewiopsis Haydenii* Lx. (Cret. Fl., pl. iii, Fig. 4), also by some Viburnums (cf. *V. Schmidtianum* Heer, Fl. Foss. Arct., Vol. V, Pt. III, Prim. Fl. Foss. Sachal., pl. xi, Figs. 9, 10). The very thick base of the midrib, rapidly parting with its fibers to the numerous lateral nerves crowded together there as well as some other characters, best shown in Fig. 6, is not unlike Newberry's still unassigned *Phyllites carneosus* (Illustrations of Cret. and Tert. Plants, pl. xxvi, Figs. 1, 2). These characters also remind us of Credneria and Protophyllum. Finally the peculiar one-sidedness of some of these leaves and the consequent dissimilarity of the nervation resemble Saporta's *Alnus sporadum Phocæensis* (Études Ann. Sci. Nat., Bot., 5e Sér., Vol. IX, pl. ii, fig. 5).

ULMUS L.

The Clear Creek beds contained leaves of this genus scattered very sparingly among those of Viburnum. Though few in number, they are different in form both from one another and also from any other forms that have been described in a fossil state. I have been compelled to regard them all as new and to group them under four different specific heads.

Ulmus planeroides, n. sp.

Plate XXIII, Figs. 1, 2.—Clear Creek, Montana.

Leaves ovate-lanceolate, 2.3cm. wide, 5 to 8 cm. long, pointed, oblique at the base, sharply and somewhat doubly crenate-dentate to near the base, unequal-sided; midrib straight or slightly curved; secondary nerves approximate and parallel, thirteen to seventeen on each side, making an angle of 50° to 60° with the midrib, slightly curving upward near the margin, terminating near the teeth, simple or once or twice forking near their extremities, the branches from the lower side smaller and proceeding to the sinuses, intermediate branches occasionally entering the subordinate teeth; nervilles very faint, percurrent, forked, or irregular and broken, often proceeding from the midrib as light intercalary nerves.

Of this species three specimens have been thus far found in the collection, two of which are figured. The petiole is wanting in all the specimens, and the point is preserved in only one (Fig. 2), where it is obtuse. The base is preserved in the specimens figured and is identical in both. They differ, however, considerably in length and in the number of secondary nerves, but this is not regarded as a specific distinction.

Ulmus Californica Lx. (Foss. Pl. Aurif. Gravels, pl. iv, figs. 1, 2; Cret. and Tert. Fl., pl. xlvB, fig. 3) has somewhat the same form of leaf as our specimens, but the nervation differs in the simpler secondaries, while the dentation is not at all double. In *U. discerpta* Sap. (Études, Ann. Sci. Nat., Bot., 5e Sér., Vol. VIII, pl. vi, fig. 4) the dentation and the nervation are similar, but the form, so far as can be gathered from the figure of the incomplete specimens found at the Bois d'Asson, is quite different.

Ulmus minima, n. sp.

Plate XXIII, Figs. 3, 4.—Clear Creek, Montana.

Leaves lanceolate or linear, very small (6 to 10mm. wide, 2 to 3cm. long), slightly curved and one-sided, simply or somewhat doubly serrate, oblique at the base; midrib curved; secondary nerves nearly all opposite, about ten pairs, short, parallel, forming an angle of 50° with the midrib, more or less branched from the under side, the short branches running into the sinuses; nervilles indistinguishable.

Small as these leaves are they seem to have the essential characters of Ulmus and are confidently referred to that genus. Of the sixteen or eighteen living species and twenty-five or thirty fossil ones thus far known, not more than one or two are as small, and these have a greater amplitude in proportion to their length. I am therefore compelled to regard these forms as representing a new and extinct species. The fragment figured by Lesquereux, from Middle Park, Colorado, under the name of *Rhus Evansii* (Tert. Fl., pl. l, fig. 4) approaches our form very closely, but lacks the tertiary nerves going to the sinuses, characteristic of Ulmus, which might have merely been indistinguishable on the specimen. I have not had an opportunity to examine this point, as the specimen is not in the collection of the National Museum.

Ulmus rhamnifolia, n. sp.

Plate XXIII, Fig. 5.—Clear Creek, Montana.

Leaf rather large (4.7cm. wide, 9 to 10cm. long), nearly equal-sided, scarcely oblique at the base, oblong-ovate, crenate-dentate to near the base, with short and somewhat blunt, broad teeth; midrib strong, straight, diminishing very gradually towards the summit; secondary nerves numerous (twelve or more on each side), approximate, parallel, making an angle of 50° to 60° with the midrib, slightly curving upward, the two or three lowest pairs opposite, the lowest pair close to the base, simple and slender, the rest more or less branched from the under side near their extremities, the tertiaries passing into the sinuses or into intermediate teeth, which are nearly as long as those that receive the main branches; nervilles distinct, parallel, percurrent, mostly straight and simple, sometimes forked or crossed at right angles, those from the midrib curved or bent to join the secondary below.

The petiole, upper portion, and a considerable part of the margin of this otherwise finely preserved leaf are wanting, and but for the fact that the sinuses that are shown nearly all have tertiary nerves running into them there might have been some doubt as to what genus it represented. The form and general aspect, however, as well as the nervation, are decidedly those of Ulmus.

Ulmus orbicularis, n. sp.

Plate XXIII, Fig. 6.—Clear Creek, Montana.

Leaf orbicular, large (8cm. in diameter), nearly equal-sided, irregularly doubly serrate to near the base, which is entire, horizontal, and apparently decurrent on the petiole, forming wings at its apex; midrib thick below, rapidly diminishing in passing through the leaf; secondary nerves strong (deeply furrowing the rock), close together, parallel, subopposite, leaving the midrib at an angle of 60° to 70°, much curved upward in passing across the broad parenchyma, the lowest pair sending off three to five tertiaries, the rest provided with short branches from the under side near their extremities, which enter the subordinate teeth and the sinuses; nervilles conspicuous, somewhat irregular, mostly percurrent, sometimes furcate, joining the secondaries nearly at right angles.

This enigmatic leaf-print wants the entire upper portion, but from the great curvature of the upper secondaries it seems certain that it was not attenuated at the apex, and may have even been concave or emarginate above. I am not sure that this may not have been due to a diseased state of the leaf, as I have seen cases among living plants, e. g., in Fraxinus, where, by some early injury to the normally pointed tip, it had become retuse and the abnormal growth had gone so far as to carry the upper nerves round and in toward the center at the apex, much as this leaf seems to have grown. Still the present leaf is otherwise very symmetrical, and this may well have been its normal form. The petiole is absent, but the downward curvature of the margins on both sides of the midrib at the base of the leaf seems to show that its upper portion at least was winged. The general character of its nervation and dentation is that of Ulmus, but the form is anomalous. I have failed to find either in the living or in the fossil flora any near analogues to this specimen.

LAURINEÆ.

LAURUS L.

The nervation of the leaves in the Laurineæ, while it is generally fairly characteristic of the order, often fails to distinguish the genera, and therefore considerable uncertainty must remain in many cases where, as is usually the case, only leaf impressions exist from which to make the diagnosis. The two species which I regard as belonging to Laurus agree well enough with forms already figured and described to make it possible to refer them to such, whatever may be the doubts as to the probability that the same species thrived at such widely separated parts of the world.

Laurus resurgens Sap.

LAURUS (OREODAPHNE?) RESURGENS Sap., Études, Ann. Sci. Nat., Bot., 5e Sér., Vol. IV, p. 132, pl. vii, figs. 9A, 9B; Vol. VIII, p. 78, pl. vii, fig. 5.
DAPHNOGENE AFFINIS Sap., Examen Analytique, &c., p. 45.
OREODAPHNE? RESURGENS Schimp., Pal. Vég., Vol. II, p. 848.

Plate XXIII, Fig 7.—Bull Mountains, Montana; collected by Dr. A. C. Peale in 1883.

The finer details of the nervation in this leaf are nearly identical with those represented by Saporta in plate vii, figs. 9A and 9B, of his Flora of Armissan. In fig. 9B the midrib is somewhat curved, but not abruptly bent as in our specimen. In *Sapindus Rotarii* Mass. (Fl. Foss. del Senigal., pl. xiv, fig. 4), we have a similar form of round arches with concentrically arranged nervilles, but in this the lower secondary nerves differ from the type of the Laurineæ.

Laurus primigenia Ung.

LAURUS PRIMIGENIA Ung., Gen. et Spec., p. 423; Foss. Fl. v. Sotzka (Denkschr. Wien. Acad., Vol. II), p. 168, pl. xl, figs. 1–4; Sylloge, III, p. 72, pl. xxii, fig. 18; Foss. Fl. v. Kumi (Denkschr. Wien. Acad., Vol. XXVII), p. 55, pl. viii, figs. 1–7. Ettingshausen, Foss. Pfl. v. Heiligenkreuz bei Kremnitz (Abh. K. K. Geol. Reichsanstalt, Vol. I), p. 8, pl. ii, figs. 1, 2; Tert. Fl. Steiermark's (Sitzb. Wien. Acad., Vol. LX, Abth. I), p. 58, pl. iii, figs. 11–11c. Weber, Palæontogr., Vol. II, p. 181, pl. xx, figs. 6*a*, 6*b*. Heer, Uebersicht d. Tert. Fl., p, 55; Fl. Tert. Helv., Vol. II, p. 77, pl. lxxxix, fig. 15; Vol. III, p. 184, pl. cxlvii, fig. 10*c*; pl. cliii, fig. 3; Proc. Acad. Nat. Sci. Philadelphia, Vol. X, 1858, p. 265; Sächs.-Thüring. Braunk. Fl., p. 7, pl. vi, figs. 12*i*, 12*k*; p. 19, pl. ix, fig. 8; Foss. Fl. of Bovey-Tracey (Phil. Trans. Roy. Soc. London, 1862), p. 1062, pl. lxv, fig. 6; Braunk. Fl. d. Zsily-Thales, p. 16, pl. iii, figs. 4, 5, 6; Fl. Foss. Arct., Vol. VI, Pt. II (Nachtr. Foss. Fl. Grönlands), p. 12, pl. iii, figs. 8*a*, 9–13. Sismonda, Pal. Terr. Tert. du Piémont (Mem. R. Accad. Sci. di Torino, Ser. II, Vol. XXII, 1865), p. 438, pl. ix, fig. 2*c*; pl. x, fig. 5. Saporta, Études, Ann. Sci. Nat., Bot., 4e Sér., Vol. XIX, pp. 20, 56; pl. vi, figs. 5, 5A; 5e Sér., Vol. III, p. 93, pl. iii, figs. 8, 8A; Vol. IV, p. 126, pl. vii, fig. 7; Vol. IX, p. 38, pl. iv, figs. 7, 8; Monde des Plantes, p. 384, fig. 116, Nos. 1–3. Engelhardt, Fl. d. Braunk. im Sachsen (Preisschr. Jablonowsk. Ges. 1870), p. 20, pl. v, fig. 3; Foss. Pfl. v. Tschernowitz (Nov. Act. L.-C. Acad., Vol. XXXIX), p. 382, pl. xxiii, fig. 5; Foss. Pfl. v. Grasseth (op. cit., Vol. XLIII), p. 300, pl. xvi, figs. 4, 5; Tert. Fl. Leitmeritz. Mittelgebirges, p. 360, pl. xvii, figs. 5–7; p. 382, pl. xxi, fig. 5; p. 405, pl. xxvi, fig. 9. Lesquereux, Ann. Rep. U. S. Geol. Surv. Terr., 1872, p. 406; Tert. Fl., p. 214, pl. xxxvi, figs. 5, 6, 8. Schimper, Pal. Vég., Vol. II, p. 818. Marion, Pl. Foss. de Ronzon (Ann. Sci. Nat., Bot., 5e Sér., Vol. XIV), p. 348, pl. xxii, fig. 19. Velenowsky, Fl. v. Vrsovic, p. 30, pl. v, figs. 1–5. Pilar, Fl. Foss. Susedana, p. 68, pl. ix, fig. 5; pl. x, fig. 8.

Plate XXIII, Figs. 8–10.—Carbon Station, Wyoming (Fig. 8). Point of Rocks, Wyoming; white sandstone bed east of station (Figs. 9, 10).

These specimens represent two of the forms which this polymorphic species assumes. The Carbon specimen (Fig. 8) is identical in form with those figured by Heer from the Zsily-Thal (pl. iii, figs. 4–6; cf., also, Saporta, Études, Ann. Sci. Nat., Bot., 5e Sér., Vol. IX, pl. iv, figs. 7, 8), while the Point of Rocks specimens (Figs. 9, 10) belong to the section of Ettingshausen's *L. phœboides* (Foss. Fl. v. Wien, p. 17, pl. iii, fig. 3), agreeing even still more exactly with the specimens from St. Jean de Garguier (Ann. Sci. Nat., Bot., 5e Sér., Vol. III, pl. iii, fig. 8). These latter constitute an addition to the already so well worked white sandstone bed at Point of Rocks.

It is not difficult to find many analogues of these elongated leaves belonging to widely different families of plants, and among such *Eugenia Hœringiana* Ung. (Sylloge, III, pl. xviii, figs. 8, 9), *Callistemophyllum melaleucœforme* Ett. (Foss. Fl. v. Bilin, III, pl. liv, figs. 1–3), *Hippophaë striata* Ludw. (Palæontogr., Vol. VIII, pl. xliv, fig. 4), and *Apocynophyllum lanceolatum* Ung. (Foss. Fl. v. Sotzka, pl. xliii, figs. 1, 2) simulate our leaves more or less both in form and nervation. The Carbon specimen may also be compared with some other species of Laurus, as, e. g., with *L. Canariensis pliocenica* Sap. (Vég. Foss. de Meximieux, pl. xxvii, fig. 6), and also with other lauraceous forms, such as *Tetranthera sessiliflora* Lx. (Tert. Fl., pl. xxxv, figs. 8*a*, 9).

Baron von Ettingshausen considers Fig. 9 as corresponding more closely to *L. ocoteæfolia* Ett. and the others as belonging to an allied species rather than to *L. primigenia*. The forms would thus embrace two new species.

LITSÆA Lam.

The nervation of this genus, which now includes Tetranthera, is very similar to that of Laurus, but still nearer to that of Ocotea (Oreodaphne Nees) and Persea. Our forms, of which only one is figured, may belong to one of the latter almost as well as to Litsæa.

Litsæa Carbonensis, n. sp.

Plate XXIV, Fig. 1.—Carbon Station, Wyoming.

Leaf lanceolate, 5cm. broad, somewhat abruptly taper-pointed, entire, with slightly irregular or wavy margins; midrib strong, flexuous above; lateral primary nerves ascending and approaching the margins above the middle, anastomosing with the first pair of secondaries, which are separated from them on the midrib by a long internode and proceed at a much greater angle (40°); secondaries only two on each side, the first pair nearly opposite, the upper pair alternate, making an angle of 60° with the midrib, joined near their extremities by those from below; nervilles joining the midrib and primaries to one another and to the secondaries, usually curved or geniculate, often forked, joined, or crossed by veinlets, meeting them at different angles.

This species closely resembles *Tetranthera præcursoria* Lx. (Cret. and

Tert. Fl., pl. xlviii, fig. 2), from the Bad Lands of Dakota, but as in that specimen the summit was wanting and the base preserved, while in ours the base is wanting and the summit preserved, it is not possible to institute a thorough comparison. In that figure, however (the specimen I have not seen), there are three pairs of opposite secondary nerves, and the lateral primaries are drawn much more slender than they are in the Carbon plant, and from the part preserved it seems probable that the summit of that leaf was much shorter-pointed. Perhaps an even closer approximation to our leaf occurs in *Oreodaphne Heerii* Gaud. (Gisements, Nouv. Mém. Soc. Helv., Vol. XVI, pl. x, fig. 7; reproduced in Saporta, Vég. Foss. de Meximieux, pl. xxvi, fig. 9), though here also the point is much less slender and no sign of the characteristic glands at the base of the lateral nerves is visible in our specimen.

CINNAMOMUM Blume.

An almost exclusively tropical genus, embracing about fifty species, confined to the Old World, but ranging on both sides of the equator. Fossil representatives are abundant in the Tertiaries of Europe, especially in the Eocene, but forms are reported as low as the Cenomanian. The four species of the Laramie thus far described argue a warm climate.

Cinnamomum lanceolatum (Ung.) Heer.

CINNAMOMUM LANCEOLATUM (Ung.) Heer, Fl. Tert. Helv., Vol. II, p. 86, pl. xciii, figs. 6-11; Foss. Fl. Bovey-Tracey (Phil. Trans. Roy. Soc. London, 1862), p. 1063, pl. lxvii, figs. 1-8, pl. lxviii, figs. 14, 15; Braunk. Pfl. v. Bornstädt (Abh. Naturf. Ges. z. Halle, Vol. XI, 1869), p. 16, pl. iii, figs. 2*a*, 2*c*; Mioc. Balt. Fl., p. 77, pl. xxii, figs. 14-17; Braunk. Fl. d. Zsily-Thales, p. 17, pl. iii, fig. 3. Massalongo, Synops. Fl. Foss. Senog., p. 62; Fl. Foss. del Senigal., p. 265, pl. viii, figs. 2, 3, 4; pl. xxxiii, fig. 9. Ludwig, Palæontogr., Vol. VIII, p. 109, pl. xliii, figs. 1-7. Saporta, Études, Ann. Sci. Nat., Bot., 5e Sér., Vol. IX, 1868, p. 40, pl. iv, figs. 11-16. Sismonda, Pal. Tert. du Piémont, p. 440, pl. xxiv, figs. 5, 6; pl. xxvi, fig. 7. Unger, Foss. Fl. v. Kumi (Denkschr. Wien. Acad., Vol. XXVII), p. 54, pl. vii, figs. 1-10. Ettingshausen, Foss. Fl. d. Wetterau (Sitzb. d. Wien. Acad., Vol. LVII, Abth. I), p. 850, pl. iii, figs. 4, 5; Foss. Fl. v. Bilin, II (Denkschr. Wien. Acad., Vol. XXVIII), p. 198, pl. xxxiii, figs. 7-9, 13, 16, 16*b*. Engelhardt, Fl. d. Braunk. Sachsen (Preisschr. Jablonowsk. Ges., 1870), p. 20, pl. iv, figs. 11, 12; Cyprissch. Nordböhm. (Sitzb. Naturw. Ges. Isis, 1879), p. 10, pl. vii, figs. 22, 23; Foss. Pfl. v. Grasseth (Nov. Act. L.-C. Acad., Vol. XLIII), p. 304, pl. xii, figs. 11, 14, 15; pl. xiii, figs. 10, 12; pl. xviii, figs. 1-5. Schimper, Pal. Vég., Vol. II, p. 842. Lesquereux, Tert. Fl., p. 219, pl. xxxvi, fig. 12. Pilar, Foss. Fl. Susedana, p. 61, pl. xi, figs. 2, 4, 12, 14?, 15.

PHYLLITES CINNAMOMEUS Rossm., Verstein., p. 23, pl. i.

DAPHNOGENE LANCEOLATA Ung., Gen. et Spec., p. 424.

Plate XXIV, Fig. 2.—Hodges Pass, Wyoming.

Notwithstanding the fact that only two doubtful specimens, Nos. 315 (Lesquereux, Tert. Fl., p. 219, pl. xxxvi, fig. 12) and 790 of the National

Museum collection, have to my knowledge been thus far found in American strata, I nevertheless was compelled to refer this form to that species on account of its great general resemblance to so many of the European specimens. As Prof. Lesquereux's specimens were found at Evanston and as I have considered the Hodges Pass beds as a northern extension of the Evanston coals, the discovery of the same form at both places is not perhaps surprising. It must, however, be admitted that our plant differs from all others thus far published in its greater length and size. Although wanting the summit there are 11 centimeters of it still preserved, and the specimen indicates that the leaf must have been nearly or quite 15cm. long, while its width is about 2.5cm. Rossmässler's original specimen, as reconstructed at the base by himself (Versteiu., pl. i, fig. 2), and which is one of the largest figured anywhere, is 11cm. long by 2.8cm. wide. The Evanston specimens indicate a leaf not more than 8 or 10 cm. long. In most other examples, too, the lateral primaries are exactly opposite, which is not the case here, though they are nearly so. Otherwise there is no material divergence in the nervation, so far as it is exhibited in the specimen, but as the matrix in which it was embedded is a very coarse sandstone the finer details of nervation are not visible and only a very few nervilles can be made out. The Marquis Saporta, to whom figures were sent, is therefore doubtless correct in regarding this as a distinct species.

? Cinnamomum affine Lx.

?CINNAMOMUM AFFINE Lx., Am. Journ. Sci., 2d Ser., Vol. XLV, 1868, p. 206; Ann. Reps. U. S. Geol. Surv. Terr., 1867, 1868, 1869, p. 196; 1870, p. 383; 1872, 383, 387; 1873, p. 401; Tert. Fl., p. 219, pl. xxxvii, figs. 1-5, 7; Cret. and Tert. Fl., p. 252, pl. lviii, fig. 9.

Plate XXIV, Figs. 3-5.—Black Buttes Station, Wyoming.

So referred in the Sixth Annual Report, pl. xlvii, figs. 1-3, but Prof. Lesquereux would refer them to Ficus and not to Cinnamomum. They would then fall into the section with *F. planicostata* Lx., but after examining a large number of unfigured specimens of that species and its varieties, as well as of *F. spectabilis* in connection with the types and figures, I conclude that the species is new.

There are in the Museum collection a number of unfigured specimens (Nos. 312 *a*, *b*, *c*) of *Cinnamomum affine*, from Point of Rocks, Wyoming, at least one of which (312*b*, Lesquereux's private number 1499) has the lateral primaries joined to the margins below the abrupt expansion of the blade, precisely as in our Fig. 1. These must be specifically identical with the Black Buttes specimens, to whatever genus it be thought proper to refer them.

There is considerably more material in the collection, and after it has all been more thoroughly studied and figured more light will probably be thrown upon the affinities of this plant.

DAPHNOGENE Ung.

This genus is only provisional, no fruits having as yet been discovered. Eighteen species are retained by Schimper in his Paléontologie Végétale.

Daphnogene elegans Wat.

DAPHNOGENE ELEGANS Wat., Pl. Foss. de Paris, p. 180, pl. li, figs. 5, 6. Saporta, Fl. Foss. de Sézanne, p. (80) 368, pl. (viii) xxix, fig. 11. Schimper, Pal. Vég., Vol. II, p. 851.

Plate XXV, Fig. 1.—Black Buttes Station, Wyoming.

The only important difference that separates this specimen from the only other two known, as described and figured in the works cited, is the smaller angle which the secondary nerves make with the midrib. As none of the authors regard the generic reference as at all settled and as our leaf doubtless belongs to the Laurineæ, it is perhaps as well to leave it here until better material shall justify a change.

MONIMIACEÆ.

MONIMIOPSIS Sap.

The genus Monimia, from the resemblance to which certain fossil forms have been called by this name, is confined, so far as known, to the Mascarene Islands of the Indian Ocean and embraces only three species, but two fossil species from Hæring in Tyrol (Oligocene) have been referred to it. To the extinct genus three species are referred by Saporta, all from the Paleocene of Sézanne. It would be something of a confirmation of the alleged homotaxy of the Laramie group with this Paleocene flora if undoubted specimens of these species should be found to occur in it. This, however, is not claimed for the two following forms.

? Monimiopsis amboræfolia Sap.

? MONIMIOPSIS AMBORÆFOLIA Sap., Foss. Fl. de Sézanne, p. (73) 361, pl. (viii) xxix, fig. 13. Schimper, Pal. Vég., Vol. II, p. 765.

Plate XXV, Fig. 2.—Seven Mile Creek, Montana; Sapindus bed.

Except in size this specimen agrees remarkably well with that of Saporta, far better than with anything else with which I have thus far been able to compare it either in the fossil or in the living flora, and this mere difference of size, especially where so few specimens are known, cannot be regarded as specific. The base of our leaf is more oblique and there is a sort of notch in the border on one side, but the latter probably represents a natural defect not common to other leaves of the species. The improbability that a species should have such a wide range is the chief objection to the reference made.

For analogues in other families bearing more or less resemblance to this leaf, see *Euonymus Proserpinæ* Ett., Foss. Fl. v. Bilin, III (Denkschr. Wien. Acad., Vol. XXIX), pl. xlviii, figs. 6, 7; *Celastrus fraxini-*

folius Lx., Cret. and Tert. Fl., pl. xl, fig. 10; *Juglans alkalina* Lx., Tert. Fl., pl. lxii, figs. 6, 7; and even *Alnus cardiophylla* Sap., Fl. Foss. de Sézanne, pl. (xv) xxxvi, fig. 8.

? Monimiopsis fraterna Sap.

? MONIMIOPSIS FRATERNA Sap., Fl. Foss. de Sézanne, p. (74) 362, pl. (viii) xxix, fig. 14. Schimper, Pal. Vég., Vol. II, p. 765.

Plate XXV, Fig. 3.—Seven Mile Creek, Montana; bed below the ironstone.

Most of what was said of the last species will apply also to the present one. The Laramie specimen is more nearly complete in outline, but much of the border is unfortunately wanting. It is, however, preserved below on one side and above on the other so that the general character of the marginal nervation can be safely inferred for the whole leaf. Still more important is the almost complete preservation of the point which is wanting in the Sézanne leaf. The body of the leaf is well preserved and the characteristic arches with tertiary veins springing from them are distinctly shown. In one case where the margin is preserved a secondary nerve appears to reach the blunt tooth directly, and others may be assumed to have done so. Three pairs of lateral nerves are approximate near the base, alternate and more erect than in Saporta's figure, while above these a long interval occurs, giving to the third pair, which are considerably stronger than the rest, somewhat the character of primary nerves of a palmately nerved leaf. In these somewhat relative characters our specimen deviates from the European, and this divergence may be specific or even generic.

In *Viburnum rugosum pliocenicum* Sap. (Pl. Foss. de Meximieux, pl. xxxi, fig. 1) the form of the upper portion of the leaf is very similar and the peculiar arching of the uppermost secondaries strikingly so, but the lower secondaries are all alternate and scattered somewhat evenly along the midrib. The margin, too, is nearly undulate, and the areolæ formed by the nervilles are of an entirely different character from those of our leaf and of the Monimiaceæ. Other analogues are *Styrax vulcanicum* Ett. (Foss. Fl. v. Bilin, II, Denkschr. Wien. Acad., Vol. XXVIII, pl. xxxix, fig. 13) and *Tetrapteris Bilinica* Ett. (loc. cit., III, op. cit., Vol. XXIX, pl. xlvi, fig. 11).

POLYPETALÆ.

CORNACEÆ.

NYSSA L.

This small genus of only five or six species is restricted in the present flora to the eastern portions of North America and of Asia. About twenty species have been described in the fossil state either from leaves or from fruits. Most of these are from Miocene deposits, such as the brown coal of the Wetterau and of Samland on the Baltic, Styria, Sused, Bonn, Quegstein, &c., on the continent, Bovey-Tracey, and numerous arctic localities, including Alaska. Within the territory of the United States we have several of the fossil fruits of Brandon, Vt., referred to that genus, and one species (*N. lanceolata* Lx.) represented, according to Lesquereux, by both leaves and fruits from the Laramie group at Golden, Colo., and by leaves from near Fort Ellis, Montana. Newberry's *N. vetusta* is referred by Lesquereux to *Magnolia alternans* Heer (see National Museum catalogue, No. 702).

Nyssa Buddiana, n. sp.

Plate XXV, Fig. 4.—Hodges Pass, Wyoming; named in honor of Mr. J. Budd, superintendent of construction of the Oregon branch of the Union Pacific Railroad, who directed me to this locality.

Leaf ovate-lanceolate, 4.5cm. wide, about 12cm. long, entire but gently wavy margined; midrib slightly sinuous below, as thick as the slender petiole, nearly uniform through the leaf, secondary nerves alternate, about fourteen on a side, issuing from the midrib at a wide angle (60°), inequidistant, the wider intervals occupied by one or sometimes two intercalary nerves, which either end blind or join the nervilles; principal secondaries curving upward near the margin after giving off from the under side one or two tertiary nerves, which pass downward and anastomose with the secondaries below, forming arches or loops from which smaller veinlets pass outward toward the margin, but become indistinguishable before reaching it; nervilles indistinct, apparently irregular.

If it may be said that these characters in the nervation are largely those of Magnolia, the answer is that in so far they are common to the two genera, for they are all present in at least two species of Nyssa of the living flora of eastern North America (*N. multiflora* Wang. and *N. uniflora* Wang.), both of which, as well as *N. Caroliniana* Walt. and *N. aquatica* L., I have carefully compared with this fossil. But the nervation of Nyssa is distinguished from that of most Magnolias by a certain irregularity in the secondaries, by the occurrence of intercalary nerves (at least in some species), and especially by the rapid diminution of the smaller veinlets, so as to make them seem to vanish or end blind.

The specimen was badly crumpled in its coarse sandstone matrix before this had hardened, but nevertheless the silicified substance of the leaf remains and coats the rock with a dark layer, in which the position of the nerves is distinctly laid down, the two counterparts complementing each other to considerable extent. The leaf was thick and coriaceous and the petiole, of which about 2 centimeters are preserved, is bent in a short angle below the blade, probably by extraneous agencies after falling from the tree.

Of the fossil forms referred to Nyssa our specimen most resembles those from Liescha (Zwanziger, Mioc. Fl. v. Liescha, pl. xxii). The form of the leaf is not unlike that of some species of Diospyros (cf. Heer, Mioc. Balt. Fl., pl. xxvii), and Ettingshausen's *Tabernæmontana Bohemica* (Foss. Fl. v. Bilin, II, pl. xxxvi, fig. 17) approaches it quite closely both in shape and nervation.

CORNUS L.

This genus consists, in the living flora of the globe, of about twenty-five species, no less than eighteen of which are natives of North America. It is therefore not to be wondered at that fossil remains of it should be found in American strata. Thus far four species have been reported from the Laramie group, one of which, *C. acuminata* Newberry (*C. Nebrascensis* Schimp.), is from the Fort Union deposits. This paucity is made up by the occurrence of a considerable number in the arctic fossil flora, three of which are from the Cretaceous.

Thus far only three species have been detected in my collections, two of which are from the lower districts and one from the Yellowstone Valley.

? Cornus Fosteri, n. sp.

Plate XXV, Fig. 5.—Upper Seven Mile Creek, 10 miles above Glendive, Montana; collected by Mr. Richard Foster, of Dr. White's party, in 1882.

Leaf ovate, entire with slightly uneven margins, rounded and oblique at the base, 8cm. wide, 15cm. long; nervation pinnate, camptodrome; midrib thick below, more slender and somewhat sinuous above; secondary nerves about ten on each side, nearly opposite below, alternate above, the lower ones more approximate than the upper, basal pair thin and parallel to the margin, second and third pairs strongest, proceeding from the midrib at an angle of 50°, and curving upward in passing out toward the margin, branching near their extremities from the under side, arching and anastomosing with the branches of the next higher, the uppermost more erect and somewhat acrodrome; nervilles indistinct, chiefly percurrent, parallel, joining the secondaries at right angles.

It seems probable that the reference of this leaf to Cornus was an error, although the acrodrome tendency of the uppermost secondaries is a good index to that genus. Still, the lower lateral nerves show too little of this acrodrome tendency and follow more nearly the character of Ficus, and the nervilles are also those of Ficus rather than of Cornus. But for the simple percurrent nervilles the resemblance to Populus would be very close (cf. *P. monodon* Lx., Tert. Fl., pl. xxiv, fig. 2; *P. hyperborea* Heer, Fl. Foss. Arct., Vol. III, Pt. II, Kreidefl., pl. xxix, fig. 6). In form it resembles the figure last cited more closely than any other I have been able to find. Upon the whole, however, I now incline to regard it as a Ficus and as having as its nearest affinity *F. spectabilis* Lx. (Tert. Fl., pl. xxxiii, figs. 4–6).

I did not visit this locality. The specimens obtained from there the previous year are all in a coarse sandy ironstone. They show little of the more detailed nervation, but the principal nerves are usually deeply impressed in the rock. In this specimen, however, we have only the under surface of the leaf with the nerves well in relief. The lower and thicker part of the midrib is channeled in the specimen, but it is evident that this is due to its imperfect preservation, the epidermis and central fibers having disappeared, leaving a groove. The upper part of the leaf was rolled in so that it was necessary to break it out and represent it as if unrolled. Although this was very skillfully and successfully done by Mr. Everett Hayden, there still remains a considerable part, including the point and most of one side, unrepresented.

Cornus Studeri Heer.

CORNUS STUDERI Heer, Uebersicht der Tertiärflora, p. 58; Fl. Tert. Helv., Vol. III, p. 27, pl. cv, figs. 18–21; Fl. Foss. Arct., Vol. V, Pt. III (Prim. Fl. Foss. Sachal.), p. 45, pl. xi, figs. 11–13. Ludwig, Palæontogr., Vol. VIII, p. 121, pl. lviii, fig. 10. Lesquereux, Tert. Fl., p. 244, pl. xlii, figs. 4, 5. Schimper, Pal. Vég., Vol. III, p. 52.

Plate XXVI, Fig. 1.—Point of Rocks, Wyoming; gray sandstone bed north of station.

If we really have in this specimen a leaf of *Cornus Studeri* our knowledge of that species is thereby considerably extended, as none of the specimens thus far figured has the petiole preserved. Our leaf, however, differs in two respects from most of the species of Cornus known, whether living or fossil, namely, in its thicker midrib, especially below, and in its nervilles, which form nearly a right angle with the nerves they join. In all the living species of Cornus that I have examined, which include all the American species and several European, the nervilles pass across the areas formed by the lateral nerves in a horizontal direction or nearly at right angles to the midrib. In Heer's largest specimen they are represented as slightly ascending. In many respects all the American specimens referred to this species resemble Ficus and its closest allies (cf. *F. artocarpoides* Lx., Cret. and Tert. Fl., pl. xlvii, fig. 1, and *Artocarpoides conocephaloidea* Sap., Fl. Foss. de Sézanne, pl. xxvii, fig. 6), and it may still be considered a question to what genus they belong.

Cornus Emmonsii, n. sp.

Plate XXVI, Figs. 2, 3.—Golden, Colo. (Fig. 2); collected for Mr. S. F. Emmons by C. W. Cross, in July, 1882. Point of Rocks, Wyoming; gray sandstone bed north of station (Fig. 3).

Leaves oblong, 4.5 to 5cm. wide, 7 to 8cm. long, rounded at both base and summit; nervation pinnate, camptodrome; midrib rather thick, visibly diminishing at each node, slightly zigzag; secondary nerves eight to nine on a side, large at their point of insertion, rapidly thinning out, the lower nearly opposite, lowest pair very light and close to the margin, which they follow a long distance, the remainder nearly equal, making an angle with the midrib of 40° to 50°, second pair giving off several short tertiaries, which curve forward slightly in crossing the narrow area to join the basilar nerves, the rest having fewer tertiaries near their extremities, which join the incurved ends of the next nerves below them and also join one another, forming loops and arches near the margin, the upper secondaries acrodrome, curving rapidly inward at the obtuse or obcordate summit of the leaf; nervilles indistinct, wavy, or bent, percurrent, or forked.

Notwithstanding the widely separated localities from which these specimens come, they present so many points of resemblance that I am unable to assign them to different species. The Golden specimen, which is from the tufa beds, is less perfectly preserved, the black glaze which once represented the lamina having been worn off, probably since its collection, from a considerable part of it; the margins, too, are difficult or impossible to make out, except for a limited part of the way round. The Point of Rocks specimen is in hard rock and shows the substance of the leaf by the deposit of a much darker coloring matter. In all that is preserved the nervation and margins are distinctly shown. The upper portion bears every indication of having been slightly depressed after the manner of certain forms of *Liriodendron Meekii* Heer, with which I was long disposed to associate it. The nervation, however, is decidedly characteristic of Cornus and appears to be identical with that of the Golden plant.

This species probably has its nearest analogue in *C. orbifera* Heer, especially as it occurs at the Bois d'Asson (Saporta, Études, Ann. Sci. Nat., Bot., 5e Sér., Vol. VIII, 1857, pl. xiii, fig. 3), but it also bears a strong resemblance to *C. impressa* Lx. (Tert. Fl., pl. xlii, fig. 3).

ARALIACEÆ.

HEDERA L.

Although only two species of this genus now exist, and only one in the northern hemisphere, there is reason to suppose that during Cretaceous and Tertiary time it played an important rôle in the vegetation of the globe. Five Cretaceous and twelve Tertiary species are described in the various works, four of which latter, however, are Pliocene, and may not be more than so many diverse forms of the immediate ancestor of the present Old World species, *H. Helix* L. Of the Cretaceous species one, *H. primordialis* (Sap.) Heer, is common to the Cenomanian of Bohemia and of Greenland; another (*H. cuneata* Heer) is common to the Cenomanian and the Senonian strata of Greenland. Three species occur in the flora of the Dakota group. Of the Tertiary species one is from the Paleocene of Sézanne, one from the Eocene of Aix, two are arctic and high northern, and three are found on the continent.

We should not therefore be surprised to find representatives of this genus in Laramie strata, although thus far none have been reported. If the four following forms have been correctly assigned we have examples from both the lower and the upper districts.

Hedera parvula, n. sp.

Plate XXVI, Fig. 4.—Clear Creek, Montana.

Leaf orbicular, small (2.2cm. in diameter), emarginate at the apex, faintly sinuate on each side near the summit, otherwise entire; nervation palmate, camptodrome; primary nerves seven, all issuing from near the base but not from the same point, median nerve (midrib) strongest, bearing four or five alternate erect branches; the six lateral ones opposite in pairs; lowest pair basilar, giving off short branches from the under side; second pair more erect (40°), dividing up somewhat dichotomously; third pair strongest, very erect (20°), forking two or three times, the upper branches becoming parallel to the midrib or slightly acrodrome; ultimate ramifications arching and anastomosing near the margin; nervilles indistinct, mostly percurrent and perpendicular to the nerves joined.

The nervation is here essentially identical with that seen in *H. primordialis* (Sap.) Heer (Fl. Foss. Arct., Vol. VI, Abth. II, Foss. Fl. Grönld., pl. xxiv, fig. 6*a*) and in some respects resembles that of *H. ovalis* Lx. (Cret. Fl., pl. xxv, fig. 3; pl. xxvi, fig. 4).

Hedera minima, n. sp.

Plate XXVI, Fig. 5.—Head of Clear Creek, Montana.

Leaf very small, as broad as long (17mm.), broadly truncate at the summit, cuneate at the base, somewhat pentagonal in outline, short petioled; nervation palmate, camptodrome, somewhat brochiodrome; primary nerves five, nearly equal, slender, all rising from the same point at the summit of the petiole; the two lower spreading and parallel to the margin, branched above; the second pair very erect (20°), curving upward and inward toward the apex of the leaf (acrodrome), giving off tertiary nerves from the outer side; median nerve (midrib) rather lighter than the lateral nerves, slightly flexuous, nearly simple; nervilles indistinguishable.

This small leaf is preserved nearly complete, including a short petiole 3 millimeters long, which does not seem to show the point of insertion. Its peculiar somewhat angled or trapezoid outline is strongly suggestive of Hedera, while the nervation is not unlike that of that genus. The reference, however, is less certain than in the last species. It somewhat resembles *Cercis parvifolia* Lx. (Cret. and Tert. Fl., pl. xxxi, figs. 5–7), from Florissant, and perhaps still more *Paliurus orbiculatus* Sap. (Études, Ann. Sci. Nat., Bot., 5e Sér., Vol. IX, 1868, pl. vii, fig. 6), which has also been found at Florissant (Lesquereux, Cret. and Tert. Fl., pl.

xxxviii, fig. 12). The erect acrodrome character of the upper lateral nerves also simulates some of the arctic species of Populus.

Hedera Bruneri, n. sp.

Plate XXVI, Fig. 6.—Black Buttes Station, Wyoming.

Leaf large, compressed-dilate, 10cm. wide, 7cm. long (exclusive of the petiole, which is 6cm. long, thick, and dilated at both extremities), entire at the base, sinuate-toothed from below the middle; nervation strongly palmate, craspedo-camptodrome, three strong primary nerves rising from the enlarged summit of the petiole carrying all its fibers; central nerve largest, giving off from above the middle five or six alternate secondary nerves and rapidly diminishing to the apex; lateral nerves diverging at an angle of 40° from the midrib and slightly curving upward, each giving off somewhat dichotomously about five secondaries from the outer side, one of these largest and sending out tertiaries, the rest branching or forking towards their extremities, the branches uniting in angled arches, from which smaller veinlets proceed to or near the margin; nervilles obscure, bent, or forked, often appearing to end blind.

The greater part of the margin of the otherwise well preserved leaf is wanting above, but in a few places the short rounded teeth can be distinguished. The specimen was found lying on the surface and was slightly weather worn, but the lower portions had to be chipped out and are shown very clearly. Over the whole of the blade are scattered loose grains of silex, which are cemented firmly to the rock and cannot be removed without injury to the specimen, but these do not seriously obscure the nervation.

This singular leaf is clearly unlike any others that have been collected in the West. I long inclined to regard it as a Populus (cf. *P. mutabilis* Heer, Fl. Foss. Arct., Vol. VII, pl. lxxxix, fig. 7), and it certainly has some points in common with the leaf I have called *P. hederoides* (Pl. VIII, Fig. 5), as also with *P. amblyrhyncha* (Pl. VI and VII), but the absence of true basilar nerves and the dichotomous character of the nervation seem positively to exclude the present specimen from that genus. It has some analogy with Menispermites (cf. Lesquereux, Cret. and Tert. Fl., pl. xv, fig. 1), though here the leaves are cordate or peltate, and it resembles some forms of Vitis and Cissites (cf. op. cit., pl. iii, fig. 3; pl. v, figs. 2–4; Saporta, Fl. Foss. de Sézanne, pl. x, fig. 10; Heer, Fl. Foss. Arct., Vol. VII, pl. xxi, fig. 8). But after examining various forms of Hedera figured from the American Cretaceous (cf. *H. platanoidea* Lx. (Ann. Rep. U. S. Geol. Surv. Terr., 1874, p. 351, pl. iii, figs. 5, 6), from Sézanne (cf. *H. prisca* Sap., loc. cit., fig. 1), and especially from Spitzbergen (cf. *H. McClurii* Heer, Fl. Foss. Arct., Vol. II, Pt. III, Mioc. Fl. Spitzb., pl. xiii, figs. 29–33; Vol. IV, Pt. I, Beitr. Foss. Fl. Spitzb., pl. xviii, figs. 1, 2), it was impossible to doubt that it is here that this form properly belongs. I am satisfied, however, that it is none of the species referred to, and I therefore take pleasure in naming it after my esteemed friend and companion during that season's campaign, Prof. Lawrence Bruner.

Hedera aquamara, n. sp.

Plate XXVI, Fig. 7.—Black Buttes Station, Wyoming.

Leaf obovate-cuneate, 3cm. wide, 6cm. long, irregularly sinuate-dentate above, nearly entire below; nervation pinnate, craspedo-camptodrome; midrib flexuous and somewhat zigzag; secondary nerves four to five on each side, alternate, very erect (20° to 30°), irregular, mostly terminating in the teeth of the upper part of the leaf, the lower ones closely following the margins below, the upper somewhat branching, the branches anastomosing with one another and sending off short veinlets which curve very near the margins, forming a marginal row of small arches; nervilles very prominent and shading insensibly into the true tertiary nervation, irregularly branching and intercrossing to form very fine quadrilateral or polygonal meshes.

I was at first disposed to regard this fossil as an oak leaf, and there are many points that favor that view, but there are others that oppose it. The secondary nerves are more erect than in any species of oak with which I am acquainted. There is a near approach to it in *Quercus affinis* Sap. (Études, Ann. Sci. Nat., Bot., 5e Sér., Vol. III, 1865, pl. iii, fig. 10), but here the general nervation is quite different. A nearer approach in all respects to our leaf is seen in *Celastrus illicinus* Burch. (Ettings., Blattsk. d. Dicotyl., pl. lxiv, fig. 2), from Van Diemen's Land, and *Telopea speciosissima* R. Br. (op. cit., pl. xxii, fig. 9), from the Cape of Good Hope, embodies many of the same characters. Nevertheless it seems to me to agree better in its general character with Hedera, and its anomalous shape may be accounted for on the assumption that the leaf belonged to a flowering branch, where, as is the habit of our living species, the leaves may have been more elongated and altered in outline from the form characteristic of the genus. The peculiar leaf from Greenland figured by Heer (Fl. Foss. Arct., Vol. II, Pt. V, pl. xlv, fig. 5*b*), which has the form and to a very great extent the nervation also of our leaf, is referred by him to his *H. McClurii*, usually so very different in form, and this reference is justified on that theory. Our plant comes from the same bed as the species last described, and may belong to it, notwithstanding the great inequality in size and difference in form. This, however, can scarcely be regarded as probable.

ARALIA L.

In referring the following forms to this genus I merely follow the precedent established in this country, as I do not consider this the proper place to open up the question as to the necessity for making a change. That some change must soon be made I feel certain, and my own material, more than anything else I have seen, tends to force it upon us. But others are becoming aware of this necessity, and in a recent letter (Sept. 7, 1885) Prof. Lesquereux, who is now working up some new material from the Dakota group, speaking of certain forms recently referred by Engelhardt to Credneria, says: "From the reference of these leaves to Credneria we should have to put in the same group or genus the Araliopsis, Grewiopsis, Platanus, Sassafras, &c., described from the Dakota group."

I need only say, in confirmation of this, that from their close general resemblance and from intermediate forms which I have myself collected and studied, I can scarcely doubt that the forms which I here refer to Aralia belong to the same "group or genus" as those which I have referred to Platanus in the earlier part of this paper.

In view of these doubts I do not deem it necessary to attempt any justification of the generic assignment here made by considerations derived from the present range of the genus.

Aralia notata Lx.

ARALIA NOTATA Lx., Tert. Fl., p. 237, pl. xxxix, figs. 2-4; Cret. and Tert. Fl., p. 232.
PLATANUS DUBIA Lx., Ann. Rep. U. S. Geol. Surv. Terr., 1873, p. 406.

Plate XXVII, Fig. 1.—Clear Creek, Montana.

This specimen was collected near the same spot where many other very large leaves were found, as well as some intermediate in size having substantially the same general form and character. The latter I had expected to be obliged to refer to Platanus, but whether to *P. nobilis* or to some new species I have not yet decided, not having completed their study. Many, if not all, of them have the margins entire throughout and the nervation camptodrome, as in this specimen, and I am as yet undecided as to whether this can be regarded as a specific character.

The present specimen, notwithstanding the narrower sinuses, closely resembles those figured by Lesquereux above cited, two of which (figs. 2 and 4) were collected on Elk Creek, near the Yellowstone, and probably come from Fort Union strata. Several other specimens having the same form occur in the reserve series of the National Museum, one of which (No. 922) is also from the north (near Fort Ellis, Montana). In all these the primary nerves originate at the very base of the leaf, and this is one of the chief distinctions which separate them from the forms referred to Sassafras (Araliopsis) from the Cretaceous. That those forms do not belong to Sassafras I have always felt satisfied. Only one species of Sassafras is known in the present flora of the globe and this is confined to North America. Although its leaves are very variable, the variations are definite and fall under a few types. The lobed leaves belong almost exclusively to non-flowering branches, the normal foliage showing entire leaves with a nervation of strongly marked Lauraceous type, usually resembling that of Laurus or Persea, but sometimes becoming more decidedly palmate and approaching that of Cinnamomum. This type is out of the question here. The Cretaceous leaves are usually symmetrically three-lobed and the assumption would be legitimate that they represent a uniformly three-lobed ancestor which is revealed only in the non-flowering branches of our modern chiefly entire leaved species, could we find in these modern lobed leaves something very near to the nervation of this ancestor. But I could never see that we do find this. The nervation of the modern lobed leaves of Sassafras is very uniform and in some respects remarkable. From the pair of lateral primaries that go to the lobes to the next pair of nerves issuing from the midrib there is usually a long interval, partly occupied by horizontal nerves, which scarcely belong to the secondary system. The first pair of true secondaries leave the midrib at a wide angle and soon curve upward, passing directly to the middle of the large rounded sinuses. Here they are not lost, but immediately fork and follow the two margins of the sinuses, usually forming its actual border (paryphodrome) for some distance. From this hem or border they may usually be seen giving off branches or leaving it altogether and passing up farther inward to join the branches of the primaries. This character in the nervation of Sassafras is so peculiar and uniform that I am surprised that it has not been more carefully considered in connection with the fossil leaves. No such character is to be found in any of these. On the contrary the first pair of secondary nerves usually fork before reaching the sinus, the two branches striding it and passing upward at some distance from the margins. Often a branch from the lateral primary goes out to meet the one from the midrib and either joins it before reaching the sinus or, as in our present specimen, arches along the inner margin of the lateral lobe, while the branch from the midrib follows in a similar manner the margin of the terminal lobe.

Whether the ancestor of our living Sassafras will ever be found in American strata is uncertain, though a near approach to it is seen in *Aralia acerifolia* Lx. (Cret. and Tert. Fl., pl. xlix, Fig. 5), and that a true Sassafras has been found in European strata is settled by the nervation of *S. Ferrettianum* Mass., from Senegal (Fl. Foss. del Senigal., pl. xii, fig. 1), in which the character above described is clearly shown. Compare also *S. primigenium* Sap. (Fl. Foss. de Sézanne, pl. viii, figs. 9, 10; Monde des Plantes, p. 219, fig. 41).

Aralia Looziana Sap. & Mar.

ARALIA LOOZIANA Sap. & Mar., Révision de la Flore Heersienne de Gelinden (Mém. Cour. Acad. Roy. de Belgique, Vol. XLI), p. 77, pl. xiii, fig. 13. Saporta, Monde des Plantes, p. 216, fig. 37.

Plate XXVII, Fig. 2.—Clear Creek, Montana; collected by Dr. White's party in 1882.

I have not seen any work in which this species is technically described, but with the exception of being a little larger our specimen agrees so perfectly with the figure cited above that it seems necessary to regard it as the same species. It wants the immediate base and the petiole, while the middle lobe is somewhat distorted. I did not find in the Clear Creek beds any forms precisely similar, and it seems to resemble more closely the specimens, found 9 miles farther up the valley, to be next described.

Aralia digitata, n. sp.

Plate XXVII, Figs. 3, 5; Plate XXVIII, Fig. 1.—Head of Clear Creek, Montana.

Leaves digitately three to five lobed, variable in size (6 to 18 cm. in width), entire and cuneate below, the base appendaged with a pair of short sagittate lobes, upper lobes lanceolate, as long as the body of the leaf, slightly broadened upward, rapidly narrowed to a point or merely rounded at the summit, entire to near the apex, sinuate-dentate at their extremities; petiole thick, 2.3cm. long, dilated below; nervation camptodrome in the entire portions, craspedodrome in the toothed portions, palmately triple nerved from near the base of the leaf, the three nerves equal, one or both of the two lateral usually branching unequally, the lesser branches (subprimaries) passing into the outer lobes; secondary nerves numerous, simple, parallel, making an angle of 40° with the primaries, arching and anastomosing close to the margins or terminating in the teeth; nervilles distinct, straight, percurrent, joining the secondaries, or longer and geniculate, joining the areas between the primaries, sometimes forking or variously crossed to form fine rhombic or polygonal meshes; basal lobes provided with a median nerve or costa.

The numerous fragments of this singular leaf, which were collected in the friable marl bed at the head of Clear Creek, represent all the sizes between the extremes shown in Fig. 5 of Plate XXVII and Fig. 1 of Plate XXVIII, so that scarcely any doubt remains that they represent a single species of varying size and somewhat varying form. In the figure last mentioned there seems to have been but one subprimary nerve and but four lobes, and in Fig. 4 of Plate XXVII enough of the base is preserved to make it pretty certain that there were no subprimaries and only three lobes, as may be seen by comparing it with Figs. 3 and 5 of the same plate.

The remarkable feature of these leaves is the unmistakable evidence they present of the existence of basal lobes. Although only one of these (Fig. 5) actually has these lobes, and in this neither lobe is absolutely complete, still this specimen leaves no uncertainty as to their character, and two of the other specimens (Figs. 3, 4) show a conformation of the base of the leaf which clearly indicates that they were also present in these. Recalling the peculiar basal lobes described in one of the species of Platanus (*P. basilobata*, p. 35, Plates XVII, XVIII, XIX) and comparing the general character of these leaves with those we are now considering, it is impossible to resist the conviction that the two forms have a close natural relationship. The obvious affinity of those leaves to *Platanus nobilis* and of that species to *Aralia notata* seems to link all the forms having this general character into one correlated group. If this be true the problem is reduced to that of discovering what the true generic relationship of this group is. As I showed when discussing that species, the presence of basal lobes argues strongly for the reference of all the forms possessing them to the Platanaceæ, and I fully believe that such a reference will become necessary. But this will not only carry with it all the American forms hitherto referred to Aralia, but, as I also believe, all those referred to Sassafras. If this sweeping change is ever made it may be thought best to distinguish these forms from true Platanus and establish a new genus of that order to be called *Protoplatanus*, or some other name indicative of its ancestral character.

Unquestionably the nearest approach that has yet been made to our form is to be found in *Aralia Saportanea* Lx. (Ann. Rep. U. S. Geol. Surv. Terr., 1874, p. 350, pl. i, figs. 2, 2*a*; Cret. and Tert. Fl., p. 61, pl. viii, figs. 1, 2; pl. ix, figs. 1, 2), and, though a Cretaceous form, but for the basal lobes and short, thick petiole, I might have felt constrained to regard it as specifically identical with that plant. In *Aralia Hercules* Sap. (Études, Ann. Sci. Nat., Bot., 5e Sér., Vol. IV, pl. ix, fig. 2), which, however, sometimes has a larger number of lobes (cf. Unger, Chloris Protogæa, pl. xlv, fig. 7), we have another near analogue, and here the petiole is short and much dilated at the base, and in *A. angustiloba* Lx. (Foss. Pl. Aurif. Gravels, pl. v, figs. 4, 5) the lobes are said to be very entire.

ONAGRARIEÆ.

TRAPA L.

Five species of Trapa are described in De Candolle's Prodromus, but Messrs. Bentham and Hooker have reduced them to two or three. They are almost altogether confined to eastern Asia, but one species occurs in temperate Europe. Prior to 1874 the genus was known in a fossil state only by fruits, which have been found in European strata, in the arctic regions in Alaska, and even in British America. Unless we admit Newberry's *Neuropteris angulata* as of this genus, which seems not improbable, leaves were first collected by Dr. F. V. Hayden at Point of Rocks, Wyoming, and later by Mr. William Cleburne in the white sandstone bed east of the station, where I also found them in 1881. Their discovery in 1882, at Burns's Ranch on the Yellowstone, fully justified Lesquereux's determination, previously regarded as doubtful, and I found them the following year not only there but also at Iron Bluff, as already reported in the Sixth Annual Report, p. 544.

Trapa microphylla Lx.

TRAPA MICROPHYLLA Lx., Bulletins U. S. Geol. Surv. Terr., Vol. I, pp. 369, 380; Ann. Rep., 1874, p. 304; Tert. Fl., p. 295, pl. lxi, figs. 16, 17, 17*a*.

?NEUROPTERIS ANGULATA Newberry, Report upon the Colorado River of the West, by Lieut. J. C. Ives, p. 131, pl. iii, fig. 5.

Plate XXVIII, Figs. 2-5.—Burns's Ranch, Wyoming.

The size, shape, and nervation of these leaves are substantially identical with those of Point of Rocks, and until fruit is found for both it will be necessary to regard them as the same species, the significance of which, in tending to homologize the upper and lower districts of the Laramie group, has already been commented upon (see Sixth Annual Report, p. 544). The very perfect specimens collected both by Dr. White and myself at Burns's Ranch show the nature of the plant almost as well as a living specimen could do and demonstrate its complete analogy with the recent forms in its habit of growth. Hitherto only detached leaves had been seen, and the generic reference was made by Prof. Lesquereux, with evident reserve, from the nervation alone. The correctness of this determination is now fully established and goes far to vindicate the oft-disputed claim of vegetable paleontologists that this character alone may in most cases be trusted to show the nature of extinct floras, provided the work be performed by competent investigators.

HAMAMELIDEÆ.

HAMAMELITES Sap.

This genus was created by Saporta for the reception of Watelet's *Corylus elegans*, from Sézanne. To it Prof. Lesquereux has referred five species from the Dakota group, two of which are not figured, and the specimens are not accessible to me. None of them seem to be oblique at the base, which is a leading characteristic not only of the Sézanne leaves but also of the genus Hamamelis. This genus is represented in the living flora by only two species, one of which is North American and the other Asiatic. It is therefore one whose ancestors should, according to modern theories of plant dispersion, be looked for in North American strata.

Hamamelites fothergilloides Sap.

HAMAMELITES FOTHERGILLOIDES Sap., Études, Ann. Sci. Nat., Bot., 5e Sér., Vol. III, p. 47; Fl. Foss. de Sézanne, p. (105) 393, pl. (xi) xxxii, fig. 3. Schimper, Pal. Vég., Vol. III, p. 57; Atlas, pl. xcv, fig. 15.

CORYLUS ELEGANS Wat., Pl. Foss. du Bassin de Paris, p. 146, pl. xxxvii, fig. 5.

Plate XXIX, Fig. 1.—Seven Mile Creek, Montana; bed below the ironstone.

Although there are a few points of distinction between this leaf and those from Sézanne, such as the longer petiole and less prominent teeth, still there is such a substantial agreement that I prefer not to create a new species for its reception. It resembles *Hamamelis Virginiana* L., the American Witch Hazel, more closely than does the European fossil, and probably belongs to the living genus. In all the leaves I have seen of that species in which the midrib has any curvature, as also in the figures of Watelet and Saporta of the extinct species, this curvature is toward the side of the leaf which shows the least development of parenchyma at the base, thus exaggerating the inequality in the two sides. In our leaf, however, this is reversed, and the side that is lower at the base is narrower above; as a consequence, the secondary nerves are of nearly equal strength on the two sides and about equally branched. Should additional specimens show this to be a constant character it would probably be necessary to assign to it a specific value.

LEGUMINOSÆ.

LEGUMINOSITES Brongn.

Along with a large number of leaves and leaflets which have been provisionally placed under this name a few enigmatic fruits have found their way into the same generic receptacle, although it would have been much more convenient had these been furnished a different name.

Leguminosites arachioides Lx.

LEGUMINOSITES? ARACHIOIDES Lx., Tert. Fl., p. 301, pl. lix, fig. 14.
CARPOLITHES ARACHIOIDES Lx., Ann. Rep. U. S. Geol. Surv. Terr., 1872, p. 403.

Plate XXIX, Fig. 2.—Clear Creek, Montana.

Although these fruits are a little longer and more slender pointed than those from Evanston, there seems no reason to doubt that they represent the same plant. My specimens contribute very little to our knowledge of their nature and are merely introduced to show that the form occurs in the Fort Union Laramie.

SAPINDACEÆ.

ACER L.

Fossil maples are chiefly found in the Miocene, where many species are known both by leaves and fruit. Only three species have been reported from the Laramie group, none of them from those beds which were formerly regarded as constituting that group.

Acer trilobatum tricuspidatum (Al. Br.) Heer.

ACER TRILOBATUM TRICUSPIDATUM (Al. Br.) Heer, Fl. Tert. Helv., Vol. III, p. 49, pl. cxiii, figs. 1, 3–10. Ludwig, Palæontogr., Vol. VIII, p. 129, pl. l, fig. 1; pl. li, figs. 4, 7–9; pl. lii, fig. 2. Engelhardt, Pflanzenreste von Liebotitz und Putschirn (Sitzb. d. Naturw. Ges. Isis, Hefte III u. IV, 1880), p. 7, pl. ii, figs. 1, 4, 5.
ACER TRICUSPIDATUM Al. Br., Neues Jahrb. für Mineralogie, 1845, p. 172.

Plate XXIX, Figs. 3, 4.—Clear Creek, Montana (Fig. 3); collected by Dr. White's party in 1882. Little Missouri River, Dakota (Fig. 4); collected by Hayden and Peale in 1883.

The first specimen (Fig. 3) occurs on a slab containing a profusion of other leaves, including those of *Corylus Americana*, *Populus cuneata*, and *Platanus Raynoldsii*. It closely resembles Heer's fig. 6, on pl. cxiii, above cited, but is larger and has the petiole more slender. The other specimen (Fig. 4) is in the buff marl of the Little Missouri bad land district, and also resembles the figure last cited more than any others I have seen. In both the dentation is less strongly marked than in most maples and they have a certain indefinable appearance that is suggestive of Platanus.

Acer indivisum Web.

ACER INDIVISUM Web., Palæontogr., Vol. II, p. 198, pl. xxii, fig. 2*a*. Heer, Fl. Tert. Helv., Vol. III, p. 60, pl. i, fig. 10; pl. cx, fig. 15; pl. cxvi, fig. 12. Schimper, Pal. Vég., Vol. III, p. 146.

Plate XXIX, Fig. 5.—Carbon Station, Wyoming.

Weber's original specimen was really unlobed, but in one of Heer's (pl. cxvi, fig. 12) there is a lobe on one side and an extra large tooth on the other which the forking of the nerve shows to be virtually a lobe. In another of Heer's figures (pl. i, fig. 10, which he refers to *A. integrilobum* Web. in Vol. I, p. 20, and to *A. indivisum* Web. in Vol. III, p. 60), the side on which the lobe would occur, as shown by the stronger nerve, is wanting; in the only other figure I have seen (op. cit., pl. cx, fig. 15), there are two large lobe-like teeth on one side, but no forking nerve, in which respect it resembles one side of our leaf; but the latter is too broad for the length, and its reference to this species will not probably be justified. It may be further compared with *A. campylopteryx* Ung. (Chlor. Prot., pl. xliv, fig. 1); also, with *Platanus cuneifolia* Göpp. (Foss. Fl. v. Schossnitz, pl. xii, fig. 2).

SAPINDUS L.

This chiefly tropical genus has one living representative in the Southwestern States and is represented by four species in the Laramie group, all but one of which are found in Fort Union strata. The Green River group furnished seven or eight additional species and one (*S. obtusifolius* Lx.) is common to the Fort Union and Green River deposits. The four following forms are from the upper districts.

Sapindus affinis Newberry.

SAPINDUS AFFINIS Newberry, Later Extinct Floras, pp. 31, 51; Illustrations of Cret. and Tert. Plants, pl. xxiv, fig. 1; pl. xxv, fig. 2. Schimper, Pal. Vég., Vol. III, p. 169. Dawson, Geol. 49th Parallel, Brit. N. A. Boundary Commission Report, 1875, p. 330; Cret. and Tert. Fl. Brit. Col. and N. W. Terr. (Trans. Roy. Soc. Can., Sec. IV), p. 32.

Plate XXX, Figs. 1, 2.—Gladstone, Dakota; collected by Hayden and Peale in 1883.

There seems no reason to doubt that these remains represent the same species as that from the mouth of the Yellowstone, although the Gladstone specimens exhibit the nervation much more clearly. In both cases we have quite a collection of the leaves, showing their character under various aspects, and, although Drs. Hayden and Peale collected no specimen showing as large a part of the leaf as does Dr. Newberry's specimen, figured on plate xxiv, above cited, still from the material obtained by them a nearly perfect leaf might be restored.

Sapindus grandifoliolus, n. sp.

Plate XXX, Figs. 3-5; Plate XXXI, Figs. 1, 2.—Seven Mile Creek, Montana; Sapindus bed.

Leaflets large for the genus (3 to 5cm. wide, 7 to 14cm. long), ovate-lanceolate, slender obtuse-pointed, falcate or slightly recurved at the summit, the lower ones stalked on the rachis, the upper sessile; margins entire, but uneven or wavy; nervation pinnate, camptodrome; midrib strong, nearly straight, diminishing perceptibly at each branch; secondaries numerous and approximate (twelve to eighteen on a side), diverging from the midrib at an angle of about 60°, simple or more commonly branching above the middle, curving upward near the margin, and anastomosing with one another or with the branches of the next higher, forming a single series of somewhat broken arches; nervilles very faint, straight, percurrent, joining the secondaries at right angles.

The only form that is fairly comparable to these specimens is that figured on plate xlviii (fig. 5) of Lesquereux's Cretaceous and Tertiary Floras, and referred by him to *S. obtusifolius*. This was collected by Prof. William Denton, in the "Bad Lands of Dakota," and is therefore probably from Fort Union strata. I have not seen that collection, but the figure shows this specimen to have been as large as many of those from Seven Mile Creek and similar to some of these in form and nervation. The leaflet was more unequal-sided, shorter-pointed, and apparently sessile. In these respects it differs from the present specimens, but still may belong to the same species.

This is the form that characterizes the Sapindus bed, or lowest layer of the Seven Mile Creek series, and which was almost the only fossil occurring in it. Although the plant was abundant I did not succeed in finding anything but detached leaflets. In one case (Plate XXXI, Fig. 2), two such leaflets occurred side by side in such a position that it was evident that they occupied their natural position and that the rachis to which they had been attached had not been preserved. This has been hypothetically restored in the figure, and the attachment of a third leaf alternating with these two is indicated.

This failure to find the rachis or the attachments of the leaflets, coupled with the presence of a petiole (Plate XXX, Fig. 5), and the general equal-sidedness of the impressions gave rise for a long time in my mind to doubts as to whether they really represented a Sapindus. The form is quite similar to that of *Juglans acuminata* Heer (Fl. Tert. Helv., Vol. III, pl. cxxviii), but the finer nervation, so far as known, is wholly different. The disposition of the secondary and tertiary nerves is not unlike that seen in Nyssa (cf. Lesquereux, Tert. Fl., pl. xxxv, fig. 5, also living species). There is, however, no good reason to doubt the correctness of the reference to Sapindus.

Sapindus alatus, n. sp.

Plate XXXI, Figs. 3, 4.—Seven Mile Creek, Montana; Sapindus bed.

Leaflets oblong-ovate, long recurved-pointed, contracted at the base into a winged stalk; nervation pinnate, camptodrome; midrib somewhat curved; secondary nerves eight to ten on each side, the lowest ones opposite; basilar pair light, simple, proceeding from the summit of the winged stalk; second pair strongest, branched above and somewhat zigzag, curving upward and following the margins; remaining pairs more or less irregular, curving and anastomosing at some distance from the margin, and forming several rows of irregular polygonal meshes; nervilles simple and percurrent, joining the secondaries, or geniculate, branched, and very irregular.

In the absence of the upper portion of the smaller of these impressions (Fig. 4) it is impossible to say whether they represent the same species. The winged stalk and general nervation are similar, but the ultimate disposition of the nerve bundles is very different. If we consider only the larger and more perfect specimen (Fig. 3), we find that, with the exception of its long recurved point, it quite closely resembles some of the forms of *S. obtusifolius* (cf. Lesquereux, Tert. Fl., pl. xlix, fig. 10; Cret. and Tert. Fl., pl. xlviii, fig. 6). The great irregularity of the secondary and tertiary nervation is suggestive of abnormality, which sometimes does occur in the course of the nerves as well as in the contour of leaves.

Sapindus angustifolius Lx.

SAPINDUS ANGUSTIFOLIUS Lx., Ann. Rep. U. S. Geol. Surv. Terr., 1873, p. 415; Tert. Fl., p. 265, pl. xlix, figs. 2–7; Cret. and Tert. Fl., p. 181, pl. xxxvii, figs. 1–8; pl. xxxix, fig. 12.

Plate XXXI, Figs. 5–7.—Seven Mile Creek, Montana; Sapindus bed; the last (Fig. 7) collected by Dr. White's party in 1882.

None of these specimens is absolutely complete. The first (Fig. 5) wants the summit, which may have been acute-pointed or somewhat obtuse. The rounded obtuse or truncate summit of the second specimen (Fig. 6) seems to be deformed and the curvature of the midrib immediately below it seems to indicate that the leaf originally had a somewhat elongated, recurved point, like that represented in Lesquereux's Tertiary Flora (pl. xlix, fig. 5). The third and smallest specimen (Fig. 7) exactly imitates the leaflets of his fig. 3, loc. cit., as also of his figs. 1 and 5 on plate xxxvii of the Cretaceous and Tertiary Floras. Numerous unfigured specimens in the collection of the National Museum further confirm these analogies.

If this reference is correct, we have two species of Sapindus common to the Green River and Fort Union deposits. But the genus is a troublesome one, owing to the difficulty in obtaining specimens with the leaflets attached and to the apparent great variation among the leaflets of the same species. Our North American species (*S. marginatus* Willd.) does not seem to show any such variation, the leaflets being of nearly uniform size and shape; but if this were assumed for the fossil forms the number of species would be very great. As all of my specimens come from the same layer in the Seven Mile Creek series, I have been tempted to regard them all as belonging to one polymorphous species, and the dozen or more species described from American strata may have to be reduced to three or four.

AMPELIDEÆ.

VITIS L.

This large genus, now made to embrace Cissus and Ampelopsis, contains over two hundred species, most of which are tropical and subtropical, but in America about fifteen species occur north of Mexico. Out of some thirty or forty fossil species that have been described five are found in the Laramie strata, but none of these comes from the Fort Union deposits. The only Eocene species are three from Sézanne, which shows the similarity of that flora to that of the Laramie. Four forms occur in my collections which seem sufficiently distinct to be classed as different species, and I have not been able to refer any of these to species already described. Two of them were collected at Carbon Station, and the remaining two at Burns's Ranch, on the Yellowstone.

Vitis Bruneri, n. sp.

Plate XXXII, Figs. 1, 2.—Carbon Station, Wyoming.

Leaves large, as broad as long (8.5cm.), three-lobed near the summit, obtuse-dentate to near the base; nervation strongly palmate, craspedodrome; primary nerves five to seven, arising together from the base of the leaf; median nerve largest, central or more or less eccentric, zigzag or somewhat curved, having four or five lateral branches on each side; inner pair of lateral primaries next in volume, proceeding at an angle of 30° from the midrib to the lateral lobes, giving off subdichotomously three or four strong branches from the under side and sometimes feeble ones from the upper side; outer pair forming an angle of 60° with the midrib and yielding secondary branches from the under side for nearly its whole length, which terminate in the lowest teeth of the margin; basilar pair when present very light, following the margin closely and uniting with the first branches of the secondary nerves; nervilles geniculate, percurrent, or forked, traversing the primary and secondary areas.

Unable to refer these fine and highly characteristic specimens to any of the species hitherto described, I have allowed them to bear the name of my esteemed companion who assisted in their collection.

There is a great similarity in nearly all the leaves collected at Carbon Station, and when all are fully studied and illustrated I hope to find data for completing the description of this form. At present it seems as if several additional species of Vitis were represented. These specimens lack the petiole and differ somewhat from one another, but not enough to warrant their separation. If we attend only to the disposition of the nerves we shall perhaps find nearer analogues in Hedera than in Vitis (cf. *H. primordialis* (Sap.) Heer, Fl. Foss. Arct., Vol. VI, Abth. II, pl. xxiv, fig. 6*a*). In all the species of Vitis that I have examined the lowest pair of primary nerves is horizontal or even pass downward, but the leaves are heart shaped, while these are nearly horizontal or slightly wedge shaped at the base. With this exception the form and nervation approach somewhat closely to *Vitis crenata* Heer (Fl. Foss. Arct., Vol. II, Pt. II, Fl. Foss. Alask., pl. viii, fig. 6), next to which may be compared *Cissus lobato-crenata* Lx. (Tert. Fl., pl. xli, figs. 1–3).

Vitis Carbonensis, n. sp.

Plate XXXII, Fig. 3.—Carbon Station, Wyoming.

Leaf long-petioled, unequal-sided, three lobed, bluntly crenate-dentate, except near the slightly wedge-shaped base, 7.5cm. wide, 8.5cm. long; petiole 6cm. long, very thick, flabellately divided at the summit into five strong primary nerves; median nerve considerably thickest, curved near the base 30° out of line with the petiole, and passing far to one side of the middle of the leaf, bearing seven or eight branches on each side, which pass into the teeth; lateral primaries unequal on the two sides, the inner pair going to the lobes, somewhat branched from the under side; outer nerve on the larger side of the leaf bearing five branches, which pass into the lower teeth; a very thin basilar nerve present on the larger side; secondary nervation simple or forked; nervilles generally indistinguishable, bent, broken, or forking.

This leaf has many characters in common with those last described, one of which is somewhat one-sided and has the middle nerve bent near the base, and, with the comparison of more material, intermediate forms may be discovered. I have compared it with *Cissus Radobojensis* Ett. (Unger, Sylloge, I, pl. ix, figs. 9, 10), which, while having much the same general form, has only three primary nerves and is more deeply lobed. It also closely resembles *Acer vitifolium* Heer (Fl. Tert. Helv., Vol. III, pl. cxvii, fig. 14), which might well represent a Vitis.

Vitis Xantholithensis, n. sp.

Plate XXXII, Figs. 4, 5.—Burns's Ranch, Montana.

Leaves small (3cm. wide, 3 to 4cm. long), ovate or elliptical in outline, bluntly and irregularly somewhat doubly-toothed all around; petiole long, slender, flexuous; nervation palmate, craspedodrome; primary nerves five, rising nearly together from the summit of the petiole; median nerve a little the largest, slightly curved, branching above; inner pair of lateral nerves strong, erect (20°), branched below from the outside, forked above; lower pair light and basilar or stronger and much branched from the under side; secondary nerves once or twice forking near their extremities, the branches sometimes joining to form angular arches, the ultimate ramifications entering the subordinate teeth; nervilles indistinct, much broken, penetrating the areas, forking at wide angles, and disappearing in the parenchyma.

This species resembles *Cissus tricuspidata* Lx. (Tert. Fl., pl. xli, figs. 6, 7), but is smaller and differently toothed. One of the specimens (Fig. 4) is almost identical in form and nervation with one of Heer's figures of *Grewia crenata* (Fl. Tert. Helv., pl. cx, fig. 6), while the other has many points in common with *Celtis trachytica* Ung. (Foss. Fl. v. Szantó, Denkschr. Wien. Acad., Vol. XXX, pl. ii, fig. 7), especially as figured by Saporta (Monde des Plantes, p. 309, fig. 3), who, however, has shown the teeth much less sharp. In many respects these leaves recall the characteristics of Hedera, but upon the whole I still incline to regard them as representing a Vitis. I am not sure that my *Populus craspedodroma* (*supra*, p. 21, Pl. VIII, Fig. 3) does not belong here.

Vitis cuspidata, n. sp.

Plate XXXII, Figs. 6–8.—Burns's Ranch, Montana (Figs. 6, 7). Seven Mile Creek, Montana; bed below the ironstone (Fig. 8).

Leaves short-petioled, coriaceous, small (1.5 to 2.5cm. wide, 3 to 4 cm. long), unequal-sided, pointed at both ends, deeply and obtusely or sharply cuspidate-toothed, except the entire wedge-shaped base; nervation craspedodrome, imperfectly palmate; midrib curved or zigzag, branching; lower lateral nerves strong, erect, dichotomously branched, passing into the longest teeth or cusps; secondary nerves branching or forking, terminating in the teeth; nervilles distinct, percurrent, crossed at right angles by veinlets that traverse the areas longitudinally, often appearing like faint, intercalary secondaries.

The three specimens embraced under this specific head all differ slightly in certain characters. In the first (Fig. 6) the teeth are sharper, some of them incurved, and the nervation is distinctly palmate, while in the third (Fig. 8) the teeth are shorter and more blunt and the lowest lateral nerves are light on one side and rather pinnately disposed. This last specimen is from a different locality, a fact which I overlooked in preparing my "Synopsis," and which in so far argues for their separation.

It is easy enough to find figures roughly corresponding with these small impressions, but it increases the difficulties greatly to find that these belong to widely different genera and families. I was from the first struck with their resemblance to the leaves of certain species of Cratægus, e. g., *C. coccinea* L., *C. monogyna* Jacq., *C. triloba* Pers., *C. tomentosa* L., but here the teeth are always too sharp and incised. In *Myrica diversifolia* Lx. (Cret. and Tert. Fl., pl. xxv, figs. 6–15) we have forms that reproduce some of the characters of our leaves, and in *Rhus incisa* Sap. (Études, Ann. Sci. Nat., Bot., 5e Sér., Vol. VIII, pl. xi, fig. 4) and *Myrsine? acanthoda* Sap. (Pl. Foss. des Arkoses de Brives, pl. v, fig. 5) we have others. The dichotomous nervation and blunt teeth of two of the specimens (Figs. 7, 8) are partially duplicated in *Viburnum spinulosum* Heer (Fl. Foss. Arct., Vol. V, Pt. III, Prim. Foss. Fl. Sachal., pl. xi, fig. 9) and less perfectly in *Grewiopsis tremulæfolia* Sap. (Fl. Foss. de Sézanne, pl. xxxiii, fig. 8). The small specimen wanting the base (Fig. 7) imitates to a remarkable degree, both in form and nervation, the fruits of Carpinus (cf. *C. cuspidata* Sap., Études, Ann. Sci. Nat., Bot., 4e Sér., Vol. XIX, pl. v, fig. 7C, and *C. Neilreichi* Kov., Unger, Europ. Waldbäume, fig. 10). But it is after all perhaps under Vitis, particularly among the forms with compound leaves, that the nearest analogues of our forms are to be sought. *Cissus quinquefolia* Pohl., from Brazil (Ettingshausen, Blattsk. d. Dicotyl., pl. xliii, fig. 5) comes quite close, and among fossils *C. tricuspidata* Lx. (Tert. Fl., pl. xli, figs. 4–7) furnishes in some of its forms (cf. loc. cit., fig. 6) the nearest analogy I have found.

RHAMNEÆ.

BERCHEMIA Neck.

This genus embraces about ten species, chiefly confined to the Old World, largely to southeastern Asia, where so many arctic and American fossil plants have their living representatives.

One species, however, still persists in North America and very closely resembles our fossil form. Three species have been reported in the fossil state, the most abundant of which occurs in American strata, and I have it from both sections of the Laramie group.

Berchemia multinervis (Al. Br.) Heer.

BERCHEMIA MULTINERVIS (Al. Br.) Heer, Fl. Tert. Helv., Vol. III, p. 77, pl. cxxiii, figs. 9–18. Capellini, Lig. Val di Magra (Mem. Reale Accad. Sci. di Torino, Ser. II, Vol. XIX), p. 385, pl. iii, fig. 6. Sismonda, Pal. Tert. du Piémont (Mem. Reale Accad. Sci. di Torino, Ser. II, Vol. XXII), p. 452, pl. xxix, fig. 8. Saporta, Études (Ann. Sci. Nat., Bot., 5e Sér., Vol. VIII), p. 107, pl. xii, figs. 2, 3. Ettingshausen, Foss. Fl. v. Bilin, III (Denkschr. Wien. Acad., Vol. XXIX), p. 41, pl. xlix, figs. 15–17; Foss. Fl. v. Sagor, II (op. cit., Vol. XXXVII), p. 196, pl. xvi, figs. 7–10. Schimper, Pal. Vég., Vol. III, p. 225. Geyler, Foss. Pfl. a. d. Obertert. Ablag. Sicilien's (Palæontographica, Vol. XXIII), p. 327, pl. ii, fig. 6. Lesquereux, Tert. Fl., p. 277, pl. lii, figs. 9, 10. Velenowsky, Fl. v. Vrsovic, p. 42, pl. iv, figs. 26, 27. Pilar, Fl. Foss. Susedana, p. 107, pl. xiv, fig. 12.

RHAMNUS MULTINERVIS Al. Br., in Buckl. Geol., Vol. I, p. 513.

BERCHEMIA PARVIFOLIA Lx., Am. Journ. Sci., 2d ser., Vol. XLV, p. 207; Ann. Reps. U. S. Geol. Surv. Terr., 1867–'69, p. 196; 1870, p. 382; 1871, Suppl., p. 15.

Plate XXXIII, Figs. 1, 2.—Bull Mountains, Montana: collected by Hayden and Peale in 1883 (Fig. 1). Golden, Colorado (Fig. 2).

Mr. Lesquereux (Tert. Fl., p. 281) seems to think that the presence of tertiary nerves proceeding from the lower secondaries could not occur in Berchemia, and he therefore referred all such to Rhamnus; but I find such nerves very faintly shown in some leaves of *B. volubilis* DC., and I do not regard this character as of sufficient weight to be treated as generic. My Golden specimen is larger than most of those referred to this species. It is also more narrowed at the base, and approaches Ludwig's figure of *Cornus orbifera* Heer (Palæontogr., Vol. VIII, pl. lviii, fig. 12), which may well have been a Berchemia. This specimen is from the tufa beds.

The Bull Mountain specimen is in red baked clay and shows the nervation very clearly. The nervilles are stronger and smoother than in other cases and pass across the areas more nearly at right angles to the secondary nerves, in so far resembling Ficus.

ZIZYPHUS Juss.

A widely distributed tropical and subtropical genus containing in the present flora about fifty species; quite abundant in a fossil state, ranging from the upper Cretaceous (Patoot, Greenland) to the Pliocene. It has been hitherto represented by eight Eocene, one Green River, and five Laramie species, none of the last being from Fort Union strata.

Z. serrulatus, n. sp.

Plate XXXIII, Figs. 3, 4.—Burns's Ranch, Montana; one specimen (Fig. 4) collected by Dr. White's party in 1882.

Leaves short petioled, ovate, 2.8cm. wide, 3.5cm. long, rather finely and sharply serrate or sometimes crenate to near the base; nervation palmate, acrodrome, craspedo-camptodrome; petiole dividing at its dilated summit into three nearly equal primary nerves; median nerve slightly curved, nearly simple; lateral primary nerves very erect (20° to 30°), curving regularly upward and inward to the point of the leaf, forming an elliptical area which the midrib divides equally, branched from the outside, the branches curving upward at some distance from the margin and joining one another in a series of undulations or arches, from which short veinlets pass directly into the teeth; nervilles geniculate or broken, crossed in the middle by finer fibers and the tertiary areas filled by a dense network of quadrate or polygonal meshes.

In both of the specimens the summit is wanting. The substance of the leaf is clearly preserved, leaving a black coating of discernible thickness upon the light-brownish or ash-colored rock. In one (Fig. 4) the area between the lateral primaries appears to have the epidermis removed, exposing the detailed nervation very perfectly. There is considerable difference in the dentation of the two specimens, as also in the shape of the base, but this can scarcely be regarded as specific.

In *Z. ovoideus* Mass. (Fl. Foss. del Senigal., pl. xxxix, fig. 10) we have precisely the same form as in our specimens, except that the teeth are entirely wanting. In that figure the central part of the leaf shows the fine network of the ultimate fibers very much as in our specimen above referred to (Fig. 4). It is, however, to *Z. Meekii* Lx. (Tert. Fl., pl. li, figs. 10–14) that our form is probably most nearly allied, and, considering the variations already admitted to occur in that species, it may not be possible to keep them permanently distinct.

Zizyphus Meekii Lx.

ZIZYPHUS MEEKII Lx., Ann. Rep. U. S. Geol. Surv. Terr., 1872, pp. 388, 389; Tert. Fl., p. 275, pl. li, figs. 10–14. Schimper, Pal. Vég., Vol. III, p. 611.

Plate XXXIII, Figs. 5, 6. Carbon Station, Wyo. (Fig. 5). Bozeman Coal Mines, Montana (Fig. 6); collected by Hayden and Peale in 1883.

None of the specimens figured by Lesquereux conform precisely to these impressions, but there are others in the collection from Carbon made by Lesquereux and Meek, but not figured, which much more closely resemble the one collected there by myself (Fig. 5). The Bozeman specimen is longer in proportion to its width than any thus far referred to this species, and in this respect it agrees better with most living species. The nervation and dentation are those of *Z. Meekii*, and I scarcely feel warranted in separating it on account of the shape alone.

Zizyphus cinnamomoides Lx.

ZIZYPHUS CINNAMOMOIDES Lx., Tert. Fl., p. 277, pl. lii, figs. 7, 8; Cret. and Tert. Fl. p. 189.

CEANOTHUS CINNAMOMOIDES Lx., Ann. Rep. U. S. Geol. Surv. Terr., 1871, p. 289.

Plate XXXIII, Fig. 7.—Seven Mile Creek, Montana; white marl bed.

Very similar to Lesquereux's fig. 7 (specimen not in National Museum collection), less distinctly toothed than his fig. 8 (No. 431, Nat. Mus.

coll.); not unlike Unger's *Ceanothus Bilinicus* (Chlor. Prot., pl. xlix, fig. 9).

A number of small obovate forms of very enigmatical character occurred in the white marl bed of the Seven Mile Creek series, of which this is a case showing the extreme elongation. I was at first disposed to regard them all as depauperate forms of *Populus cuneata*, so abundant in the same bed, but their further study has compelled me to distribute them to the three genera Zizyphus, Paliurus, and Grewia. They will be further considered under the two last named genera.

PALIURUS Juss.

Only two species of Paliurus are known in the living flora of the globe, one of which is confined to southern China, the other to southern Europe and western Asia. About a dozen fossil species have been described, chiefly from leaves alone, of which two are from the Laramie group and one from Green River strata, at Florissant, Colo. Without the winged fruit no one will claim that it is possible to distinguish this genus from Zizyphus, or, perhaps, from Ceanothus. The three following forms, therefore, are liable to be transferred to either of those genera should they ever be discovered in connection with their fruits.

Paliurus Colombi Heer.

PALIURUS COLOMBI Heer, Fl. Foss Arct., Vol. I, p. 122, pl. xvii, fig. 2*d*; pl. xix, figs. 2–4; Vol. II, Pt. III (Mioc. Fl. Spitzb.), p. 67, pl. xiv, fig. 11; Pt. IV (Foss. Fl. N. Greenland), p. 482, pl. l, figs. 18, 19; Vol. IV, Pt. I (Foss. Fl. Spitzb.), p. 91, pl. xxxi, fig. 8; Vol. V, Pt. II (Foss. Fl. Sibir.), p. 35, pl. ix, fig. 2*a*, 2*b*; Pt. III (Prim. Fl. Foss. Sachal.), p. 52, pl. xiii, figs. 1–3. Lesquereux, Tert. Fl., p. 273, pl. l, figs. 13–17. Schimper, Pal. Vég., Vol. III, p. 217.

Plate XXXIII, Figs. 8–10.—Burns's Ranch, Montana (Figs. 8, 9, the latter collected by Dr. White's party in 1882). Carbon Station, Wyoming (Fig. 10).

The Burns's Ranch specimens are identical in form with those previously collected at Carbon, while my specimen from Carbon is longer in proportion to its width and entire margined; it is, however, obscure, and the portions of the margin where a tooth or small lobe sometimes occurs is wanting. It may be compared with Heer's Spitzbergen figure, and especially to his Sachalin, figures 2 and 3. As this specimen occurs on the same slab as the next one to be described, I think it quite possible that it represents the same plant, although the differences, as will be seen, are very considerable.

Paliurus pulcherrimus, n. sp.

Plate XXXIII, Fig. 11.—Carbon Station, Wyoming.

Leaves small (2.7cm. wide, 4cm. long), petioled, ovate-lanceolate, pointed, rounded at the base, undulate margined to near the base, the undulations small, numerous, and regular; petiole about a centimeter long; nervation palmate, camptodrome; midrib strong, straight, central, having about ten thin alternate branches above the middle; lateral primary nerves rather small, rising from the base of the blade, opposite, symmetrical, leaving the midrib at an angle of 40°, curving upward and at length inward (acrodrome), giving off eight or nine short, nearly straight, parallel, secondary nerves at equal distances apart, which fork and either anastomose in a series of arches near the margins or appear to lose themselves in the parenchyma; secondaries from the midrib more distant and less regular, forking, the two lowest joined to the primaries; nervilles very faint, dichotomous or broken.

By the aid of counterparts all but the immediate point of this leaf is found to be preserved and there can be no doubt as to its characters as above described. It occurs upon a slab of calcareous sandstone of a very dark color, which contains impressions of other leaves and confused vegetable remains, among which are branching stems of coaly aspect, one of which passes along the base of the petiole of this leaf in such a manner as to render it next to certain that it grew from it, although it is difficult to make out the actual attachment. Among the fragments of leaves scattered about on the stone are several that seem to be identical with this, and it is here, as above remarked, that one of the specimens last mentioned (Fig. 10) occurs. More minute study of all these impressions may necessitate the union of all the forms of similar nervation and justify their attachment to the stems with which they are associated.

Paliurus Pealei, n. sp.

Plate XXXIII, Figs. 12-14.—Little Missouri River, Dakota; collected by Dr. A. C. Peale in 1883.

Leaves small (1 to 2.5cm. wide, 1 to 4cm. long), petioled, ovate, pointed, somewhat oblique or gibbous, finely and regularly crenate-toothed to near the narrowed or nearly horizontal base; petiole 6 to 12 mm. long, slightly curved, rather thick; nervation subpalmate, craspedo-camptodrome, one or two basilar nerves on each side, usually rising from near the summit of the petiole, either simple or the stronger ones giving off short tertiary nerves to the lower teeth; lateral subprimaries rising from a short distance above the base of the blade, very erect, curving, and acrodrome, having numerous outer branches which fork and unite near the margin, from which short branches run into the teeth; nervilles bent or geniculate, traversing the areas between the primaries.

These pretty little leaf-prints occur in buff shales of the Bad Lands of the Little Missouri and, with the exception of their immediate summits, are in a very good state of preservation. The extremes in size represented by Figs. 12 and 14 are joined by the intermediate form shown in Fig. 13, and all doubts as to their specific identity are thus removed.

Their form is closely imitated by many leaves (cf. *Celtis McCoshii* Lx., Cret. and Tert. Fl., pl. xxxviii, fig. 8; *Celastrinites elegans* Lx., op. cit., pl. xxxi, figs. 9, 10; *Celtis Japeti* Ung., Iconogr., pl. xliii, fig. 26, Europ. Waldb., fig. 28; *Myrsine Radobojana* Ung., Sylloge, III, pl. vii, fig. 1), but the nervation does not correspond precisely in any I have examined. In *Zizyphus Ungeri* Heer, the type of which is more elongated, there occur forms which approach them quite closely (cf. Unger, Foss. Fl. v. Sotzka, pl. lv, figs. 3, 5, 7, 8; Ettingshausen, Foss. Fl. v. Hæring, pl. xxv, figs. 18, 25, 29, 37), but these all want the basilar nerves and have the acrodrome lateral primaries rising from nearer the base and passing up much closer to the margin. In *Paliurus tenuifolius* Heer, especially the specimen from Aix figured by Saporta (Études, Ann. Sci. Nat., Bot., 4e Sér., Vol. XVII, pl. xii, fig. 5), we find perhaps the nearest approach to our plant, with suprabasilar nerves and short thick petiole, but no nerves are shown below the principal primaries and the dentation is comparatively feeble.

CELASTRINEÆ.

CELASTRUS L.

Of the eighteen species known to occur in the present flora of the globe only one (*C. scandens* L.) is a native of North America. The greater part of the species, however, inhabit the mountains of eastern Asia, where they seem to have taken refuge on the retreat of the glacial invasion. A few lingered in the southern hemisphere and became acclimated there.

In the fossil flora this genus plays a very important rôle. Schimper in 1874 was able to enumerate fifty-four species, and the number has since been largely increased. Up to that time the genus had been confined to the Tertiary deposits of Europe. Subsequent arctic explorations have revealed the existence of a number of species at the north, in the Miocene strata of Greenland, Spitzbergen, Alaska, and Sachalin. One species is found in the upper Cretaceous of Patoot, but most of the celastraceous fossils occurring in the Cretaceous, as well as those from the Paleocene of Sézanne and Gelinden, are assigned to the extinct genera Celastrinites and Celastrophyllum. Two species of Celastrinites are described by Lesquereux from the Laramie group and three species of Celastrus from the Green River group.

Realizing the importance to paleontology of this group of plants, Baron von Ettingshausen, as early as 1856, published a memoir on the nervation of the Celastrineæ (Denkschr. Wien. Acad., Vol. XIII, p. 43), illustrated physiotypically by ten plates; but the species of Celastrus figured in that work belong chiefly to the Cape of Good Hope and now fall under the genus Gymnosporia, and it is not among these that we have to look for the analogues of our American fossil forms. The specimens here referred to this genus, and in fact all that I place in this order, come from Fort Union strata. I am unable to assign them to any known species and am forced to regard them as new, at least for the present. One type of nervation, with minor modifications, characterizes them all, and this seems to me best exemplified in the American species of Celastrus, especially in the more ample leaves of that species. The most striking and uniform feature of this type of nervation is the peculiar manner in which the secondary nerves arch near their extremities and supply short subsidiary nerves to the teeth of the margin.

Celastrus ferrugineus, n. sp.

Plate XXXIV, Figs. 1-4.—Burns's Ranch, Montana (Fig. 1). Iron Bluff, Montana; collected by Dr. White's party in 1882 (Figs. 2-4).

Leaves thin and membranaceous, ovate or oblong, petioled, slightly heart-shaped, pointed, regularly and sharply simply serrate to near the often oblique base, 4 to 6cm. wide, 6 to 8cm. long; petiole short (5 to 9mm. long), thick, usually somewhat curved, dilated downward; nervation pinnate, craspedo-camptodrome; midrib large below, somewhat dilated at the nodes, rapidly diminishing upward, the reduction very perceptible at each node, sometimes slightly zigzag, more or less curved; secondary nerves well developed, approximate, parallel, seven to ten on each side, often unequally distant on the two sides, issuing from the midrib at a broad angle (40° to 60°), curving upward in crossing the lamina, each nerve branching more or less dichotomously toward its extremity, the branches only entering the teeth, the lowest ones being previously joined by the main portion of the nerve below in such a manner as to form a series of angled arches along and at some distance from the border; nervilles distinct, percurrent or forking, more or less flexed, somewhat horizontal.

These four specimens differ somewhat from one another and may possibly represent two or more species, but they agree in so many particulars that no difficulty is experienced in giving them a common character. The Burns's Ranch specimen (Fig. 1) seems certainly to be the same as the largest one from Iron Bluff (Fig. 2). From this to the other Iron Bluff specimen of the same ovate shape (Fig. 3) the transition is not violent, although the oblique base and somewhat knotted midrib are quite peculiar features. It is in these last named characters that this specimen agrees with the remaining one (Fig. 4), giving these two a very similar general aspect, which seems to make one ignore the considerable difference of form. All the specimens are thus bound together by characters such that, although when we compare the extremes (as Fig. 1 with Fig. 4) we see little to prove their relationship, still, when we consider them all as a group, we find it very difficult to say where the line of separation should be drawn. If any separation is to be made it would seem that all must be disunited and four distinct forms recognized; for even in the case of the first two (Figs. 1 and 2) the continuation of the teeth to the very base in one of them (Fig. 2) is a character not elsewhere seen in the group.

These forms all differ from *C. scandens* L. by their heart shaped base and sharper teeth. In both these respects, however, they are more nearly matched by *C. scandentifolius* Web. (Palæontogr., Vol. II, pl. xxii, fig. 10*a*) from the lignites of the Lower Rhine, but in the more angular arches their nervation deviates from both these species.

While I believe that all the characters of these leaves taken together point more strongly to Celastrus, or at least to the Celastrineæ, as their proper affinity than to any other group of plants, it must nevertheless be admitted that other genera and families combine many of them and that their final assignment must be postponed until further evidence is received. I was at first disposed, as Baron Von Ettingshausen seems to be, to refer them to the Rosaceæ, and I found in the living genus Amelanchier many things with which to compare them (see leaves of *A. Canadensis* T. & G. and of *A. Botryapium* DC., Ett. Blattsk. der Dicotyl., pl. lxxxix, fig. 11). I do not, however, consider this view at all strengthened by a comparison with *A. similis* Newberry (Illustrations, pl. xxv, fig. 6), which is as likely to be a celastraceous leaf (cf. *Celastrus scandentifolius* Web., loc. cit.; also in Unger, Sylloge, II, pl. ii, fig. 22).

The nervation of Fraxinus is also somewhat like what we see here, but the leaflets of that genus are usually narrower. In *F. abbreviata* Lx. (Cret. and Tert. Fl., pl. xxviii, figs. 5, 6), however, we have them exhibiting nearly the same proportions as in our leaves. I have already mentioned (*supra*, p. 33) the analogy which these forms present with Juglans, and some of our present specimens may profitably be compared with some species of that genus (see Heer, Foss. Fl. Arct., Vol. II, Pt. II, Alaska, pl. ix, fig. 5).

Celastrus Taurinensis, n. sp.

Plate XXXIV, Figs. 5, 6.—Bull Mountains, Montana (Fig. 5). Burns's Ranch, Montana; collected by Dr. White's party in 1882 (Fig. 6).

Leaves rather thin, large (7cm. wide, 12cm. long), oblong, slightly heart shaped, pointed, sharply and coarsely serrate to near the base; nervation pinnate, craspedodrome; midrib rather thin, slightly curved, thickened at the nodes; secondary nerves nine to eleven on each side, alternate or subopposite, curving upward, forking or branching, occasionally arching and supplying short veinlets to the teeth, lowest pair thin, basilar, and mostly simple; nervilles more or less curved, percurrent or more commonly forked, joining the secondaries at right angles.

It is with some hesitation that I have finally decided to unite these two forms in one species and refer them to Celastrus. They come from widely different sections and occur in very dissimilar rock, the Bull

Mountain specimen being in soft white clay. In the Burns's Ranch leaf the secondaries are more erect and straighter and the teeth, which are larger, are slightly incurved. In form and size they are comparable to *Populus balsamoides* Göpp. (cf. Foss. Fl. v. Schossnitz, pl. xv, fig. 3; Gaudin, Gisements, pl. iii, fig. 1), but the sharp teeth and craspedodrome nervation seem to make such a reference out of the question. Possessing the peculiar nervation of the Celastrineæ, I seem compelled to assign them to that family, but reasons will be given later (*infra*, p. 95) for considering it possible that they may belong to Pterospermites or Grewiopsis. The specimen, Fig. 15, may be compared with *Elæodendron Sagorianum* Ett. (Foss. Fl. v. Sagor, II, Denkschr. Wien. Acad., Vol. XXXVII, Abth. I, pl. xvi, fig. 25).

Celastrus alnifolius, n. sp.

Plate XXXV, Figs. 1, 2.—Burns's Ranch, Montana; one of the specimens (Fig. 2) collected by Dr. White's party in 1882.

Leaves broad, oblong-ovate, 6cm. wide, 8cm. long, irregularly serrate to near the oblique base; petiole 2.5cm. long, slightly inflated below, curved to one side; nervation pinnate, craspedodrome; midrib strong, nearly straight; secondary nerves about nine on a side, the lower nearly opposite, the upper alternate, issuing at an angle of 40° to 45°, slightly curving upward and forking or branching, usually anastomosing to form angled arches which give off short nerves to the teeth of the margins; nervilles distinct, usually forking, joined by very fine oblique veinlets, which form a network of polygonal meshes.

The shape and general aspect of these two leaves are very similar, but a difference is visible in the nervation, which at first strongly inclined me to separate them. In one of the specimens (Fig. 2) the secondary nerves are less curved upwards and branch dichotomously, the two divisions often running directly into the teeth. This, however, is not always the case, and some of the branches show a disposition to form arches. Upon the whole I can scarcely doubt, coming as they both do from the same bed, that they represent the same species; but the nearly opposite lower nerves, the general shape, dentation, &c., certainly remind one strongly of Alnus. In *Alnus cardiophylla* Sap. (Fl. Foss. de Sézanne, pl. xxxvi, fig. 8) the characters here presented are visible along with still greater anomalies; compare also *A. serrata* Newberry (Illustrations, pl. xvi, fig. 11). Nevertheless, it seems impossible to detach these forms from the general series now under consideration.

Celastrus pterospermoides, n. sp.

Plate XXXV, Figs. 3-6.—Burns's Ranch, Montana (Figs. 3, 4, 6). Iron Bluff, Montana (Fig. 5).

Leaves thin, rather large (5 to 6cm. wide, 10 to 15cm. long), oblong, slightly heart shaped, horizontal, or oblique at the base, coarsely and prominently serrate, petioled; nervation pinnate, craspedodrome; midrib very thick below, rapidly diminishing; secondary nerves inequidistant, the lower ones crowded together, horizontal or directed a little downward, middle and upper ones somewhat curved upward, branching, arching, and joining, the arches supplying short branches to the teeth; nervilles mostly percurrent, somewhat flexuous, the areolæ between them occupied by a fine network of quadrate or polygonal meshes.

The special characteristic of all these leaves by which they seem separable from the others of this series is the manner in which the lateral nerves near the base are huddled together on the thick midrib, proceeding out horizontally or somewhat radially, reminding one of the nervation of Credneria, Protophyllum, and Pterospermites. Otherwise they seem to have the general nervation of the group and may be compared with *Celastrus borealis* Heer (Fl. Foss. Arct., Vol. II, Pt. II, Alaska, pl. x, fig. 4).

Celastrus ovatus, n. sp.

Plate XXXVI, Fig. 1.—Iron Bluff, Montana.

Leaf ovate, pointed, narrowed and rounded at the base, very symmetrical, 6cm. wide, 11cm. long, sharply and somewhat unequally serrate; nervation pinnate, craspedodrome; midrib thick below, rapidly thinning above, straight; secondary nerves twelve to thirteen on a side, nearly equidistant and parallel, alternate, slightly curving upward, forking or branching and arching, the ultimate ramifications entering the teeth; nervilles indistinguishable.

This nearly perfect and very symmetrical leaf from Iron Bluff was considered sufficiently distinct to be separated from those previously described, but such separation is chiefly based on the ovate shape. It seems to occupy an intermediate position, having the base similar to *C. alnifolius.* The petiole is wanting, but from the midrib it is safe to judge that it was thinner than in the last species. While it seems to belong to this group, its affinities with the Betulaceæ are strong and it may be compared with *Betula Sezannensis* Sap. (Fl. Foss. de Sézanne, pl. xxxvi, figs. 9, 10).

Celastrus grewiopsis, n. sp.

Plate XXXVI, Fig. 2.—Burns's Ranch, Montana.

Leaf lanceolate, obliquely heart shaped, strongly serrate to the base; nervation pinnate, craspedo-camptodrome; midrib very large, straight; secondary nerves issuing at a wide angle and curving upward, following the margin or curving inward to join the next higher, giving off from the elongated arches thus formed a number of short tertiary nerves which enter the teeth; nervilles percurrent, somewhat flexuous, occasionally forked.

This specimen, of which the upper portion is wanting, presents a considerable modification of the general type, both in its narrower elongated outline and in the extreme upward curvature of the lateral nerves. Its strongly toothed, heart shaped base recalls forms of Grewia. But for the strongly craspedodrome tertiary nerves the nervation would be that of *Juglans nigella* (cf. Fl. Foss. Arct., Vol. II, Pt. II, Alaska, pl. ix, fig. 2*a*), and the leaf figured by Sieber under the name of *Rhus Meriani* Heer (Zur Kenntniss d. Nordböhm. Braunkohlenflora, Sitzb. Wien. Acad., Vol. LXXXII, Abth. I, pl. v, fig. 39) imitates it very closely. The specific name should be written with a small initial letter to denote its resemblance to Grewia and not to Grewiopsis.

Celastrus curvinervis, n. sp.

Plate XXXVI, Figs. 3, 4.—Burns's Ranch, Montana; the larger specimen (Fig. 4) collected by Dr. White's party in 1882.

Leaves elliptical or lanceolate, recurved-pointed, 5 to 8cm. wide, 12 to 15cm. long, regularly serrate; nervation pinnate, craspedo-camptodrome; midrib curved; secondary nerves much curved upward and at length inward, forming elongated arches, from which short tertiaries proceed to the teeth; nervilles very oblique, usually forked, the areolæ occupied by quadrate meshes.

The great difference in the width of these leaves is perhaps sufficient to warrant their separation, but the nervation seems to be precisely the same. The midrib is too thin to justify their union with the form last described, to which they are related by the much curving secondary nerves. The base is wanting in both. The nervation, including the form of the finer meshes, is very similar to that of *Euonymus Proserpinæ* Ett. (Foss. Fl. v. Bilin, III, Denkschr. Wien. Acad., Vol. XXIX, pl. xlviii, figs. 6, 7); it may also be compared with that of *Celastrus Dianæ* Heer (Fl. Foss. Arct., Vol. VI, Abth. I, Pt. II, Nachtr. z. Foss. Fl. Grönlands, pl. iii, fig. 6*a*) and of *C. fraxinifolius* Lx. (Cret. and Tert. Fl., pl. xxxiii, figs. 2–4).

EUONYMUS L.

The genus Euonymus embraces about forty species, the greater part of which inhabit the mountains of India, China, and Japan. Three species are indigenous in North America. About fifteen fossil species are known, only one of which is from American strata.

Euonymus Xantholithensis, n. sp.

Plate XXXVII, Figs. 1, 2.—Burns's Ranch, Montana.

Leaves oblong or obovate, 4.5cm. wide, 10cm. long, petioled, rather finely and sharply serrate to near the base; nervation pinnate, craspedo-camptodrome; midrib thick below, rapidly diminishing above, nearly straight; secondary nerves about twelve on a side, alternate or subopposite, irregular as to distance and angle, curving upward near the margin and following it, uniting at their extremities with the branches of the next higher, furnishing short tertiary nerves to the teeth of the margin; nervilles oblique, chiefly percurrent.

This form finds its nearest representatives in the living species *E. atropurpureus* Jacq., common in the United States, and in the East Indian species, *E. pendulus* Wall. (Ettingshausen, Nervation d. Celastrineen, Denkschr. Wien. Acad., Vol. XIII, pl. x, fig. 7). It wants the long point and sharp, coarse teeth of the Green River form (*E. flexifolius* Lx., Cret. and Tert. Fl., pl. xxxviij, fig. 13). It approaches somewhat closely to some of the figures of *Rhamnus Gaudini* Heer (cf. Fl. Tert. Helv., pl. cxxv, fig. 1), and may also be compared with *Cupania Neptuni* Ung. (Sylloge, I, pl. xv, figs. 7, 8). That it is generically distinct from the preceding forms it would be rash to insist.

ELÆODENDRON Jacq.

Of the dozen or more fossil species of this now chiefly tropical Old World genus that have been thus far described only one has been found in American strata (*E. Helveticum* Heer, Lesquereux, Mioc. Fl. of Alaska, Proc. Nat. Mus., Vol. V, 1882, p. 449, pl. ix, fig. 4). The form and nervation of the leaves which I have grouped under this name are too near those that have been so referred to be separated generically from them without additional data for so doing. The genus to which they are next most closely related by these characters is Ilex, and to this they may eventually be relegated. But they seem to form part of the same general group which has just been considered, and it seems best to regard them as members of the same family. They are generally smaller and more elongate and are distinguished as to their nervation by the curving of the secondary nerves farther from the margin and the frequent formation of a double row of arches or of a series of large polygonal areolæ.

Elæodendron serrulatum, n. sp.

Plate XXXVII, Figs. 3-5.—Burns's Ranch, Montana (Figs. 3, 4). Seven Mile Creek, Montana (Fig. 5).

Leaves thin, short petioled, elliptical or ovate, 4 to 4.5cm. wide, 7 to 8cm. long, pointed at the summit, narrowed or slightly heart shaped at the base, finely and sharply irregularly serrate to very near the base; nervation pinnate, craspedo-camptodrome, brochiodrome; midrib straight or somewhat uneven, strong; secondary nerves rather light, distant, branching early, and turning abruptly upward and at length inward, uniting with the lowest branch of the next higher, forming angled arches, or often continuing upward and joining with other branches of the next higher in such a manner as to produce a series of secondary undulations inclosing rows of D-shaped areolæ; nervilles usually percurrent, flexuous, curved, or geniculate.

The nervation of these leaves approaches more nearly that of *E. Hœringianum* Heer (Fl. Tert. Helv., pl. cxxii, fig. 6) than that of any other plant that I have been able to compare it with. It nevertheless resembles that of certain Rosaceæ more closely than in any of the previous cases (cf. Fig. 3 with *Amelanchier typica* Lx., Cret. and Tert. Fl., pl. xl, fig. 11; also, with *A. Canadensis* T. & G., living, and with *Pyrus serrulata* Göpp., in Palæontogr., Vol. VIII, pl. lxiii, fig. 6). In *Euonymus Szantoinus* Ung. (Foss. Fl. v. Szantó, Denkschr. Wien. Acad., Vol. XXX, pl. iv, fig. 5) we have again this type of nervation, which is an exaggeration of the normal celastroid type. All the species of Elæodendron physiotypically figured in Ettingshausen's memoir above cited (Denkschr. Wien. Acad., Vol. XIII, pl. i, ii) exhibit it in greater or less degrees.

Elæodendron polymorphum, n. sp.

Plate XXXVIII, Figs. 1-7.—Burns's Ranch, Montana; the first four specimens (Figs. 6-9) collected by Dr. White's party in 1882.

Leaves rather thick and coriaceous, elliptical-lanceolate, narrowed or somewhat truncated at the base, pointed at the summit, very variable in size (2 to 3.5cm. wide, 5 to 8cm. long), short petioled, finely and sharply serrate to near the base; petioles thick, dilated below, slightly curved; nervation craspedo-camptodrome, brochiodrome; midrib slightly curved; secondary nerves rather distant, irregular, curving upward and forming one or two rows of angled arches inclosing loose polygonal areolæ, the numerous short ultimate branchlets entering the teeth; nervilles distinct, flexed near their centers, forking and variously joining within the areas to form rather coarse polygonal meshes.

The seven specimens here figured, all from the same bed, differ greatly in size and considerably in form and nervation, but after prolonged study I have not found constant characters upon which I can consistently separate them. The smaller ones show only one row of arches; one of these (Fig. 9) has a much longer petiole than the rest, and the secondary nerves are more approximate and regular; another (Fig. 12) is ovate-lanceolate and somewhat heart shaped at the base. The ultimate nervation is also different in different specimens, the nervilles being simply percurrent in some.

The first specimen (Fig. 6) may be compared with *E. Gaudini* Heer (Fl. Tert. Helv., pl. cxxii, fig. 3). In *E. degener* Ett. (Foss. Fl. v. Bilin, III, Denkschr. Wien. Acad., Vol. XXIX, pl. xlix, figs. 9, 10) we have forms allied to other of our specimens (Figs. 9, 10, 11). *Celastrinites Hartogianus* Sap. (Fl. Foss. de Sézanne, pl. xxxvi, fig. 15) may also be compared with Fig. 6, and *Celastrus Persei* Heer (Fl. Tert. Helv., pl. cxxii, fig. 1), with Fig. 7. *Euonymus Radobojanus* Ett. (Foss. Fl. v. Bilin, III, pl. xlviii, fig. 8) furnishes as near an approach as we find to the small specimen, Fig. 9, while in *Celastrus fraxinifolius* Lx. (Cret. and Tert. Fl., pl. xl, fig. 10) we have a form similar to Fig. 11. We thus find forms of fossil plants that have been referred to the Celastrineæ with which to compare nearly all the specimens here grouped together. None of these, however, are very similar to the smallest of these specimens (Fig. 12), and for analogues to this we are obliged to look in other genera. Perhaps the nearest approach to this specimen is furnished by Heer's *Fraxinus prædicta*, particularly the Portuguese specimens (cf. Fl. Foss. du Portugal, pl. xxii, figs. 5–8). Next to this come forms of Salix (cf. *S. varians* Heer, Fl. Foss. Arct., Vol. II, Pt. II, Alaska, pl. ii, fig. 8; *S. primæva* Sap., Fl. Foss. de Sézanne, pl. xxviii, figs. 5–8). Notwithstanding these close analogies I am disposed to regard this form as representing an extreme modification of the general type to which all these specimens belong. In fact it is not difficult to find analogues of all the rest in genera that have not been referred to the Celastrineæ. Compare, for example, *Ilex ambigua* Ung. (Fl. Foss. v. Kumi, Denkschr. Wien. Acad., Vol. XXVII, pl. xiii, fig. 19) and *Aralia hederacea* Sap. (Fl. Foss. de Sézanne, pl. xxx, fig. 5) with our Fig. 6, *Rhamnus Warthana* Heer (Braunk. Fl. Zsily-Thal., pl. v, figs. 2, 3) and *Cunonia Bilinica* Ett. (Foss. Fl. v. Bilin, III, pl. lv, fig. 21) with Fig. 9.

TILIACEÆ.

GREWIA L.

A large genus (sixty species) of mostly tropical Old World plants, found in considerable abundance in the European Miocene, also in that of the arctic regions. One species, *G. auriculata* Lx., is reported from the John Day River region of Oregon, also Miocene.

Grewia crenata (Ung.) Heer.

GREWIA CRENATA (Ung.) Heer, Fl. Tert. Helv., Vol. III, p. 42, pl. cix, figs. 12–21; pl. cx, figs. 1–11; Fl. Foss. Arct., Vol. IV, Pt. I (Foss. Fl. Spitzb.), p. 84, pl. xix, figs. 12–14. Ettingshausen, Fl. Tert. v. Bilin, III (Denkschr. Wien. Acad., Vol. XXIX), p. 15, pl. xlii, fig. 7. Schimper, Pal. Vég., Vol. III, p. 118. Zwanziger, Mioc. Fl. v. Liescha, p. 68, pl. xxvi, fig. 1. Saporta, Monde des Plantes, p. 325, fig. 98, No. 1. Staub, Aquitan. Floraja, p. 31, pl. iii, figs. 2, 3.

DOMBEYOPSIS CRENATA Ung., Gen. et Spec., p. 448.

Plate XXXIX, Fig. 1.—Bull Mountains, Montana; collected by Hayden and Peale in 1883.

This impression, which occurs in the soft white clay of Bull Mountains and wants both petiole and summit, has precisely the form of many of the figures of *G. crenata*. The parts of the leaf that are present are very perfectly preserved, and upon close inspection it appears that the margins, instead of being crenate, are minutely sharply serrate, the teeth being usually provided with short nervelets from the arches of the secondary system. Whether this is sufficient to remove it from this species or even from the genus I will not now attempt to decide. Should the latter be necessary the Rhamneæ would seem to be the order into which it must find its way, where it will find analogues in Paliurus, Ceanothus, Zizyphus, &c. In this connection it may be advantageous to compare it with *Zizyphus tiliæfolius* (Ung.) Heer (Chlor. Prot., pl. xlix, figs. 3, 4) and with *Paliurus Favonii* Ung. (op. cit., pl. l, figs. 7, 8).

? Grewia celastroides, n. sp.

Plate XXXIX, Fig. 2.—Iron Bluff, Montana.

Leaf large (8cm. wide), ovate (?), slightly heart shaped, coarsely and sharply serrate to near the base, petioled; nervation pinnate, craspedodrome; midrib as thick as the petiole, curved near the base; secondary nerves numerous, approximate, parallel, comparatively light, gently curved upward, lower ones nearly horizontal, opposite, branched, the rest alternate, forking, the ultimate ramifications entering the teeth; nervilles distinct, flexuous, often forked, traversing the areas at nearly right angles to the nerves.

Since submitting my paper for the Sixth Annual Report of the United States Geological Survey, in which this species and the next received their present designations after such a study as I was then able to give them, I have been led by grave doubts to reinvestigate this entire group, and while I cannot claim to have settled the question of the generic relationship of these forms I have at least found reason to doubt still more strongly their affinity with the genus Grewia. It is true that in *G. tiliacea* Ung. (Sylloge, III, pl. xiii, figs. 12, 13) the nervation is pinnate and analogous to that of these specimens and that some living species, as *G. Asiatica* L., *G. occidentalis* L., &c., have a somewhat similar nervation, but the normal disposition of the nerves of the genus is palmate or subpalmate and somewhat acrodrome. While many are crenate and even dentate they are rarely so prominently and sharply toothed as in these forms. They are generally more or less camptodrome, even when serrate, and the secondary nerves do not fork.

In Grewiopsis, as founded by Saporta on Sézanne specimens, there is considerable deviation from the type of Grewia in the direction of a more pinnate nervation, but the lowest nerves are usually more ascending and none of the secondaries are dichotomous. As extended by Lesquereux to embrace Laramie forms this deviation is carried further. In *G. Saportana* Lx. (Tert. Fl., pl. l, figs. 10–12), though the margins are nearly entire, the secondary nerves are pinnate and somewhat dichotomous. In the Dakota group forms of the same author (Cret. Fl., pl. iii, figs. 2, 4; pl. xxiv, fig. 3) these characters appear still more distinctly, and if these references are correct they seem to furnish a clew to the proper relationship of the forms under consideration.

Our present specimen, as will be perceived, is from the same bed that furnished the forms referred to Celastrus. If its upper portion had been preserved it might have exhibited the peculiar celastroid nervation seen in these forms, but this peculiar nervation is also seen in some forms of Grewiopsis (cf. *G. tremulæfolia*, Fl. Foss. de Sézanne, pl. xxxiii, fig. 8; *G. Saportana* Lx., Tert. Fl., pl. 1, fig. 11; *G. Cleburni* Lx., op. cit., pl. lxii, fig. 12), and the question may yet arise whether these forms can be so widely separated, as well as the question to what family of plants they really belong.

? Grewia Pealei, n. sp.

Plate XXXIX, Figs. 3-5.—Bull Mountains, Montana; collected by Dr. A. C. Peale in 1883.

Leaves petioled, ovate, heart shaped, 6 to 7cm. wide, 7 to 10cm. long, strongly toothed to near the base; petiole 2 to 3cm. long, thickened below, straight; nervation pinnate, craspedodrome; midrib thick at the lower end, visibly diminishing at each slightly dilated node, straight; secondary nerves comparatively light, close together, especially near the base of the leaf, chiefly alternate, the lowest ones rising at an acute angle, immediately curving outward and somewhat downward nearly parallel to the auriculate base, giving off short tertiary nerves which enter the lower teeth, successively higher ones becoming horizontal and somewhat erect, curving upwards and branching more or less dichotomously, yielding tertiaries which sometimes further branch or fork, the ultimate ramifications reaching the margin without arching or anastomosing; nervilles faint, percurrent or forked, straight or somewhat bent, traversing the areas at right angles to the nerves.

These specimens occur in the soft white clay of Bull Mountains, and, though none of them shows the summit of the leaf, the base and central portion are preserved in the most perfect state. All that was said respecting the last species applies to the present one and need not be repeated. The specimen (Pl. XXXIV, Fig. 6) which is described on page 79 as *Celastrus Taurinensis* is from the same bed and occurs in immediate association with these. I was at first inclined to regard them all as belonging to the same variable plant, but a close comparison shows a great difference in the nervation, not, however, without numerous points of resemblance. It may still be necessary to unite them.

I have found scarcely anything with which to compare these forms. Perhaps they approach more closely to *Grewiopsis sidæfolia* Sap. (Fl. Foss. de Sézanne, pl. xxxii, fig. 10) than to any other form thus far made known, and it is to that genus rather than to Grewia that I now incline to refer them, along with the one last described

Grewia obovata Heer.

GREWIA OBOVATA Heer, Fl. Foss. Arct., Vol. IV, Pt. I (Foss. Fl. Spitzb.), p. 86, pl. xix, figs. 15, 15*b*.

Plate XXXIX, Figs. 6, 7.—Seven Mile Creek, Montana; white marl bed.

One of the greatest difficulties in the study of such forms as these is the great number of plants which it is possible to find having wholly different botanical relationships which still imitate them very closely, even to the details of nervation. Thus we may compare these leaves with *Persoonia laurina* Heer[1] (Fl. Tert. Helv., pl. xcvii, figs. 25–28), with *Paliurus zizyphoides* Lx. (Tert. Fl., pl. li, figs. 1–6), with *Elæodendron psilocarpum* (Ettingshausen, Blattsk. d. Dicotyl., pl. lxiii, fig. 3), with forms of Coprosma (op. cit., pl. xxiv, xxv), of Celastrus (op. cit., pl. lxii, lxiii), of Salix (Heer, Fl. Foss. Arct., Vol. II, Pt. III, Spitzb., pl. xvi, figs. 62–66; Ett., Physiotypia Pl. Austr., Vol. I, pl. xxv, figs. 4–6), of Cinnamomum, Bumelia, Aralia, Proteoides, Pterocelastrus, Melastomites, Hypericum, &c. Great confusion and doubt necessarily result, and one is compelled to fall back largely upon circumstantial evidence. Thus, as already remarked when speaking of another of these forms (*supra*, p. 75), I was at first disposed to look upon them as immature and anomalous leaves of *Populus cuneata*, and this I still regard as possible, but upon the whole not probable. They may all belong to Zizyphus or Paliurus, or they may possibly be proteaceous. This last, however, is improbable on general principles. The nervation, so far as it can be made out, seems to be that of the species to which I have referred them, and one of the specimens (Fig. 6) is an almost exact reproduction on a little smaller scale of Heer's plant as restored by him (loc. cit., fig. 15*b*). Doubtful as their affinities are, the impressions are in themselves quite perfect.

GREWIOPSIS Sap.

Forms of this extinct type were first described by Marquis Saporta from the Paleocene of Sézanne, and Prof. Lesquereux's discovery of several Laramie species supposed to belong to the same genus is a further proof of the correctness of his remark that there is a close resemblance between the Laramie and these lowest Eocene beds of France and Belgium. The following forms, if correctly referred to this type, will go far to confirm this view, as well as to show the essential unity of the Fort Union and lower Laramie system.

As already remarked my two species, *Grewia celastroides* and *Grewia Pealei*, above described, should also probably be referred rather to Grewiopsis.

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[1] *P. laurina* Pers. (*P. ferruginea* Smith) is an Australian species having almost precisely the same form (cf. Ettingshausen, Blattsk. d. Dicotyl., pl. v, figs. 8, 9). Heer makes no mention of this in the text (op. cit., p. 95), but names *P. daphnoides* as the nearest analogue of his plant. This seems to be a remarkable coincidence, if it is nothing more.

Grewiopsis platanifolia, n. sp.

Plate XL, Fig. 1.—Seven Mile Creek, Montana; Sparganium bed.

Leaf ovate, pointed, broadly cuneate at base, petioled, 9cm. wide, 10cm. long, sinuate-dentate to below the widest part; nervation palmate, craspedodrome; midrib strong, slightly curved; lateral primaries rather light, rising from the base of the leaf at an angle of 35°, proceeding straight to the margin above the middle of the leaf, or curving inward near the margin and uniting with a branch of the next nerve above, each throwing out a large branch from the lower side a short distance above the origin (which also proceeds nearly straight to the margin and bears four or five tertiaries), branching again two or three times near the extremities or from the arches; secondary nerves from the midrib five on each side, the lower ones nearly as large as the lateral primaries, opposite and parallel to them and to one another, simple or with one or two branches from the lower side and one light branch from the upper side, which curves and joins the outer one from the next higher, forming a sort of arch from the summit of which a short nervelet passes into the adjacent tooth of the margin; nervilles indistinct, simple and percurrent, or forked, straight, and somewhat oblique, or more or less bent or curved.

This specimen was picked up on the surface, where it had been somewhat weather worn, so as to render certain parts of the nervation difficult to make out, which doubtless accounts for the apparent difference in the nervation of the two sides. It is not possible to say with certainty whether it is the main trunk of the secondaries that curves upward near the margin to join a branch from the lower side of the next higher or whether this proceeds directly to the margin and gives off a smaller nerve from the upper side. The latter is what seems to take place on the left side of the figure above, but it is so unusual and the other so common that I can but think that if the specimen were better preserved the latter would be found to be the real state of the case. So, too, on the other side, the absence of branches or arches must be attributed to their indistinctness or complete obliteration on the rock. This celastroid nervation is seen in several of Saporta's figures of Grewiopsis, particularly in *G. tremulæfolia* (Fl. Foss. de Sézanne, pl. xxxiii, fig. 8), and to better advantage in the American species (cf. *G. Saportana* Lx., Tert. Fl., pl. l, fig. 11, and *G. Cleburni* Lx., op. cit., pl. lxii, fig. 12). But for this character there might be good reason for referring this plant to Platanus, although its resemblance to *P. Guillelmæ*, the principal nonlobate species, is not close in other respects. It is perhaps nearer to Lesquereux's figure of *Quercus platania* Heer (Tert. Fl., pl. xxi, fig. 1).

Grewiopsis viburnifolia, n. sp.

Plate XL, Fig. 2.—Burns's Ranch, Montana.

Leaf small (4.2cm. wide, 5.7cm. long), elliptical or somewhat rhombic, obtuse-pointed, cuneate, at base, sharply toothed to below the widest part; petiole nearly 2cm. long, curved below; nervation palmate, craspedodrome; midrib strong, straight; lateral primary nerves comparatively light, subopposite, rising from above the base of the blade at an angle of less than 30° and proceeding straight to near the margin, where they abruptly curve upward and terminate in the teeth, each provided with a very light basilar nerve and five or six parallel, equidistant tertiary nerves which curve and sometimes fork in passing to the margins; secondary nerves from the midrib five or six on each side, alternate, parallel to the lateral primaries and to one another, curving slightly upward and inward at their extremities, rarely forking close to the margin; nervilles distinct, mostly percurrent and perpendicular to the nerves joined, those near the margins often flexed in the middle and sending short veinlets to the sinuses or to subordinate teeth.

The character last described gives the nervation a slightly celastroid appearance. In the species last described the curved veins that skirt the margins and were regarded as branches of the secondaries are so faint that it may well be doubted whether they may not be more correctly regarded as nervilles such as we have here. In the present case all doubts are removed.

I had long supposed that this specimen, which, with the help of a counterpart, we are able to present in an almost perfect state, represented a form of Heer's *Viburnum Whymperi* (Fl. Foss. Arct., Vol. II, Pt. IV, Greenland, pl. xlvi, fig. 1*b*), which Prof. Lesquereux thinks may occur in Laramie strata (cf. Tert. Fl., p. 225, pl. xxxviii, fig. 7; pl. lxi, fig. 23), and which is closely related to *V. vitifolium* Sap. & Mar. (Saporta, Monde des Plantes, p. 216, fig. 36); but close inspection shows that it can scarcely belong to that genus. It is not impossible that it is a diminutive form of *Platanus Guillelmæ* Göpp. (cf. Tert. Fl. v. Schossnitz, pl. xi, figs. 1, 2); but this theory, too, I have been compelled to abandon in favor of regarding it as a Grewiopsis. Its nearest analogue would then be *G. Cleburni* Lx., already so often cited, which differs only slightly from *G. tremulæfolia* Sap., also frequently referred to in discussing the present group. For other analogues, see *Platanus Newberriana* Lx. (Cret. Fl., pl. ix, fig. 3), which may well be a Grewiopsis; *Populus attenuata* Al. Br. (Ludwig in Palæontographica, Vol. VIII, pl. lxvii, fig. 8); and *Alnus trinervia* Wat. (Pl. Foss. de Paris, pl. xxxiv, fig. 7).

Grewiopsis populifolia, n. sp.

Plate XL, Figs. 3-5.—Burns's Ranch, Montana; the first (Fig. 3) collected by Dr. White's party in 1882.

Leaves rather large (6 to 10cm. wide, 7 to 12cm. long), round elliptical, sinuate-dentate or blunt toothed to near the cuneate, more or less decurrent base, petioled; nervation palmate, craspedodrome; midrib straight or slightly curved, central, rather light, sometimes dichotomous at the summit; lateral primary nerves alternate, subtended by thin basilar ones, rising from above the base of the blade at an angle of 35° to 40° from the midrib, gently curving upward in passing to the margin far above the middle, giving off about six developed branches from the outer (lower) side which also curve slightly upward, often branch or fork and go to the margins; secondary nerves from the midrib about five on each side, chiefly alternate, parallel to the lateral primaries and to one another, branching, sometimes dichotomously, towards their extremities; nervilles rather faint, chiefly straight, percurrent and perpendicular to the nerves they join, those near the margins flexed in the middle and sending short veinlets to subordinate teeth.

These three impressions, all from the same bed, are perhaps sufficiently similar to be grouped together as one species, and it is possible that the form last described, which resembles the last of the present group (Fig. 5), may belong with it. They have a strong general resemblance to the larger Sézanne forms (*G. credneriæformis* Sap., *G. anisomera* Sap., and *G. tiliacea* Sap., Fl. Foss. de Séz., pl. xxxiii, xxxiv), but no very close analogy with the American forms of Grewiopsis, unless it be *G. tenuifolia* Lx. (Tert. Fl., pl. xl., fig. 14).

The presence in each case of basilar nerves, as well as the rounded teeth, recalled the character of Populus so forcibly that I was once of the opinion that the second and third forms (Figs. 4, 5) at least belonged to that genus. The last of these (Fig. 5) imitates states of *P. alba* L. of the living flora (cf. Saporta, Vég. Foss. de Meximieux, pl. xxiv, fig. δ) and the other (Fig. 4) may be compared to *P. nervosa elongata* Newberry (Illustr., pl. xiii, fig. 1), *P. Gemellarii* Mass. (Fl. Foss. del Senigal., pl. ix, fig. 13), or *P. sclerophylla* Sap. (Études, Ann. Sci. Nat., Bot., 5e Sér., Vol. IV, pl. vi, fig. 13A). This leaf also simulates certain fossils belonging to other genera, as, e. g., *Cissus parrotiæfolia* Lx. (Tert. Fl., pl. xl., fig. 15), *Protoficus crenulata* Sap. (Fl. Foss. de Séz., pl. xxvii, fig. 5), *Sterculia variabilis* Sap. (loc. cit., pl. xxxiii, fig. 6), *Pterospermites inæquifolius* Sap. (loc. cit., figs. 3–5), *P. spectabilis* Heer (Fl. Foss. Arct., Vol. VI, Abth. I, Pt. II, Nachtr. Foss. Fl. Grönld., pl. vi, fig. 10), and *Alnus trinervia* Wat. (Fl. Foss. de Paris, pl. xxxiv, fig. 7). The largest specimen (Fig. 3), however, is more on the type of Platanus and was at first regarded as such. Excepting that it is not at all lobed it has somewhat the character of *P. Raynoldsii* Newberry, as shown in his Fort Union specimen (Illustr., pl. xviii). It may also be compared to *P. Heerii* Lx. (Cret. and Tert. Fl., pl. iii, fig. 1), as may also the smaller leaf (Fig. 5). This last also very forcibly recalls certain arctic forms of *P. affinis* Lx. (Fl. Foss. Arct., Vol. VII, pl. lvii, figs. 2, 4, pl. lix, fig. 7), a species which Lesquereux now relegates to Cissites (Cret. and Tert. Fl., p. 67).

Notwithstanding these affinities this puzzling group may for the present be left where it is.

Grewiopsis ficifolia, n. sp.

Plate XLI, Figs. 1, 2.—Black Buttes Station, Wyoming.

Leaves thin, ovate or elliptical, 4cm. wide, 7 to 8cm. long, rounded at the summit, cuneate at base, denticulate or nearly entire, except at the apex; nervation pinnate, craspedo-camptodrome; midrib conspicuously zigzag or nearly straight; secondary nerves about six on each side, very irregular, erect, branched or forked, curving upward near the margin, and uniting with branches of the next higher, forming somewhat angular undulations from which nervelets either proceed to the margin or in turn curve before reaching it and form lesser arches, the outer arches sending veinlets to the margins; nervilles very prominent, irregular in direction, much bent or broken and variously combined and traversed by short branches, forming rather large, quadrate, rectangular, or trapeziform meshes, those near the margin heavier, geniculate in the middle, where they are joined to the border by a short veinlet.

The characters of the nervation above described, as well as the form of the leaf, are so similar to those of *G. Saportana* Lx. (Tert. Fl., p. 257, pl. l, figs. 10–12) that, when we remember that those specimens also came from Black Buttes Station, Wyoming, it seems very probable that they all belong to one and the same species of plant. The chief difference is in the ultimate nervation, which is much more prominent in our specimens, though this may have been due to the accident of preservation. This has many things in common with Ficus and may be compared to that of *F. asarifolia* Ett. (Fl. Tert. v. Bilin, I, Denksch. Wien. Acad., Vol. XXVI, pl. xxv, figs. 2, 3) and *F. tiliæfolia* Heer (loc. cit., fig. 4). It may also be seen in *Ficus Carica* L. and other living species. But this same peculiarity also occurs in the Laurineæ, the nervation of which closely resembles that of Ficus. The specimen from the same bed (Pl. XXV, Fig. 1) referred to *Daphnogene elegans* Wat. (*supra*, p. 51) is similar in some respects to the specimen Fig. 2, and the other specimen (Fig. 1), aside from its denticulate apex, very closely agrees with *Laurus Clementinæ* Pilar (Fl. Foss. Susedana, pl. vii, fig. 15). It is also interesting to compare the nervation of these leaves with the Cretaceous forms of Hedera (*H. platanoidea* Lx., Cret. and Tert. Fl., pl. iii, fig. 5, 6; *H. Schimperi* Lx., op. cit., pl. iv, fig. 7).

Grewiopsis paliurifolia, n. sp.

Plate XLI, Fig. 3.—Black Buttes Station, Wyoming.

Leaf of firm consistency, small (3.5cm. wide, 4.5cm. long), obovate, blunt-pointed, cuneate at base, coarsely and irregularly sinuate-dentate to below the middle, petioled; nervation pinnate, craspedodrome; midrib somewhat zigzag, central; secondary nerves few (four or five on a side), very erect (30°), irregular and curving upward and passing into the teeth, the lowest bearing four or five outer tertiaries, the rest simple or once branched, joined near their extremities by flexed cross-nerves (nervilles?), which supply from the angle at the middle short branchlets to intermediate teeth of the margin; nervilles faint, irregular and variable, sometimes forming quadrate or trapeziform meshes.

The size and to some extent the shape of this leaf are intermediate between *G. Cleburni* Lx. (Tert. Fl., pl. lxii, fig. 12) and *G. orbiculata* Sap. (Fl. Foss. de Séz., pl. xxxii, figs. 11, 12), but it is more narrowed at the base, so as to appear slightly obovate. The nervation is characteristic of the group.

Of all other outlying genera it approaches most closely to *Paliurus Colombi* Heer (cf. Fl. Foss. Arct., Vol. I, pl. xvii, fig. 2*d*), but it may also be compared to *Parrotia pristina* Heer (op. cit., Vol. IV, Pt. I, Spitzb., pl. xxi, fig. 5). Some of the smaller and doubtful forms of *Viburnum marginatum* Lx. (cf. Tert. Fl., pl. xxxviii, figs. 2, 3) resemble it, as does *V. dichotomum* Lx. (loc. cit., fig. 6), and, coming as they do from the same locality, these may really represent the same plant. Two of these specimens (loc. cit., figs. 3 and 6) show the characteristic nervation of Grewiopsis and may not belong to Viburnum. There is another specimen of *V. dichotomum* in the collection (No. 966) which is narrowed at the base and agrees still better with our plant. This specimen is remarkable for having a fragment of a bone of the famous dinosaur, *Agathaumas sylvestris* Cope, preserved on the reverse of the same stone, all these specimens having been collected in this saurian bed.

STERCULIACEÆ.

PTEROSPERMITES Heer.

The genus Pterospermum embraces fourteen species, which are all confined to tropical Asia. Baron von Ettingshausen referred to that genus certain leaf impressions found near Vienna, but Schimper prefers to refer these, as well as all the leaves and fruit resembling those of Pterospermum, to the allied extinct genus Pterospermites, founded by Heer on the fruits found in Switzerland. The greater part of the species known by their foliar organs have been found at the North and are described in Heer's Flora Fossilis Arctica. They are for the most part distinguished by the presence of light horizontal or somewhat descending basilar nerves, sometimes by a slightly peltate character, recalling the forms of Credneria, Protophyllum, and Aspidiophyllum. In *P. inæquifolius* Sap., however, and the other continental forms these characters are not manifest. In those which I would place here they are more or less apparent.

Pterospermites cordatus, n. sp.

Plate XLI, Fig. 4.—Seven Mile Creek, Montana; bed below the ironstone.

Leaf coriaceous, heart shaped, 8cm. wide, entire at the base; nervation pinnate, camptodrome; midrib large below, rapidly diminishing;

secondary nerves alternate, distant, two pairs rising together from the immediate base of the midrib, the lowest ones light and descending following the margins of the lobes, the other pair still somewhat descending and following the curvature of the margins at some distance curving inward at their extremities and uniting with branches of the next higher, giving off several tertiary nerves which arch and anastomose with one another, the rest stronger, ascending, branched, forming arches along the margin; nervilles simple, percurrent, straight or curved, traversing the very broad areas, joining the secondaries together and to the midrib, forming a sort of concentric network.

Only the lower portion of one side and a triangular segment 7cm. long of the central part of this leaf are preserved, but these parts are so distinctive that they furnish reliable data for restoring the leaf. The thin basilar nerves are not wholly unlike those of the arctic forms. The entire and deeply cordate base somewhat resembles that of *P. cordifolius* Heer, from the Greenland Cretaceous (Fl. Foss. Arct., Vol. VI, Abth. II, Kreidefl. v. Grönlnd., pl. xxvii, figs. 2, 3); it is also much like *P. spectabilis* Heer (loc. cit., Abth. I, Pt. III, Mioc. Fl. N. Can., pl. ii, fig. 1).

From a superficial point of view this form might be regarded as more nearly related to Apeibopsis, and may be compared to *A. discolor* Lx. (Tert. Fl., pl. xlvi, figs. 4, 6), also to *A. Doloesi* Heer (Fl. Tert. Helv., pl. cix, figs. 9–11). There is, however, some probability that the upper portion of the leaf was sinuate or even dentate margined.

Pterospermites Whitei, n. sp.

Plate XLI, Figs. 5, 6.—Burns's Ranch, Montana; collected by Dr. C. A. White in 1882.

Leaves thick and coriaceous, large (7 to 8cm. wide, 12cm. long), oblong, heart shaped, regularly sinuate or rounded dentate; petiole 3 to 4cm. long, straight, very thick, broadening downward, and grooved or fluted, the auricles of the leaf overlapping its summit from the under side; nervation pinnate, craspedo-camptodrome; midrib strong, rapidly diminishing, slightly inflated at the nodes, more or less curved or sinuous above; secondary nerves five or six on a side, lowest pair opposite, very thin and short, strictly basilar, the rest alternate, distant, horizontal or ascending, curving upward and forming arches, or more frequently giving off tertiary nerves from near their extremities, which pass directly into the rounded teeth of the margins; nervilles very prominent, passing into tertiary nerves, simple and percurrent or forked and variously intersected, those from the midrib curved, forming an open concentric web.

The two specimens here designated are the only ones that have as yet been discovered in the collection. The preliminary study which I gave them in the spring of 1883 sufficed to keep their characters fresh in my mind when a few months later I visited the spot where Dr. White had obtained them and searched diligently for additional representatives, but without success. I was at first disposed to regard them as belonging to Apeibopsis, and I compared them carefully with Heer's *A. Deloesi*, above referred to. In general form they agree with his figures quite well, but the nervation is here decidedly craspedodrome above and the margins are nowhere entire. The first specimen of the group next to be considered (Plate XLII, Fig. 1) was obtained at the same time and place, and, though much smaller, seems to belong to the same type of leaves, so much so that I was quite disposed to attach it rather to the present group. But this specimen shows several sharp teeth along its upper left border, and these probably continued increasingly to the summit. From the great similarity in the two forms I think it not improbable that either of these specimens, had the summits been preserved, might have shown a tendency there to the formation of a more decided dentation. On the reverse of the same stone that contains one of these specimens (Fig. 6) occurs the specimen that is described on page 82 as *Celastrus curvinervis* (Pl. XXXVI, Fig. 4), the direction of the nerves of which, as well as its size and shape, inclined me to hope that it represented the summit of another leaf of this species. The very different dentation, however, and also the markedly celastroid nervation decided me to separate them, but not without some misgivings, and I regard the question as still debatable whether a considerable number of the forms above described, both as celastraceous and as tiliaceous, may not be genetically related to these supposed sterculiaceous forms, and whether these three families of plants may not have some common phylogenetic stock (such as the Credneriaceæ, for example), to which they may yet all be traced. This subject is one of interest only second to that of the paleontologic history of Platanus, and singularly enough both these series of forms seem to point to Credneria as a possible converging point for them all.

Pterospermites minor, n. sp.

Plate XLII, Figs. 1-3.—Burns's Ranch, Montana; two of the specimens (Figs. 1 and 3) collected by Dr. White's party in 1882.

Leaves rather thick, oblong, 3 to 4cm. wide, 5 to 8cm. long, obliquely heart shaped, more or less serrate above, entire or merely undulate below, petioled; nervation pinnate, craspedo-camptodrome; midrib straight or sinuous; lowest secondary nerves light and basilar, nearly opposite, the rest more or less ascending, alternate, branched from the under side, curving upward near their extremities and either entering the teeth or joining the tertiaries as they pass to the margin; nervilles distinct, mostly percurrent, simple and curving, sometimes forking or interlacing.

The considerable differences in these three specimens seem scarcely to justify their separation. The first one (Fig. 1) has already been mentioned and forms a sort of connecting link between the last and the present group. The second (Fig. 2) is shorter and broader and the teeth come farther down. This was obtained by my own party in 1883, but at the same locality. The third occupies the same slab on which one of the preceding forms (Plate XLI, Fig. 6) occurs. It has more the aspect of a Grewiopsis and is toothed to near the base; the nervation is also faintly celastroid. It is smaller than either of the others. In none of the specimens of this group, or, indeed, of all that are here referred to this genus, is the absolute summit preserved. It is strongly hoped that such specimens may yet be found in the collection, as these specimens have only been roughly selected, without the close study and comparison that remain to be given to the material.

The first specimen (Fig. 1) resembles *Pterospermites spectabilis* Heer (Fl. Foss. Arct., Vol. VII, pl. lxxxi, fig. 2) and *Pterospermum suberifolium* Willd., from the East Indies (cf. Ettingshausen, Blattsk. d. Dicotyl., pl. xlix, fig. 9), and the second (Fig. 2) may be compared to *P. ferox* Ett. (Foss. Fl. v. Wien, pl. iv, fig. 4). The third (Fig. 3), it must be confessed, resembles the other two more than it does any Pterospermum or Pterospermites that I am able to compare it with. It has, however, as already remarked, much the appearance of a Grewiopsis, and does not differ very widely from *G. tremulæfolia* Sap. (Fl. Foss. de Sézanne, pl. xxxiii, fig. 8). It also approaches Lesquereux's *Viburnum dichotomum* (Tert. Fl., pl. xxxviii, fig. 6), and still more the unfigured specimen (No. 966, already mentioned). It is also very probably the same as *Phyllites cupanioides* Newberry (Illustr., pl. xx, fig. 5), while the *P. venosus* Newberry (loc. cit., pl. xxiv, fig. 4) must probably also fall into this group.

For outlying analogues as to form and other superficial characters we may compare the specimen, Fig. 1, with *Ficus Colloti* Sap. (Monde des Plantes, p. 317, fig. 1); the specimen, Fig. 2, with *Quercus negundoides* Lx. (Tert. Fl., pl. xxi, fig. 2) and with *Rhus Evansii* Lx. (loc. cit., pl. lviii, fig. 5); and the specimen, Fig. 3, with *Ficus elegans* Web. (Palæontogr., Vol. II, pl. xix, fig. 7*a*).

CREDNERIACEÆ.

CREDNERIA Zenk.

It is unnecessary here to renew the discussion which has gone on ever since the first description of leaves of this genus by Zenker, in 1833 (Beiträge zur Naturgeschichte der Urwelt, Jena, 1833, p. 15), relative to their proper systematic position. From what has been said on the preceding page there would seem to be as yet no reason to suppose that the time has come when we can make any safe advance upon the suggestion of M. Schimper (Pal. Vég., Vol. III, p. 59) that they are more or less related to Pterospermites and Sterculia.

? **Credneria daturæfolia, n. sp.**

Plate XLII, Fig. 4; Plates XLIII, XLIV, and XLV.—Seven Mile Creek, Montana; white marl bed. Plate XLVI, Fig. 1, represents a leaf of *Datura Stramonium* L., introduced to illustrate the similarity of its nervation to that of the fossil leaves.

Leaves large (8 to 15cm. in diameter), thick, and coriaceous, wrinkled as if by contraction of the substance within the epidermis, roundish or ovate in outline, more or less inequilateral, provided around the border with large, unequally distant, more or less curved, sharp, spinulose teeth, often produced into long (3cm.) filliform appendages, abruptly sharp-pointed at the apex, sometimes cordate or horizontal, but usually narrowed, cuneate, or even decurrent-alate at the base; petiole nearly as long as the blade, sometimes much longer, very thick, grooved below; nervation pinnate, craspedo-camptodrome; midrib very large below, rapidly diminishing upward, somewhat zigzag and swollen at the nodes, more or less one side of the middle, often far to one side and much curved toward the smaller side; secondary nerves very variable, alternate, usually well developed, a light basilar pair sometimes present, the rest usually more or less curved upward and passing into the spinous teeth, the lower giving off strong tertiaries which generally enter the teeth, but sometimes curve and form arches along the wide entire intervals between the teeth, the upper usually simple, often curving inward near the apex of the leaf, becoming acrodrome; nervilles mostly percurrent, curved, bent or wavy, sometimes forked or broken and appearing to end blind.

A few fragments of this fossil accompanied Dr. White's collection of 1882, and my attention was strongly attracted to the peculiar indentation that some of them presented. It reminded me more of the spinulose teeth of the leaves of some species of Ilex than of those of any other leaf. The peculiar wrinkled appearance of the specimens also interested me, since it sometimes gave the impression of a very thin, rather than a thick, leathery, leaf. It was, therefore, with especial satisfaction that I found, on visiting the spot the next year under the guidance of Professor Foster, who collected the first specimens, that much better material was to be obtained. The figures represent ten of the best specimens collected by us, but a large number remain to be figured, some of which have been drawn and are before me for comparison. These furnish considerable addition to our knowledge of the plant. Its true character is masked by several circumstances. The fine wrinkles and numerous blemishes on the rock obscure the nervation so that this does not strike the eye until carefully worked out by the draftsman and shown in the drawings freed from those defects. The clay in which the leaves were embedded was filled with a great quantity of other vegetable matter that must have floated in the overlying waters: stems of various kinds, short sticks, and frequently long filiform objects that very closely imitate veins of leaves and cannot be distinguished from the spinous processes at the ends of some of the teeth. That such processes occur there is no doubt, and one is tempted to believe that the detached filaments covering and projecting from other parts of the leaves are such appendages which belonged to nearly all the teeth and had been broken off. This view is strengthened by the fact that at points in the same bed where these leaves did not occur such loose filaments were absent.

In speculating as to the true relationship of these remarkable leaf prints and in concluding to refer them provisionally to Credneria, I am far from claiming that this disposition satisfies all the conditions of the problem and regard it as only somewhat better than calling them Phyllites. They lack almost entirely the peculiar horizontal basilar nerves, but these are not considered essential to the genus (see *C. integerrima* Zenk., Stiehler, in Palæontogr., Vol. V, pl. ix, fig. 2; *C. triacuminata* Hampe, Hos. & Mck., in Palæontogr., Vol. XXVI, pl. xxxix, fig. 156; *C. macrophylla* Heer, Kreidefl. v. Moletein, pl. iv). They are also wanting in Ettingshausenia, a genus allied to Credneria and perhaps its immediate ancestor. If we neglect this character, i. e., the lower portion of the leaf, and compare our form, Fig. 1 of Plate XLIII, with Stiehler's figure of *C. triacuminata* Hampe (Palæontogr., Vol. V, pl. x, fig. 9), we cannot but be struck with the similarity. Of course, the number of teeth in our plants is greater, teeth occurring in this same specimen to near the base, but in *C. subserrata* Hampe (loc. cit., pl. xi, fig. 10) and in *C. denticulata* Zenk. (loc. cit., pl. ix, fig. 4, and Zenker, Naturgeschichte d. Urw., pl. ii, fig. E) we have teeth at the summit not unlike those of our Figs. 2 and 3 of Plate XLIV. The leaves of most crednerias are more or less palmately triplinerved, but this is not the case with two species figured by Heer, the one from Moletein above referred to and his *C. integerrima* Zenk , from Igdlokunguak (Fl. Foss. Arct., Vol. VI, Abth. II, Kreidefl. v. Grönld., pl. xxxvi, fig. 4). In the Moletein and Greenland specimens the lower lateral nerves are disposed in very much the same general way as in ours. The smaller leaves toothed above (Pl. XLIV, Figs. 2, 3), of which more occur in the collection, resemble Ettingshausenia much more closely than they do Credneria, and may be compared with *E. cuneifolia* (Bronn) Stiehl. (in Bronn, Lethæa Geognostica, Atlas, pl. xxviii, fig. 11) and *E. tremulæfolia* (Brongn.) Stiehl. (Brongniart, Tableau des gen., p. 111; Schimper, Pal. Vég., Vol. III, p. 62, Atlas, pl. xcvi, fig. 28). The only serious objection to referring them to that genus seems to be the more simple (pinnate) nervation. But transition forms occur, as seen in Fig. 5 of the same plate and Fig. 1 of Plate LVII, which forbid the separation of any of the Yellowstone specimens.

If we look entirely outside of this group for analogues of certain characters possessed by these impressions we shall find many, but it will be difficult to find any considerable number of them combined in one species or genus. If we take the teeth, which are perhaps the most interesting feature and the one most difficult to reconcile with the

Credneria theory, we find something like them not only in our *Ilex opaca* L., but in *I. odora* Sieb. and other living species, and still more pronounced in the fossil species, *I. horrida* Sap. (Études, Ann. Sci. Nat., Bot., 5e Sér., Vol. IV, pl. xi, fig. 9, and Vol. IX, pl. vi, fig. 3). Much the same character is also seen in forms of Hakea, figured by Saporta in the Études (*H. attenuata* R. Br., *H. mahoniæformis* Sap., op. cit., 4e Sér., Vol. XIX, pl. vii, figs. 6, 7*a*). Berberis presents other analogues, but perhaps the nearest approach is to be seen in forms of Quercus belonging to the biennial fruiting section, as, e. g., *Q. coccinea* Wang. Here there are fine spinulose filaments which are somewhat soft, at least not spiny, projecting to some distance beyond the termination of the proper lobes or teeth. In *Q. armata* Sap. (op. cit., 5e Sér., Vol. IV, pl. vi, fig. 8), we probably see an oak of this group. In *Q. grandidentata* Ung. (in Web., Palæontogr., Vol. II, pl. xviii, fig. 12) and *Q. Scillana* Gaud. (Contr., II, pl. vi, fig. 3) we see further examples of sharply toothed oaks somewhat similar to our plant.

The general form of these leaves is somewhat similar to that of some species of Platanus, such as lack the decidedly palmate nervation, as, for example, *P. Œynhausiana* Göpp. (Tert. Fl. v. Schossnitz, pl. x, figs. 1–4), and the manner in which the nerves enter the curved teeth is often imitated by *P. orientalis* L. *Cissites Heerii* Lx. (Cret. and Tert. Fl., pl. v, fig. 2) from the Dakota group is very similar to an Ettingshausenia (see figures above cited) and is vividly recalled by our smaller specimens (Pl. XLIV, Figs. 2, 3) with teeth across the summit. This comparison may prove valuable both for the Cretaceous and the Fort Union plants. Pterospermum is usually entire margined, but in *P. suberifolium* Willd. (Ett., Blattsk. Dicotyl., pl. xlix, fig. 9) and in the undetermined species figured by its side (loc. cit., fig. 6) we see a tendency to lobation above that recalls Credneria and may point to some ancestor with these characters.

Without enumerating the many other forms which have presented themselves in my somewhat exhaustive attempts to match these leaves, I will conclude by referring to an unexpected analogue, the discovery of which is due to Mr. Everett Hayden, who has so successfully delineated all these specimens, in the common Jamestown-weed (*Datura Stramonium* L.). Mr. Hayden's familiarity with every detail of the nervation unconsciously led him to compare every leaf seen by him anywhere with those upon which he had bestowed so much attention, and when this came before him he was much struck by the resemblance it bears to these enigmatic fossils. He conferred with me on the subject, and I requested him to draw a leaf of the Datura to accompany his drawings of the fossils. That figure (Pl. XLVI, Fig. 1) shows how far the two forms will bear comparison and also the points of divergence. I deemed the resemblance sufficiently close to be commemorated by the specific name adopted, while at the same time I cannot say I have the least idea that it has any phylogenetic significance. The detailed nervation (nervilles) is very unlike the fossil plant, the general form more elongate, though this varies in both the fossil and the living plants, but the general character of the secondary nerves and that of the dentation are remarkably similar in the two forms.

MENISPERMACEÆ.

COCCULUS DC.

Two of the ten species of Cocculus known to the present flora of the globe are indigenous to North America, one of which, *C. Carolinus* DC., comes as far north as Virginia. The rest belong to warmer parts of the Old World (Asia and Africa). Although this family is so unquestionably represented in a fossil state and belongs to the earliest dicotyledonous forms, it has been necessary to refer these archetypes to Menispermum or a closely allied and now extinct genus, Menispermites, or else to the problematical genus Macclintockia Heer, which its author first placed in the Proteaceæ; then, following Saporta, in the Menispermaceæ; but still later, changing his opinion again with the French author, in the Urticaceæ. If any of these types can be regarded as related to Cocculus it is this last, but its elongated form assimilates it to the Old World species, especially to *C. laurifolius* DC., and not to *C. Carolinus*.

If we except the very imperfect and questionable fragments, *C. Kanii* Sap. and *C. Dumonti* Sap., from the Heersian marls of Gelinden (Saporta, Essai, pp. 63, 65, pl. x, figs. 1, 4), no fossil Cocculus has been discovered below the Pliocene, unless we accept the view of Saporta (Vég. Foss. de Meximieux, p. 265) that many of the arctic forms referred by Heer to Populus really belong to this genus.

Cocculus Haydenianus, n. sp.

Plate XLVII, Figs. 1–4; Plate XLVIII, Fig. 1.—Burns's Ranch, Montana (Plate XLVII, Figs. 1–3). Iron Bluff, Montana (Plate XLVII, Fig. 4; Plate XLVIII, Fig. 1); one of the specimens (Plate XLVII, Fig. 4) collected by Dr. White's party in 1882. Named in honor of Mr. Everett Hayden, who has taken a special interest in this plant.

Leaves large (7 to 20cm. wide), broadly ovate or orbicular, mucronate, deeply heart shaped, entire or faintly undulate, slightly contracted above the middle, occasionally with a large rounded notch or sinus on one side near the apex or near the base or both, bounded all round by a thick marginal nerve or hem (paryphodrome); petiole long and very thick and succulent; nervation palmate or actinodrome, craspedo-camptodrome, brochiodrome; primary nerves seven to nine, rising from nearly a common point at the summit of the petiole, radiating in all directions at angles of from 30° to 50°, branching in passing out towards the borders, curving and anastomosing and forming two or three series of loops or festoons bounded by right lines, from the outer of which short straight veinlets pass directly to the bounding nerve, each loop occupied by a somewhat radiately or concentrically arranged network of quadrate or trapeziform meshes.

The highly anomalous character of these impressions had enlisted my special interest when, in the spring of 1883, with the assistance of Mr. Everett Hayden, I made a preliminary study of the few fragments contained in Dr. White's collection of the preceding season. The nearest approach that we were able to make on that occasion was found in numerous species of Aristolochia[1] and Asarum. So vividly had the form impressed itself upon the mind of Mr. Hayden that later in the season, while I was in the Lower Yellowstone region collecting better material from the same beds, I received a letter from him, then operating with Mr. Diller's party in the Cascade Range, inclosing leaves of an Asarum (*A. Hartwegi* Watson) which he had seen growing on the mountains and thought to resemble closely the fossil leaves, as in fact they do. But after returning from that season's work with rich supplies of excellent material it soon became apparent, upon a renewal of the study of this form, that the Aristolochiaceæ did not furnish the required solution of the problem, and it was not until I had met with Saporta's figures of *Cocculus latifolius* Sap. & Mar. (Vég. Foss. de Meximieux, pl. xxxi, figs. 4–7; pl. xxxii, fig. 1) that I felt satisfied that I was at last in the way of such a solution. In these I found great solace, and the more I studied them and the genus the more satisfied I felt that the Laramie plant not only belongs to Cocculus, but to a species very closely related both to the Pliocene form and also to the living American species, *C. Carolinus* DC. In some respects our fossil forms agree better with the living plant than with that of Meximieux. For example, the marginal nerve is clearly visible in the former. This is in both cases a true hem (Saumläufer of Heer), such as we see in Callistemon and Melaleuca, and not merely a nerve running close to and parallel to the margin, as seen in many species of Eucalyptus and in *Myrica Torreyi* Lx. (Tert. Fl., p. 124, pl. xvi, figs. 4, 8), which should be distinguished by a different name. I propose to designate the truly hemming nervation by the term *paryphodrome.* Into this hem, in both the American fossil and living forms, run the short veinlets that go off from the outer loops or arches. This latter peculiarity is observable in some species of Cinnamomum, and we met with it in our *Ficus speciosissima* (*supra*, p. 39, Pl. XXI, Fig. 3), though these cases do not seem to show the bounding nerve. The presence of a distinct mucro is also a common feature of both these plants. In form, however, our fossil is nearer the Pliocene species, and the obtuse lobe seen in one of Saporta's specimens (loc. cit., pl. xxxi, fig. 5) is almost exactly reproduced in our specimen (Plate XLVII, Fig. 3).

[1] It seems to me very probable that Heer's Puilasok specimen of *Aristolochia borealis* (Fl. Foss. Arct., Vol. VII, pl. cvii, fig. 13) may represent a Cocculus very similar to ours, if not the same species.

In one of the unfigured specimens which shows scarcely anything else there occurs a still incomplete petiole over 6cm. long and of about the thickness of that of specimen Fig. 4. The petioles have the appearance of being succulent, and I can scarcely divest myself of the idea that the plant was semi-aquatic or grew in marshy districts, although this is not the habit of the living species of the genus.

This reference of these impressions to Cocculus furnishes so many evidences of being the correct one and satisfies the conditions of the question so much better than any of the other hypotheses that have at different times been acted upon that I scarcely deem it worth the reader's while to review the steps in the researches that I have made or to examine the many other forms that have been found to present some one and some another of the peculiarities that characterize this new and interesting addition to the Laramie flora.

MAGNOLIACEÆ.

LIRIODENDRON L.

Only a single species of Liriodendron, the common tulip tree of North America, remains in the present flora as the descendant of the dozen or more that have been described in the fossil state, running back to the earliest date from which we have any consistent record of the existence of dicotyledonous plants.

Liriodendron Laramiense, n. sp.

Plate XLVIII, Fig. 2.—Point of Rocks Station, Wyoming; gray sandstone bed north of station.

Leaf nearly 9cm. broad, horizontal at base, the sides vertical, entire, petioled; nervation pinnate, camptodrome, brochiodrome; midrib straight, central, rapidly diminishing upward; secondary nerves strong, straight, issuing at an angle of 60°, the lower branching dichotomously, the rest forking at some distance from the margins, forming one or two series of loops which furnish camptodrome nerves of the third and fourth order that form small areolæ close to the margin; nervilles traversing the larger areas percurrent, and straight or curved, or forking and interlacing in the middle, those within the festoons resolved into a fine network of regular quadrate or rectangular meshes.

The absence of all the upper part and much of one side of this leaf renders it impossible to say whether it possessed the characteristic lobes and truncate apex of the genus, but enough is preserved to show that if lobed the lobes are much higher up than is usual with the living species. In all the parts that are present the form and nervation are so clear and so characteristic of the genus that there seems little doubt as to its affinity. It resembles *L. Tulipifera* L. more than any of the fossil species, nearly all of which are smaller. Next after this species it should be compared to *L. Proccacinii* Mass., which has the lobes rather high. The analogy to *Populus Stygia* Heer was mentioned in the Sixth Annual Report of the United States Geological Survey (p. 534), but the more I examine this the more I incline to regard it as accidental and superficial.

MAGNOLIA L.

This genus embraces about fourteen species, more than half of which are natives of North America, the rest occurring in eastern Asia and Japan. It is therefore just such a genus as we should expect to be represented in North American strata. We have, in fact, six Laramie species of the thirty or forty already known in the fossil state. There are seven or eight Cretaceous species, ranging from the Cenomanian to the Senonian, as many Eocene, and the remainder are Miocene. The specimens to be described are from the same bed as the one last considered. I have not succeeded in relegating them to any species thus far made known.

Magnolia pulchra, n. sp.

Plate XLVIII, Figs. 3, 4.—Point of Rocks Station, Wyoming; gray sandstone bed north of station.

Leaves broad (7 to 8cm. wide, 10 to 12cm. long), elliptical or somewhat obovate, entire, obtuse or somewhat acute short-pointed; nervation pinnate, camptodrome, somewhat brochiodrome; midrib strong throughout, nearly straight; secondary nerves proceeding from it at an angle of 50°, eight or nine on a side, subopposite or alternate, dichotomously branching once or twice, the branches anastomosing and forming arches or loops from which faint veinlets proceed towards the margin, usually appearing to lose themselves in the parenchyma; nervilles very faint, forking and joining in the middle of the areas, forming elongated cuneate areolæ.

The characters as above described are those of Magnolia. The specimen, Fig. 3, shows, with the help of a counterpart, nearly a complete leaf, except the base, which had begun rapidly to narrow. The outline is clear, black upon a gray ground, but the nervation is obscured by the presence of white blotches or dots of some material that had worked its way into the crevice made by the presence of the leaf. The other specimen is not thus affected, and shows that the nervation was somewhat hyphodrome in character, tending to prove that the leaf was rather thick, which would not otherwise appear from the specimens. The point of this latter specimen, which shows only the upper part of a smaller leaf, is quite obtuse, that of the other being acute; this, however, does not seem to constitute a specific difference.

The form seems to be nearly related to *M. Capellinii* Heer (Phyll. Crét. du Néb., pl. iii, figs. 5, 6), which, though never abruptly contracted at the summit, is sometimes obtuse, sometimes acute (compare Fl. Foss. Arct., Vol. III, Pt. II, Kreidefl., pl. xxxiii, fig. 4, with op. cit., Vol. VI, Abth. II, Kreidefl. v. Grönland, pl. xlv, fig. 1). They also have much the same shape and character as the smaller Cretaceous species, *M. obovata* Newberry (Illustr., pl. ii, fig. 2).

GAMOPETALÆ.

EBENACEÆ.

DIOSPYROS L.

A very large genus of universal distribution, though chiefly tropical and subtropical. Of the more than one hundred and fifty species only two are North American. One of these, *D. Virginiana* L., the common Persimmon, is found throughout the Southern States and as far north as Southern New York, Ohio, and Iowa. The other, *D. Texana* Scheele, the Mexican Persimmon, is chiefly confined to Mexico and Texas.

The evidence is convincing that the genus played a prominent rôle in the floras of past geologic epochs, especially in the Tertiary, remains of its leaves, fruits, and characteristic calyx having been found in abundance. The genus ranges from the Arctic Cenomanian and American Dakota group to the upper Miocene and perhaps into the Pliocene. A large number of the species are Arctic Miocene and four are Alaskan. Of the strictly American species four are from the Dakota group, four from the Laramie group, and two from the Green River group. Two are from Vancouver Island, one from the Cretaceous of British America, and four from the Miocene of Alaska.

Diospyros brachysepala Al. Br.

DIOSPYROS BRACHYSEPALA Al. Br., Tert. Fl. v. Œningen, N. Jahrb. f. Min., 1845, p. 170. Unger, Blatterabdr. v. Swoszowice, Abh. Haidinger, III, Abth. I, p. 125, pl. xiv, fig. 15; Gen. et Spec. Pl. Foss., p. 435. Heer, Fl. Tert. Helv., Vol. III, pp. 11, 191, pl. cii, figs. 1–14; Fl. Foss. Arct., Vol. I, p. 117, pl. xv, figs. 10–12; pl. xvii, figs. 5*h*, 5*i*; Vol. II, Pt. IV (Foss. Fl. N. Greenld.), p. 475, pl. lv, fig. 8; Vol. V, Pt. II (Foss. Fl. Sibir.), p. 41, pl. xi, figs. 3–6*a*; Vol. VI, Abth. I, Pt. II (Nachtr. z. Foss. Fl. Grönld.), p. 13, pl. iii, figs. 15, 16; Vol. VII, p. 109, pl. lxxix, figs. 1–8; pl. xcii, fig. 10; pl. xciv, fig. 6; Mioc. Balt. Fl., p. 84, pl. xxvii, figs. 1–6; pl. xxviii, fig. 1; Braunkohlenpfl. v. Bornstädt, p. 16, pl. iii, figs. 7, 8; Urw. der Schweiz, pp. 354, 355, fig. 215. Sismonda, Pal. Terr. Tert. du Piém., p. 443, pl. xi, fig. 6; pl. xvi, fig. 5; pl. xix, fig. 3. Ettingshausen, Foss. Fl. v. Bilin, II (Denkschr. Wien. Acad., Vol. XXVIII), p. 232, pl. xxxviii, fig. 28; pl. xxxix, fig. 1; Foss. Fl. d. Wetterau (Sitzb. Wien. Acad., Vol. LVII, Abth. I), p. 865, pl. iii, fig. 7. Engelhardt, Fl. d. Braunk. Sachsen (Preisschr. Jabl. Ges., 1870, XVI), p. 21, pl. v, figs. 8–10; Tert. Fl. v. Göhren (Nova Acta L.-C. Acad., Vol. XXXVI), p. 28, pl. (v) xii, fig. 7; Tert. Pfl. Leitmeritz (op. cit., Vol. XXXVIII), p. 362, pl. xviii, figs. 1, 2. Lesquereux, Tert. Fl., p. 232, pl. xl, figs. 7–10; pl. lxiii, fig. 6; Cret. and Tert. Fl., p. 174, pl. xxxiv, figs. 1, 2. Schimper, Pal. Vég., Vol. II, p. 949. Geyler, Foss. Pfl. a. d. Obertert. Ablag. Sicilien's, p. 326, pl. (i) lxviii, figs. 12, 13. Zwanziger, Mioc. Fl. v. Liescha, p. 66, pl. xxv, figs. 1, 2. Pilar, Fl. Foss. Susedana, p. 82, pl. xiv, fig. 1.

Plate XLIX, Figs. 1, 2.—Burns's Ranch, Montana (Fig. 1). Seven Mile Creek, Montana (Fig. 2).

The nearly perpendicular nervilles and the slightly decurrent base are about the only objections to this reference. The first of these may be seen in many of the figures that have been assigned to this species, while the latter is clearly visible in two of Heer's figures (Fl. Tert. Helv., pl. cii, figs. 4, 7). I therefore refer these two impressions to that widespread and polymorphous species with considerable confidence.

Diospyros ficoidea Lx.

DIOSPYROS ? FICOIDEA LX., Bulletin U. S. Geol. Surv. Terr., Vol. I, p. 387; Ann. Rep. U. S. Geol. Surv. Terr., 1874, p. 314; Tert. Fl., p. 231, pl. xl, figs. 5, 5*a*, 6.

Plate XLIX, Figs. 3, 4.—Burns's Ranch, Montana (Fig. 3). Clear Creek, Montana (Fig 4).

The close correspondence between these specimens and those from Black Buttes collected by Mr. F. B. Meek leaves little room for doubting their specific identity. There is one unfigured specimen (No. 336 Nat. Mus., Lesquereux's original No. 862) which shows the base and petiole. It is smaller than our specimen, Fig. 4, but agrees substantially with it in the form of the base. The petiole is here shown to be 1.5cm. long and somewhat curved. This specimen should be figured. The Clear Creek specimen occurs in immediate association with the abundant Viburnum leaves. In the Burns's Ranch specimen we have the oblique nervilles, nearly perpendicular to the midrib, slightly curving first upward and then downward, in strict imitation of those of *D. Virginiana* L. The ultimate nervation in both specimens is very similar to that figured by Lesquereux from the Black Buttes specimens (loc. cit., fig. 5*a*).

? Diospyros obtusata, n. sp.

Plate XLIX, Fig. 5.—Seven Mile Creek, Montana; bed below the ironstone.

Leaf thick, coriaceous, ovate, 4.2cm. wide, 7cm. long, entire, rounded at the base, obliquely obtuse at the summit; nervation pinnate, camptodrome; midrib strong, nearly straight, central; secondary nerves eight on a side, inequidistant, issuing at an angle of 40°, branching above, curving upward and forming single or double rows of arches, lower ones opposite, lowest pair light basilar, simple, third and fourth pair strongest, uppermost curving inward; nervilles rather indistinct, simple, straight or slightly curved, percurrent, somewhat oblique to the nerves they join.

This specimen seems to represent a hitherto undescribed species of Diospyros. Its nearest affinities are perhaps with *D. varians* Sap. (cf. Études, Ann. Sci. Nat., Bot., 5e Sér., Vol. III, pl. vi, fig. 4A), which, however, is usually much more elongated and often acute at the base. In general form and principal nervation it approaches the *Phyllites ovatus* of Rossmässler (Verstein., pl. ii, fig. 9) more closely than any other figure with which I have been able to compare it, but in that the secondary nerves are all alternate and the finer details are obscure, especially around the margin. That figure may represent a Diospyros, though no author has, to my knowledge, ever thus referred it.

Our form is not unlike certain leaflets of the Leguminosæ and may be compared to *Dalbergia grandifolia* Sap. (op. cit., Vol. IV, pl. xiii, fig. 13) or to *Leptolobium tomentosum* Pohl (Ettingshausen, Nervation d. Papilionaceen, Sitzb. Wien. Acad., Vol. XII, pl. xviii, figs. 3, 4).

CAPRIFOLIACEÆ.

VIBURNUM L.

The important rôle which this genus has played in the fossil flora of the globe is the more remarkable as it is always assigned to the gamopetalous division of dicotyledonous plants, otherwise so rare in the fossil state. But this need not perhaps surprise us when we remember that so far as known all the species of Viburnum are shrubby and that they grow chiefly in low ground along the banks of streams and bodies of water, where their leaves have an excellent opportunity to be embedded in the mud of river deltas and inland seas. The classification according to the presence or absence of petals or their freedom or cohesion is no longer believed to have any great phylogenetic value, and the chief reason for believing that the Gamopetalæ were the last to appear is the fact that in the present flora a so much larger proportion of them are herbaceous than of the other divisions of Dicotyledons. This fact, too, supposing it to have always been so, would account for the small number found fossil, since it is very difficult for herbs to be preserved. But it is not believed that it has always been so, for nearly all the fossil floras bear evidence of a warmer climate, and the effect of a warm climate is to convert the herbs into shrubs and trees. Again, this condition of the floral envelopes has manifestly been subject to alteration through geologic periods, and it by no means follows that because a form is now gamopetalous or polypetalous it was so in Miocene or Eocene time, and the discovery of the flowers themselves in sufficiently perfect condition to test this question is an event that rarely, one may almost say never, happens.

That Viburnum is a very ancient type there is much evidence. It now embraces about eighty species and is distributed throughout all the temperate and subtemperate regions of the northern hemisphere. It is also found on the Andes. Fourteen species are indigenous to North America, nearly all of which are abundant. About forty species are known in the fossil state, among which the two now living species, *V. Tinus* L. and *V. pubescens* Pursh, are thought to be identified. They range from the upper Cretaceous of Greenland (Patoot) and Westphalia to the Pliocene of Meximieux and the Canary Islands. Thus far none have been reported from the Cenomanian or Dakota group and none from the Green River group. Aside from the Miocene, which, ot course, furnishes a great number, the Laramie group seems to be the richest ot all the formations in plants of this type, no less than fifteen species having been already reported from its several beds in the west. Seven of these come from the upper or Fort Union deposits, and it is from these latter that all the additions that I have to make are also derived. In the several beds on the Lower Yellowstone visited by Dr. White in 1882 and by myself in 1883, and notably those of Clear Creek and Cracker Box Creek on the left bank of the river, there was found a vast profusion of Viburnum leaves and numerous seeds referable with great certainty to that genus. The study of these impressions, which was still unfinished when my paper for the Sixth Annual Report went to press, had then revealed the presence in those collections of much greater variety in these forms than I had believed when engaged in collecting them, and I was obliged to regard as distinct species no less than fourteen of the forms referable to that genus, ten of which must be provisionally treated as new to science.

Viburnum tilioides.

TILIA ANTIQUA Newberry, Later Extinct Floras, pp. 30, 52; Illustr., pl. xvi, figs. 1, 2. Lesquereux, Ann. Rep. U. S. Geol. Surv. Terr., 1876, p. 514; Cret. and Tert. Fl., p. 233. Schimper, Pal. Vég., Vol. III, p. 115.

Plate L, Figs. 1-3; Plate LI, Figs. 1-8; Plate LII, Figs. 1, 2.—Clear Creek, Montana; one of the specimens (Plate LII, Fig. 2) collected by Dr. White's party in 1882.

Leaves thickish, ovate or elliptical, 6 to 12cm. wide, 7 to 14cm. long, heart shaped, short-pointed, rather coarsely and regularly simply toothed to very near the base; nervation pinnate, craspedodrome, very prominent, forming deep furrows or ridges upon the stone; midrib nearly straight, generally central, but sometimes far to one side; secondary nerves about nine on each side, the lower approximate or wedging together near the base of the leaf, sometimes nearly opposite and horizontal, the rest more distant and ascending, all but the upper branching somewhat sympodially from the under side, the upper strictly once or twice forked near their extremities; tertiary nerves usually entering the teeth; nervilles very distinct, usually simple, straight, approximate, parallel, percurrent, traversing the areas at right angles to the nerves, sometimes curved or wavy, rarely forked or united, branches from the outer ones sometimes entering the sinuses of the margin; drupes 2 to 2.5cm. long, 1cm. thick, short pediceled; putamen deeply 2 to 3 grooved longitudinally.

The eight leaf specimens here brought together differ considerably from one another, more perhaps than would be found to be the case with as many leaves of the same species of a living plant, even though taken at random from different trees and from different parts of the trees. Yet any one who has made a practice of comparing leaves in this way from known species is prepared to expect a wide variation in almost any class of plants. At the same time, after a renewed study of these forms, I am ready to eliminate the specimens, Figs. 1, 2, Plate LI, and Fig. 1, Plate LII, and refer them to other species. The rest, notwithstanding the variety observed, seem with scarcely any doubt to belong to one and the same species.

The above description, as any one may see, will include all the characters of *Tilia antiqua* Newberry, and there is no assignable difference between the only specimen I have seen of that species, which is one of those figured in the Illustrations of his Later Extinct Floras (pl. xvi, fig. 2), and several of those collected by myself (cf. Figs. 1, 3, Pl. L; Fig. 3, Pl. LI). In two of the specimens (Fig. 2, Pl. L, and Fig. 2, Pl. LII) the only noteworthy difference is that these are quite obviously inequilateral; but, as Dr. Newberry states that his plant is "often somewhat unsymmetrical," it may be inferred that he has specimens of a similar character.

The question of the identity of the plants described under these two names may then be regarded as settled, and it remains to justify the reference of them all to Viburnum rather than to Tilia. Messrs. Bentham and Hooker, in their Genera Plantarum, admit only eight species of Tilia as known to the living flora, although ten are described in De Candolle's Prodromus. I have carefully examined specimens referred by their labels to sixteen different species, several of them, of course, merely synonyms, but differing somewhat, and I believe these to embrace nearly all the forms known. I find them all to agree in possessing a strictly palmate nervation. The bundles of the petiole divide at the very base of the blade into a number (five to seven), often an even number, of primary nerves, one of which is always somewhat larger than the rest, but not analogous to the midrib of a penninerved leaf. The first true secondary nerves rise from the midrib, usually nearly opposite, at a considerable distance above the common origin of the lateral primaries. In this important respect the Fort Union leaves do not agree with Tilia. They are strictly penninerved leaves. The lowest secondaries arise from above the base of the blade. They do not all arise from precisely the same point, but are somewhat alternate. The next succeeding secondary nerves are not distant from these, but are nearer to them than to the ones above them. These are not characters of Tilia. All other authors have respected these facts, and of the great number of alleged fossil linden leaves which have been figured I find only one or two cases in which they have been disregarded, as, for example, Ettingshausen's *T. Milleri* (Tert. Fl. Steiermark's, Sitzb. Wien. Acad., Vol. LX, Abth. I, pl. v, fig. 2) and one of Heer's Spitzbergen specimens of *T. Malmgreni* (Fl. Foss. Arct., Vol. IV, Pt. I, Spitzb., pl. xix, fig. 18), and these I would incline to exclude from the genus.

When, however, we turn to Viburnum and look in the section Lantana we find nearly all these conditions satisfied. We find ovate, dentate penninerved leaves, the lower nerves more approximate than the upper, and somewhat wedging in together at the base, branching below and becoming dichotomous above. And if we are not satisfied with the size and amplitude of *V. Lantana* L., which, however, sometimes has leaves of considerable size (cf. Ettingshausen, Blattsk. d. Dicotyl., pl. xx, fig. 12), we have only to turn to our indigenous *V. lantanoides* Michx., the hobble-bush or wayfaring-bush, which inhabits the moist woods of the northern parts of the United States and of Canada and the mountains of more southern districts, and we here find a leaf having almost exactly the size, shape, and nervation of the fossils figured by Dr. Newberry, the resemblance being nearer to these than to any of the specimens collected by myself. The teeth only are a little less prominent, those of *V. Lantana* approaching more nearly those of the fossil form. With Dr. Newberry's willingness to find living species among fossil remains, the wonder is not so much that he should have referred these forms to Tilia as that he did not declare them merely a fossil state of *V. lantanoides*.

Finally, in addition to this evidence, I find in the beds where these leaves are so abundant as to obscure the presence of all other kinds a large number of detached fruits having all the characteristics of the drupes of Viburnum, but as large as those of the section Lentago, the black-haw or sheep-berry. Unlike these latter, however, yet agreeing in this respect with the section Lantana, the stone of these fruits is distinctly grooved or fluted. They are similar to Heer's *V. macrospermum* (Fl. Foss. Arct., Vol. II, Pt. III, Spitzb., pl. xiii, figs. 24–28). In some (Pl. LI, Figs. 6, 8) the stone alone seems to have been preserved. In others (Figs. 5, 7) the softer portions have left their impression. As several of the species still to be described were also found in this bed it is not certain, of course, that some or all of these fruits may not have belonged to one or more of these; yet, in view of the much greater abundance of this form, it seems more safe to refer the seeds to this species, and as no good characters have yet been found on which to separate them it seems that they must all go together. Still it is quite probable that some of them may belong to other species.

The size of these seeds would alone be sufficient to separate them specifically from both *V. Lantana*, which has seeds scarcely more than a centimeter long, and from *V. lantanoides*, which has them considerably less than a centimeter in length, and, therefore, we may treat both leaves and seeds as constituting an extinct species and commemorate the analogy of the former with the genus Tilia by giving the species a name derived from that genus.

Viburnum perfectum, n. sp.

Plate LII, Figs. 3, 4; Plate LIII, Fig. 1.—Clear Creek, Montana.

Leaves elliptical, provided with a long slender petiole which is more or less bent, curved, or hooked at its proximal extremity; otherwise as in the last, of which it is probably merely a form.

I am, on further study, fully satisfied that these specimens do not constitute a species distinct from the one last described. It was a peculiarity of these Viburnum leaves at Clear Creek that they were nearly all without petioles, so much so that for a long time I was inclined to doubt whether they ever possessed them. But finally a very few specimens were found with petioles, and one (Plate LII, Fig. 4) with a very long one, curiously, and doubtless accidentally, bent below. I know of no living Viburnum that has a petiole of any such length. In the specimen, Fig. 3, Plate LII, the petiole is probably nearly complete and much shorter, hooked near the point of attachment. The specimen Fig. 1, Plate LIII, should evidently have been grouped with Fig. 3, Plate LI, and it is open to doubt whether it was narrowed or heart shaped at the base, though the way in which the lowest pair of nerves issue from the midrib indicate the former, and Mr. Hayden has thus restored it.

Viburnum macrodontum, n. sp.

Plate LIII, Fig. 2.—Clear Creek, Montana.

Leaves elliptical, sharp-pointed, provided with large and long unequal teeth above; otherwise as in the last two species.

A number of fragments occur in the collection from Clear Creek with large prominent teeth, though differing in no other respect, so far as the specimens indicate, from the other large Viburnum leaves. I am inclined to think that if we had perfect specimens it would be found that these represent a distinct species. The teeth are similar to those of *V. Dentoni* Lx. (Cret. and Tert. Fl., pl. xlix, figs. 2, 3), but less sharp, and the other characters are different. That plant is from the "Bad Lands of Dakota," and is probably a near ally of the Clear Creek species.

Viburnum limpidum, n. sp.

Plate LIII, Figs. 3-6.—Clear Creek, Montana.

Leaves small (4 to 6cm. wide, 5 to 8cm. long), petioled, round-ovate or somewhat obovate; nervation as in the preceding species.

If it were a question of size alone I should hesitate to separate these forms from those previously described, when the nervation is so nearly identical. I have observed differences in *V. Lantana* of from 5 to 10cm. in length of leaf, but it is fair to say that the smaller ones accompany flowering specimens and may have been immature. Such leaves do not fall off, and therefore would not occur in a fossil state. I have never observed such differences in *V. lantanoides*. In the present case, however, the shape is somewhat different. The leaves are truncate or narrowed, not heart shaped, at the base, and tend to be obovate. The first specimen (Fig. 3), which is the smallest, is more ovate, and the nervation is more lax and erect. It may be distinct from all the others. It closely resembles Ettingshausen's *Tilia Milleri* (Tert. Fl. Steiermark, Sitzb. Wien. Acad., Vol. LX, Abth. I, pl. v, fig. 2), to which reference has already been made. The other three are very homogeneous and clearly belong together. They form a transition to the next species, which probably belongs to another section of the genus.

Viburnum Whymperi Heer.

VIBURNUM WHYMPERI Heer, Fl. Foss. Arct., Vol. II, Pt .III (Mioc. Fl. Spitzbergens), p. 60, pl. xiii, figs. 3*a*, 4, 5; Pt. V (Foss. Fl. N. Greenland), p. 475, pl. xlvi, fig. 1*b*; Vol. VII, pl. cii, fig. 13*a*. Lesquereux, Ann. Rep. U. S. Geol. Surv. Terr., 1872, p. 395; 1874, p. 306; Tert. Fl., p. 225, pl. xxxviii, fig. 7; pl. lxi, fig. 23. Schimper, Pal. Vég., Vol. II, p. 885.

Plate LIV, Fig. 1.—Clear Creek, Montana.

The agreement with Heer's figure of the Greenland leaf is very close, and I have before me leaves of *V. dentatum* L. which, for both size and form, might almost have served as the original of the drawing. Heer's figure of the fruits from Spitzbergen, however, show no grooves, which puts them into another section, perhaps with *V. pubescens* Pursh.

Viburnum perplexum, n. sp.

Plate LIV, Figs. 2, 3.—Burns's Ranch, Montana; collected by Dr. White's party in 1882.

Leaves rather small (5cm. wide), unsymmetrical, obliquely ovate, truncate at base, blunt-pointed, somewhat regularly and coarsely simply serrate, petioled; midrib eccentric, curved, sinuous, or zigzag; secondary nerves erect at their insertion, rising and curving outward, the upper ones more or less sinuous; otherwise as in the preceding species.

It was with considerable doubt that I placed these two forms together, and the second one (Fig. 3) is very probably an irregular form of *V. Whymperi* Heer. The other (Fig. 2) is very anomalous in form and somewhat so in nervation, yet seems to conform vaguely to the one general type to which all the above specimens belong. In a general way it recalls several figures of more or less problematical character scattered through the books (cf. *Tilia Saviana* Mass., Fl. Foss. del Senigal., pl. xxxix, fig. 9; *Phyllites De-Visianii* Sism., Pal. Terr. Tert. du Piém., pl. xxx, fig. 6; *Betula Sezannensis* Sap., Fl. Foss. de Sézanne, pl. xxxvi, fig. 10), but agrees with none in its essential characters. It is almost certainly one of the Viburnums, but whether a mere sport or the representative of a distinct species the one specimen we possess, notwithstanding that this is admirably preserved, cannot make us certain. It has a certain general resemblance to the specimens from the same bed that I have called *Ficus viburnifolia* (*supra*, p. 42, Pl. XXII, Figs. 4–8), and putting the characters of both these forms together they embody most of those of *Phyllites carneosus* Newberry (Later Extinct Floras, p. 75; Illustr., pl. xxvi, figs. 1, 2), which may represent an archaic Viburnum.

Viburnum elongatum, n. sp.

Plate LIV, Figs. 4, 5.—Clear Creek, Montana.

Leaves elliptical-lanceolate, 5 to 6cm. wide, 10 to 12cm. long, rounded or truncate at the base; somewhat irregularly obtuse-dentate to very near the base; midrib curved, slightly zigzag; secondary nerves all ascending; otherwise as in *V. tilioides*.

A large number of these elongated leaves occur in the collection, and they agree substantially without presenting transition forms to the other species already described. I therefore regard them as constituting a distinct species. I incline to believe that this is the same plant that Dr. Newberry described in his Later Extinct Floras (p. 75) and figured (Illustr., pl. xxvi, figs. 3, 4) as *Phyllites venosus*, though the widest part is here a little higher.

Viburnum oppositinerve, n. sp.

Plate LV, Figs. 1, 2.—Clear Creek, Montana.

Leaves small (2.5 to 3cm. wide, 5 to 6cm. long), ovate or ovate-lanceolate, sharp-pointed, narrowed, or rounded at the base, oblique or one-sided, toothed all round; midrib curved; some of the principal lateral nerves opposite or subopposite, rising at a wide angle and immediately curving upward. Otherwise as in *V. tilioides*.

This species has a very close resemblance to *V. pubescens* Pursh, a native of North America. The two specimens do not exactly agree in dentation and one is considerably more elongate than the other, but I do not feel justified in separating them on these grounds. The teeth are too coarse and the lower secondaries too light for *V. lanceolatum* Newberry (Illustr., pl. xvi, fig. 10); the analogy is closer, except as to size, with *V. Dakotense* Lx. (Cret. and Tert. Fl., pl. xlviA, fig. 9), especially as regards the first specimen (Fig. 1).

Viburnum erectum, n. sp.

Plate LV, Fig. 3.—Clear Creek, Montana.

Leaf lanceolate, long and sharp-pointed, toothed above; secondary nerves very erect, some of the upper ones curving inwards to join the branches of the next higher, the short tertiary nerves from the angled arches thus formed passing into the teeth; nervilles approximate, parallel, mostly percurrent, generally somewhat curved or bent in the middle, traversing the areas at right angles to the nerves.

It must be freely confessed that this specimen is too imperfect to found a species upon, and if better material is ever found it may be either confirmed or rejected. But several of the characters that appear in this fragment are not seen in any of the other specimens. The slightly celastroid tendency of the nervation, also faintly seen in one of the specimens of the last species (Fig. 2), is thus far new to this group, and may have some special significance. Aside from this there are many reasons for uniting it with the larger species from Cracker Box Creek (cf. Plate LVI, Figs. 1, 5, and 6)

Viburnum asperum Newberry.

VIBURNUM ASPERUM Newberry, Later Extinct Floras, pp. 31, 54; Illustr., pl. xvi, figs. 8 (9?). Schimper, Pal. Vég., Vol. II, p. 884. Lesquereux, Cret. and Tert. Fl., p. 230.

Plate LV, Figs. 4–9.—Cracker Box Creek, Montana (Figs. 4–8). Seven Mile Creek, Montana; Sparganium bed (Fig. 9).

I am now disposed to regard the specimen from Seven Mile Creek (Fig. 9) as distinct from the others. It should, perhaps, be classed with one from Clear Creek above described (Fig. 1 of the same plate). It may also be compared with *V. lanceolatum* Newberry (loc. cit., fig. 10).

I can scarcely persuade myself that Newberry's *Rhamnites concinnus* loc. cit., fig. 7) is anything but a very regular and symmetrical form of this plant with the upper secondary nerves nearly simple.

Viburnum Newberrianum, n. sp.

Plate LVI, Figs. 1–6.—Cracker Box Creek, Montana.

Leaves ovate or ovate-lanceolate, slightly heart shaped, acuminate, more or less regularly and rather finely and sharply simply serrate to the base, 3 to 6 cm. wide, 6 to 12 cm. long, exclusive of the long (4 to 5 cm.) petiole, which is thickened and grooved below; nervation subpalmate, craspedodrome; midrib strong, usually straight; lateral nerves all, or all but a very light basilar pair, branching freely from the under side, the upper ones forking, lower ones opposite, second or third pair much stronger than the rest, ascending at an angle of 30° to 35°, carrying six to nine strong, branched or forking secondaries, slightly curving upward and reaching the margins far above the middle; branches from the midrib alternate, rising at angles successively more acute, the uppermost becoming nearly vertical, the lowest remote from the principal lateral nerves; nervilles rather faint, nearly all simple and percurrent, traversing the areas somewhat obliquely and nearly at right angles to the midrib, sometimes curved, bent, or forking.

This species, although from the same beds and much resembling it otherwise, is clearly distinguished from the preceding by its compound (subpalmate) nervation, that of *V. asperum* being always simply pinnate. In this respect it also differs from all the non-lobate Viburnums with which I am acquainted and approaches more closely to Ceanothus. In *C. Americanus* L., the common North American species, however, the leaf is decidedly triplinerved, the lateral primaries somewhat acrodrome and having their origin at the very base or even running for some distance below the blade and inclosing a little parenchymatous tissue between them and the petiole. But there is a Mexican species (*C. azureus* Desf.) which has these characters much less marked and closely approaches these fossil leaves in this respect as well as in general shape (cf. Ettingshausen, Blattsk. d. Dicotyl., pl. lxix, fig. 16). There is, however, in our specimens a peculiar dichotomy and definite symmetry which are characteristic of Viburnum and not of Ceanothus, and, until fruits or other convincing proofs are found, they may be left where they are. It seems at least certain that any change must affect *V. asperum* as well as the present species.

In naming this very handsome species I have wished to do honor to a pioneer in the work of bringing to light the floral treasures hidden in the Fort Union strata, where these specimens were found, and by the light of whose researches my own investigations have been so largely guided.

Viburnum Nordenskiöldi Heer.

VIBURNUM NORDENSKIÖLDI Heer, Fl. Foss. Arct., Vol. II, Pt. II (Fl. Foss. Alask.), p. 36, pl. iii, fig. 13; Vol. IV, Pt. I (Foss. Fl. Spitzb.), p. 77, pl. xv, fig. 5*a*; pl. xviii, fig. 7; pl. xxiii, fig. 4*b*; pl. xxix, fig. 5; Vol. V, Pt. I (Mioc. Fl. Grinnell Land.), p. 36, pl. iv, fig. 4*d*; pl. vii, figs. 5–7; Vol. VI, Abth. I, Pt. III (Mioc. Fl. N. Can.), p. 15, pl. i, fig. 8; Vol. VII, p. 115, pl. xcii, fig. 11; pl. xcvi, fig. 2. Schimper, Pal. Vég., Vol. II, p. 885. Lesquereux, Cret. and Tert. Fl., p. 230, pl. xlviA, figs. 6, 7.

Plate LVII, Figs. 1–3.—Clear Creek, Montana (Fig. 1). Little Missouri River, Dakota (Fig. 3). Gladstone, Dakota (Fig. 2). The last two were collected by Dr. A. C. Peale in 1883.

It is altogether probable that these specimens belong to the same plant as Lesquereux's specimen fig. 7, but there is much doubt in my mind as to the identity of that specimen with those of the north. Heer's figures all show a degree of irregularity and indefiniteness which does not comport with the forms from Dakota and Montana. The Gladstone specimen deviates somewhat from the other two in that the principal pair of lateral nerves rise nearer the base and keep nearer the margin, allying it with *V. asperum*, while the strong branching lower nerves and erect lateral subprimaries of the Clear Creek and Little Missouri specimens ally them rather with *V. Newberrianum*. They all bear, moreover, a certain resemblance to the forms which I have referred to Grewia (*G. celastroides*, supra, p. 86, Pl. XXXIX, Fig. 2, and *G. Pealei*, p. 87, Pl. XXXIX, Figs. 3–5); and in one of the specimens (Fig. 1) traces of the peculiar marginal nervation of that group are visible. In lacking the dichotomous branching of the Viburnum group these forms are even more assimilated to Ceanothus than the ones last considered. Their reference to this species is therefore, on the whole, of very doubtful propriety.

Viburnum betulæfolium, n. sp.

Plate LVII, Fig. 4.—Burns's Ranch, Montana; collected by Dr. White's party in 1882.

Leaf thick, coriaceous, broadly ovate, short-pointed, 4.2cm. wide and but little longer, coarsely and irregularly toothed; nervation pinnate craspedodrome; midrib straight, nearly central; secondary nerves rising at a large angle (50° to 60°), sometimes branching dichotomously from near their origin, once to thrice forking towards their extremities, the ultimate ramifications entering the blunt teeth; nervilles straight, generally simple, percurrent, crossing the intervals at right angles to the nerves, sometimes forking in the middle.

The base is wanting and its form cannot be safely divined. The leaf differs from all others in the collection that I have thus far studied, and also from any living or fossil leaf known to me, but it seems to have many of the characteristics of a Viburnum. Its nearest analogue from a superficial point of view seems to be one of Heer's Sachalin specimens of *Betula prisca* Ett. (Fl. Foss. Arct., Vol. V, Pt. III, Prim. Fl. Foss. Sachal., pl. v, fig. 9), which, however, is much smaller, and in the other large figure (fig. 10) the form is different. It also resembles somewhat in form *Betula Blancheti* Heer (Fl. Tert. Helv., pl. lxxi, fig. 26), but the teeth are less sharp and the lateral nerves less straight and regular, besides being forked. It also vaguely simulates some leaves of Cratægus.

Viburnum finale, n. sp.

Plate LVII, Fig. 5.—Iron Bluff, Montana.

Leaf rather thin, ovate-lanceolate, somewhat falcate, 5cm. wide, 10cm. long, rounded and oblique at the base, pointed at the summit, finely and sharply serrate; nervation pinnate, craspedodrome; midrib very thick, rapidly diminishing above the middle, regularly curved, slightly eccentric; secondary nerves relatively slender, nearly uniform and parallel, about fourteen on each side, the lower branching from the under side, the branches forking near the margin, the rest once to thrice forked, the ultimate ramifications entering the teeth; nervilles faint, percurrent, parallel, crossing the spaces at nearly right angles to the secondary nerves.

Notwithstanding the dichotomous viburnoid nervation of this leaf, I find it difficult to believe that it is not after all a member of the group of forms found at Iron Bluff and Burns's Ranch, most of which I have referred to the Celastrineæ. They seem to possess the characters of that family in varying degrees and to diverge in several directions towards other classes of plants. One I was reluctantly compelled to single out and refer to Juglans, and this one has found its way into the group of Viburnums. Those which I have called *Celastrus alnifolius* I was strongly tempted to treat as forms of Alnus, and the species last described may belong to Betula. Yet they all seem to me to be related. This feeling, however, may be partly due to local association, and there is certainly nothing strange in finding so many different families of plants represented at one spot, since that is what we actually find in the present flora. Although we here have the outline of the leaf very well shown, the finer details of the nervation are obscured, especially along the margins, and it is possible that if more could be made out the characteristic features of the group with which it was associated might be found to belong in some degree to this specimen.

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PLATES.

INDEX.

[Genera and all higher groups are printed in SMALL CAPITALS; synonyms in *italics*. Heavy-faced figures refer to pages on which descriptions are given.]

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— Younger Mesozoic Flora of Virginia, by William M. Fontaine.

— Description of New Fossil Plants from the Dakota Group, by Leo Lesquereux.

— Report on the Denver Coal Basin, by S. F. Emmons.

— Report on Ten-Mile Mining District, Colorado, by S. F. Emmons.

— Report on Silver Cliff Mining District, by S. F. Emmons.

— Flora of the Dakota Group, by J. S. Newberry.

BULLETINS.

The Bulletins of the Survey will contain such papers relating to the general purpose of its work as do not properly come under the heads of Annual Reports or Monographs.

Each of these Bulletins contains but one paper and is complete in itself. They are, however, numbered in a continuous series, and may be united into volumes of convenient size. To facilitate this, each Bulletin has two paginations, one proper to itself and another which belongs to it as part of the volume.

Of this series of Bulletins Nos. 1 to 38 are already published, viz:

1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross, with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons. 1883. 8°. 42 pp. 2 pl. Price 10 cents.

2. Gold and Silver Conversion Tables, giving the coining values of troy ounces of fine metal, etc., by Albert Williams, jr. 1883. 8°. 8 pp. Price 5 cents.

3. On the Fossil Faunas of the Upper Devonian, along the meridian of 76° 30′, from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams. 1884. 8°. 36 pp. Price 5 cents.

4. On Mesozoic Fossils, by Charles A. White. 1884. 8°. 36 pp. 9 pl. Price 5 cents.

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6. Elevations in the Dominion of Canada, by J. W. Spencer. 1884. 8°. 43 pp. Price 5 cents.

7. Mapoteca Geologica Americana. A catalogue of geological maps of America (North and South), 1752–1881, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.

8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Van Hise. 1884. 8°. 56 pp. 6 pl. Price 10 cents.

9. Report of work done in the Washington Laboratory during the fiscal year 1883–'84. F. W. Clarke, chief chemist; T. M. Chatard, assistant. 1884. 8°. 40 pp. Price 5 cents.

10. On the Cambrian Faunas of North America. Preliminary studies, by Charles D. Walcott. 1884. 8°. 74 pp. 10 pl. Price 5 cents.

11. On the Quaternary and Recent Mollusca of the Great Basin; with Descriptions of New Forms, by R. Ellsworth Call; introduced by a sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert. 1884. 8°. 66 pp. 6 pl. Price 5 cents.

12. A Crystallographic Study of the Thinolite of Lake Lahontan, by Edward S. Dana. 1884. 8°. 34 pp. 3 pl. Price 5 cents.

13. Boundaries of the United States and of the several States and Territories, by Henry Gannett, 1885. 8°. 135 pp. Price 10 cents.

14. The Electrical and Magnetic Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1885. 8°. 238 pp. Price 15 cents.

15. On the Mesozoic and Cenozoic Paleontology of California, by Charles A. White. 1885. 8°. 33 pp. Price 5 cents.

16. On the higher Devonian Faunas of Ontario County, New York, by John M. Clarke. 1885. 8°. 86 pp. 3 pl. Price 5 cents.

17. On the Development of Crystallization in the Igneous Rocks of Washoe, Nevada, by Arnold Hague and Joseph P. Iddings. 1885. 8°. 44 pp. Price 5 cents.

18. On Marine Eocene, Fresh-water Miocene, and other Fossil Mollusca of Western North America, by Charles A. White. 1885. 8°. 26 pp. 3 pl. Price 5 cents.

19. Notes on the Stratigraphy of California, by George F. Becker. 1885. 8°. 28 pp. Price 5 cents.

20. Contributions to the Mineralogy of the Rocky Mountains, by Whitman Cross and W. F. Hillebrand. 1885. 8°. 114 pp. 1 pl. Price 10 cents.

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21. The Lignites of the Great Sioux Reservation, by Bailey Willis. 1885. 8°. 16 pp. 5 pl. Price 5 cents.

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24. List of Marine Mollusca, comprising the Quaternary fossils and recent forms from American localities between Cape Hatteras and Cape Roque, including the Bermudas, by William H. Dall. 1885. 8°. 336 pp. Price 25 cents.

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27. Report of work done in the division of Chemistry and Physics, mainly during the fiscal year 1884–'85. 1886. 8°. 80 pp Price 10 cents.

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29. On the Fresh-water Invertebrates of the North American Jurassic, by Charles A. White. 1886. 8°. 41 pp. 4 pl. Price 5 cents.

30. Second contribution to the studies on the Cambrian Faunas of North America, by Charles D. Walcott. 1886. 8°. 369 pp 33 pl. Price 25 cents

31. A systematic review of our present knowledge of Fossil Insects, including Myriapods and Arachnids, by Samuel H. Scudder. 1886. 8° 128 pp. Price 15 cents.

32. Lists and Analyses of the Mineral Springs of the United States; a preliminary study, by Albert C. Peale. 1886. 8°. 235 pp. Price 20 cents.

33. Notes on the Geology of Northern California, by Joseph S. Diller 1886. 8°. 23 pp. Price 5 cents.

34. On the relation of the Laramie Molluscan Fauna to that of the succeeding Fresh-water Eocene and other groups, by Charles A. White. 1886 8°. 54 pp. 5 pl. Price 10 cents.

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36. Subsidence of fine Solid particles in Liquids, by Carl Barus. 1887. 8°. 58 pp. Price 10 cents.

37 Types of the Laramie Flora, by Lester F. Ward. 1887. 8°. 354 pp. 57 pl. Price 25 cents.

Numbers 1 to 6 of the Bulletins form Volume I; Numbers 7 to 14, Volume II; Numbers 15 to 23, Volume III; Numbers 24 to 30, Volume IV; Numbers 31 to 36, Volume V; Volume VI is not yet complete.

The following are in press, viz:

38. Peridotite of Elliott County, Kentucky, by Joseph S. Diller.

39. The Upper Beaches and Deltas of the Glacial Lake Agassiz, by Warren Upham.

40. Changes in River Courses in Washington Territory due to Glaciation, by Bailey Willis.

41. Fossil Faunas of the Upper Devonian—the Genesee Section, by Henry S. Williams.

42. Report of work done in the division of Chemistry and Physics, mainly during the fiscal year 1885–'86. F. W. Clarke, chief chemist.

43. On the Tertiary and Cretaceous Strata of the Tuscaloosa, Tombigbee, and Alabama Rivers, by Eugene A. Smith and Lawrence C. Johnson.

In preparation:

44. Historic statement respecting geologic work in Texas, by R. T. Hill.

45. The Nature and Origin of Deposits of Phosphates of Lime, by R. A. F. Penrose, jr.

46. Bibliography of North American Crustacea, by A. W. Vogdes.

— The Gabbros and associated rocks in Delaware, by F. D Chester.

— Report on Louisiana and Texas, by Lawrence C. Johnson.

STATISTICAL PAPERS.

A fourth series of publications, having special reference to the mineral resources of the United States, has been undertaken.

Of that series the following have been published, viz:

Mineral Resources of the United States [1882], by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1883 and 1884, by Albert Williams, jr. 1885. 8°. xiv, 1016 pp. Price 60 cents.

Mineral Resources of the United States, 1885. Division of Mining Statistics and Technology. 1886. 8°. vii, 576 pp. Price 40 cents.

Correspondence relating to the publications of the Survey, and all remittances, which must be by POSTAL NOTE OR MONEY ORDER (not stamps), should be addressed

TO THE DIRECTOR OF THE
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UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

PERIDOTITE

OF

ELLIOTT COUNTY, KENTUCKY

BY

J. S. DILLER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1887

CONTENTS.

ILLUSTRATIONS.

PERIDOTITE OF ELLIOTT COUNTY, KENTUCKY.

By J. S. Diller.

INTRODUCTION.

Several years ago Prof. A. R. Crandall, of the Geological Survey of Kentucky, discovered dikes of an interesting eruptive rock between Isom's and Critche's Creeks, near Fielden post office, 6 miles southwest of Willard, in Elliott County, Kentucky. The position of these dikes is shown upon two of the geological maps of Eastern Kentucky. Both maps were prepared under the supervision of John R. Procter, the director of the Kentucky Geological Survey, by Professor Crandall and J. B. Hoeing. One, on a scale of about 4 miles to an inch, is designed to show the relation of the conglomerate uplifts and the dikes; the other, on a scale of 2 miles to an inch, gives the areal distribution of the dikes, the Coal Measures, and the conglomerate in Elliott County. In a vertical section on the same sheet the relations of these terranes are illustrated.

A chemical analysis of the dike rock was made by Messrs. A. M. Peter and J. H. Kastle, in the laboratory of the Geological Survey of Kentucky. Samples of the same material were sent to the United States Geological Survey for microscopic examination. It was found to be a peridotite, and a brief notice of its occurrence was published in Science, January 23, 1885, page 65.

At the request of Mr. Procter and with the approval of Capt. C. E. Dutton and the Director of the United States Geological Survey, I joined Professor Crandall in an excursion to the dikes to collect a complete series of specimens for petrographic investigation.

DISTRIBUTION AND MODE OF OCCURRENCE.

The accompanying map, Plate I, was prepared by enlarging a small portion of the map of Elliott County and introducing the additional data obtained during our late excursion.

At my request, Professor Crandall, who has visited the region a number of times, kindly furnished the following field notes:

This dike represents an eruption of very limited extent laterally, being found only in a small part of the valley of the Little Fork of the Little Sandy River. From its limited range, and also from the readiness with which the rock of which it is composed disintegrates, it does not appear as a noticeable factor in the topography of the region, and it is with some difficulty that it can be traced beyond the exposures which mark a few points along its surface prolongation. It appears to extend in two diverging lines from Critche's Creek into the valley of Isom's Creek, with several minor offshoots of undetermined but doubtless limited extent, possibly no more than wedge-like projections from the main dike between the strata of the Coal Measures which make up the whole height of the hills of this region. The whole length of the dike in its greatest surface extension appears to be less than a mile, with a width of from a few feet to fifty or more, as indicated by one exposure near Isom's mill, though the slight local disturbance of the including rocks and the inconsiderable metamorphic action, as well as the limited area, indicate no great mass of the intrusive rock. These considerations and some of the conditions noted at Isom's mill suggest the possibility that the exposure there shows a local lateral expansion, rather than the width of the dike. All the rocks of this part of the coal field, including the beds up to coal seven (the Coalton coal of Kentucky, the Sheridan and Nelsonville of Ohio), are cut by both arms of the dike.

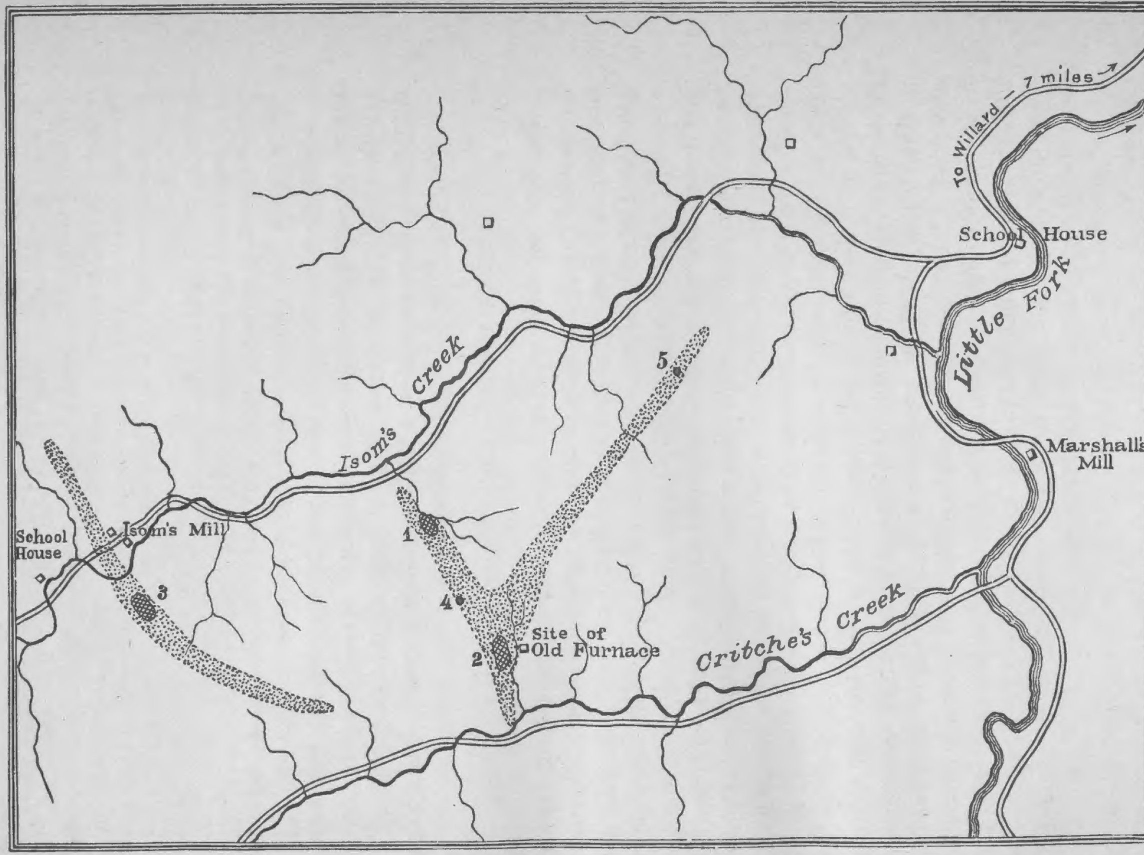
Although there are but three localities where the peridotite is exposed, its areal distribution, as indicated upon the accompanying map (Plate I), can be made out with a high degree of probability by the occurrence of numerous small fragments of ilmenite and pyrope in the soil resulting from its decomposition.

MINERALOGICAL COMPOSITION AND STRUCTURE.

The best and freshest specimens of peridotite were collected at locality marked 1 upon the map, where the specimens were prepared for the educational series. It is a compact, dark greenish rock, with a specific gravity of 2.781. In it are embedded many grains of yellowish olivine, uniformly distributed throughout the mass. Rarely it is fine granular and dense, like many darker colored basalts, but generally the grains of which it is composed are medium sized. Occasionally the olivine grains disappear and the deep green serpentine pervades the whole mass. Besides the olivine and serpentine, which together form nearly 75 per cent. of the rock, there are other minerals which appear in the hand specimen. Most important among these are pyrope and ilmenite, the latter appearing in the form of irregular grains which sometimes attain a diameter of nearly 2 centimeters. A few scales of biotite may be observed. Near the exposed surface the rock becomes yellowish, due to the oxidation of the iron, and softens so that it readily disintegrates. The garnet and much of the ilmenite withstand the atmospheric influences and are found quite fresh and abundant in the sand resulting from the disintegration of the peridotite.

The specimens from localities 1 and 2, the exposures of the eastern dike, are free from included fragments of the rocks through which the peridotite has been extravasated; but those from locality 3, in the western dike near Isom's mill, are full of fragments of shale, which have been greatly indurated and metamorphosed in the operation.

The following table is based directly upon estimates made under the microscope of the areal distribution of the various minerals in the



Exposed Peridotite.

Soil containing Pyrope and Ilmenite.

Loose fragments of Feldspathic rocks.

Scale

0 1/16 1/8 1/4 1/2 1 Mile

MAP OF THE PORTION OF ELLIOTT COUNTY IN WHICH THE DIKES OCCUR.

freshest portions of the sections from locality 1, where the peridotite is less altered than at any of the other exposures:

Primary minerals.	Per cent.	Secondary minerals.	Per cent.
Olivine	40	Serpentine	30.7
Enstatite	1	Dolomite	14
Biotite	1	Magnetite	2
Pyrope	8	Octahedrite	1.1
Ilmenite	2.2		
Apatite	Trace		

It is not claimed, of course, that this table represents with a high degree of accuracy the mineralogical composition of the rock, yet it closely approximates the real proportions in the sections studied. The table clearly indicates that originally at least 80 per cent. of the rock was olivine and that ultimately it will be nearly all serpentine—or, perhaps, in some places dolomite—with a small proportion of magnetite, ilmenite, garnet, and octahedrite.

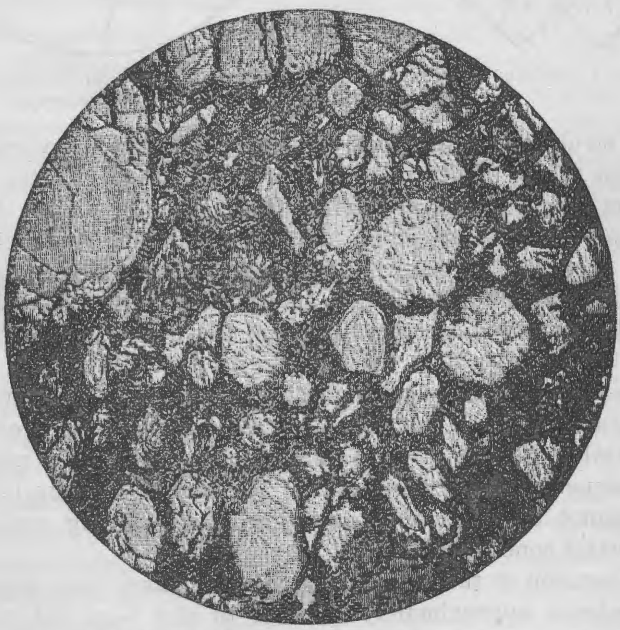


FIG. 1. Section of peridotite seen under the microscope.

The general structure of the rock is illustrated in Fig. 1, which shows the remaining grains of olivine inclosed in a network of serpentine with other products of alteration. The high proportion of olivine in the rock places it among those peridotites which are generally designated dunites, but the presence of some enstatite shows its relationship to another member of the same family.

The olivine grains are generally irregular in form, varying from 0.1 to 1.5 millimeters in diameter, and are penetrated by many fissures. Occasionally, however, they are bounded by sharply defined crystallographic planes, a feature which is unusual for the olivine in peridotites. It occurs in the form, which is common in basaltic lavas, of a short prism terminated by brachydomes without the base, as in Fig. 2. The

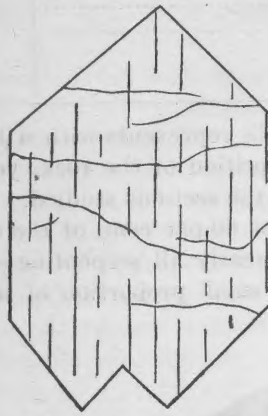


FIG. 2. Crystal of olivine.

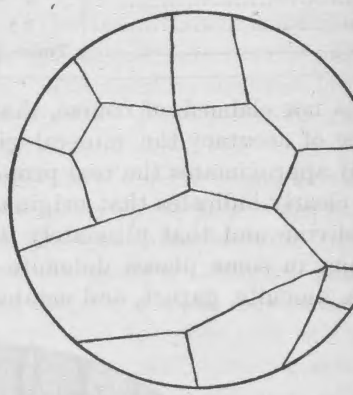


FIG. 3. Original structure of peridotite seen under the microscope.

original structure of the rock is nearly obliterated by recent alteration; but at one point, which is represented in Fig. 3, the manner in which the coarse grains of olivine fit together is plainly discernible. Rarely the aggregating grains are very small, and, although optically distinct, each fits into the irregularities of the other so as to produce a fine granular structure similar to that of the dunite of North Carolina. Under the microscope, especially when the dunite is slightly altered, it holds such a superficial resemblance to a stratified rock that A. A. Julien[1] regarded it as an accumulation of olivine sand derived from an earlier eruptive mass; but Dr. M. E. Wadsworth[2] has shown that in all probability it is eruptive in its present position. The presence of a similar structure in the peridotite of Kentucky, the eruptive origin of which cannot be reasonably questioned, lends strong support to Dr. Wadsworth's conclusions.

The alteration of the olivine to serpentine takes place rapidly in the cross-fractures approximately parallel to the base, but very slowly along the numerous minute fissures in the prism zone. Cleavage parallel to the brachypinacoid is scarcely discernible.

The olivine contains numerous small inclusions, some of which are of a liquid containing a movable bubble. They are arranged in more or less regular planes, often but not always approximately parallel to the

[1] The Dunyte Beds of North Carolina. Proc. Bost. Soc. Nat. Hist., Vol. XXII, p. 141.

[2] Olivine Rocks of North Carolina. Science, Vol. III, p. 486, Apr. 18, 1884.

base. Besides these inclusions, there are other small yellowish-brown or black ones scattered like dust, but rarely so abundant as to interrupt the transparency of the olivine. Occasionally they accumulate in bands across the grains or around their borders, as described by J. W. Judd[1] and others, producing dark cloudings which remain after the olivine has been replaced by serpentine. The olivine was observed to envelop scales of biotite, indicating that the latter belong to an earlier stage of crystallization than the olivine.

In the process of alteration the olivine is transformed into serpentine with the secretion of magnetite. Among the secondary products there is much dolomite, which appears to result from the transformation of the olivine. The abundance of the carbonate present suggests that the olivine might contain a considerable percentage of lime, and to determine this it was prepared for chemical analysis. By means of the Sonstadt solution, with a specific gravity of 2.9, the magnetite, biotite, ilmenite, enstatite, octahedrite, and olivine were separated from the serpentine and other secondary products, With a magnet the magnetite was then removed, and by passing the powder over paper the mica was separated from the other minerals. The mixture of olivine, ilmenite, enstatite, octahedrite, and garnet was then put into the Klein solution and evaporated until crystallization began. At this point the olivine and a trace of enstatite were lifted by the solution and, by decantation, separated from the other minerals. This operation was repeated many times, and finally, picking out all foreign matter under the microscope, the olivine was obtained remarkably pure for chemical analysis. Its specific gravity, determined by using a picnometer, is 3.377. The results of the chemical analysis of the olivine by T. M. Chatard, in the chemical laboratory of the United States Geological Survey, are given in the table of analyses, page 24. It will be noticed that the percentage of lime and alkalies present is unusually large.

Pyroxene plays so small a part among the minerals of this rock that it cannot be considered an essential constituent. In the form of irregularly corroded grains, such as is represented in Fig. 4, it is distributed throughout the mass with approximate uniformity, but it constitutes not more than 1 per cent. of the whole. The cleavage is nearly rectangular and the extinction in prismatic sections parallel, indicating with a high degree of probability that the pyroxene is rhombic. It is generally transparent, with a sprinkling of fine dark grains, and is surrounded by a clouded border con-

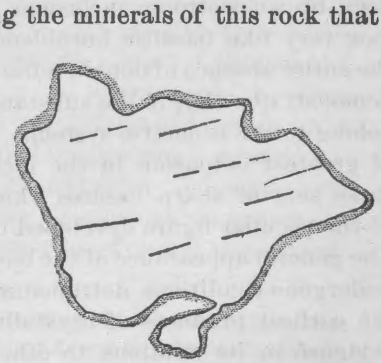


FIG. 4. Corroded enstatite with border.

[1] On the Tertiary and Older Peridotites of Scotland. Quarterly Journal of the Geological Society, August, 1885, p. 354.

forming to the embayed contour. This border is irregular in structure and composition, but is almost always present. Where most prominent it is formed of acicular crystals radiating from the enstatite, but generally it is composed of translucent grains of pyroxene rendered somewhat clouded, apparently by the secretion of ferritic matter. The fibrous mineral is transparent, with strong double refraction and small angle of extinction, indicating that it is hornblende.

The embayments of the irregular enstatite sometimes contain olivine, demonstrating that the pyroxene is an earlier product of crystallization than the olivine and owes its border, at least in part, to the subsequent corrosive action of the magma.

The mica is dark colored, strongly dichroic, with a very small optic axial angle in the plane of the principal ray of the radial figure (Schlagfigur) produced by puncturing a thin plate of the mica with a sharp needle. It doubtless belongs to the biotite series and is sparingly distributed throughout the rock. Figure 5 represents a cross section of a somewhat uncommon scale of brown biotite made up of laminæ differing from one another in pleochroism. The foliæ forming the top and the base of the scale, the shaded portions in Fig. 5, are more deeply colored and strongly dichroic than the light brown portion in the middle. All portions are optically continuous and surrounded by a prominent border composed of colorless mica and oxide of iron. The mica of the border is continuous with the other, and evidently owes its loss of color to leaching out the oxide of iron. With the exception of fine ferritic dust irregularly scattered throughout the scales of mica it is generally free from inclusions. One scale, however, has prominent deep brown isotropic inclusions which lie in the basal plane. They look very like basaltic hornblende in ordinary transmitted light, but the entire absence of double refraction and consequent properties clearly demonstrates that if the substance is crystalline in structure it must belong to the isometric system. It is perhaps significant that the axes of greatest extension in the inclusions are approximately parallel to three sets of sharp fissures which apparently correspond to the rays of the peculiar figure developed by pressure, the so-called Druckfigur. The general appearance of the biotite conveys the impression that it has undergone conditions detrimental to its existence and must belong to the earliest products of crystallization. Of this we have convincing evidence in its relations to other minerals, for biotite is frequently included in olivine. Rarely the biotite is surrounded by an irregular secondary border composed of magnetite and biotite differing widely in pleochroism from the biotite within the border. The biotite of the grain and its border are optically continuous, but, while the pleochroism of the

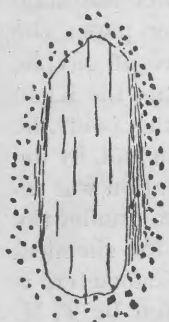


FIG. 5. Biotite.

former ranges from almost colorless to light brownish yellow, that of the latter in corresponding positions is orange-yellow and green.

The relation of the biotite to the garnet is of especial interest and will be noted in discussing the composition of that peculiar envelope in which the pyrope is inclosed. It is evident, however, that the biotite upon the periphery and in the fissures of the garnet is of secondary origin.

Pyrope cannot be considered one of the essential minerals in this rock, yet it is among the most prominent. It occurs in spherical and ellipsoidal grains varying from 1 millimeter to more than a dozen millimeters in diameter. They are found abundantly along the line of the dike in the soil resulting from its disintegration. The small, clear, deep red grains have a specific gravity of 3.673 and are locally regarded as rubies of problematical value, but the paler red, much fractured fragments of larger size have attracted little attention.

The most interesting feature of the pyrope is prominent under the microscope, where it is seen to be surrounded by a border of radial fibers analogous to that described by Fr. Becke[1] and A. Schrauf,[2] and later critically examined by A. v. Lasaulx.[3] The general character of the border is represented in Fig. 6. It is composed of two essentially different substances, both of which are always present, although varying much in proportions. First of these may be mentioned a dark powder, which is frequently so abundant as to render the border opaque. It occurs most abundantly in the outer portion of the border and is chiefly, if not wholly, magnetite; for when carefully detached by a sharp needle from an uncovered section it is found to be strongly magnetic. The second usually inner substance of the ring is of a grayish or reddish brown color and is generally fibrous in structure. Schrauf studied the fibrous substance enveloping the garnets in the serpentine of Kremze, Bohemia, and named it kelyphite. The investigations of Lasaulx have shown that in some cases the border instead of being a single mineral is a mixture of several minerals, chiefly of the pyroxene and amphibole groups. In the example under consideration its composition appears to be exceptional. Although it is commonly made up of closely compacted,

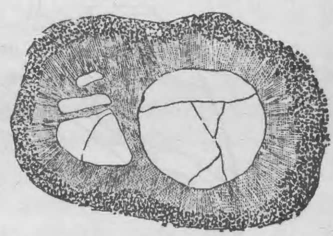


FIG. 6. Pyrope, showing border of biotite and magnetite.

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[1] Tschermak's Mittheilungen, iv, 1881, pp. 189, 285.

[2] Beiträge zur Kenntniss des Associations-kreises der Magnesia-Silikate. Zeitschrift für Krystallographie, 1882, VI., pp. 321–388; also Ueber Kelyphite. Neues Jahrbuch, 1884, Bd. II, p. 21.

[3] Ueber Umrindungen von Granat. Sitzungsberichte der niederrhein. Gesellschaft, Bonn, 1882, Juli 3; Verhandlungen des naturhistorischen Vereins der preussischen Rheinlande und Westfalens. Neununddreissigster Jahrgang, zweite Hälfte, Bonn, 1882, p. 114.

very fine, parallel fibers perpendicular to the outer surface of the garnet, it frequently appears as an irregular, non-fibrous fringe upon the inner side of the border, or even completely inclosed within the garnet, where it is usually of a deep brown color. Generally it is distinctly doubly refracting, and when finely fibrous is sometimes strongly colored red and green between crossed nicols. The non-fibrous form of the substance, although deeply colored, is isotropic and consequently not dichroic, but when fibrous the absorption parallel to the fibers is occasionally almost complete. On account of the fineness of the fibers and the density of their aggregation it is not possible to determine the angle of extinction with great precision; nevertheless if the extinction is not parallel the angle is very small indeed. Although many of these borders have been studied about the pyrope in the peridotite from Kentucky, I have not been able to discover convincing evidence of the presence of either pyroxene or hornblende; on the contrary, the evidence clearly indicates that the mineral belongs to the mica group. This conclusion is completely demonstrated by a border, part of which is represented in Fig. 7.

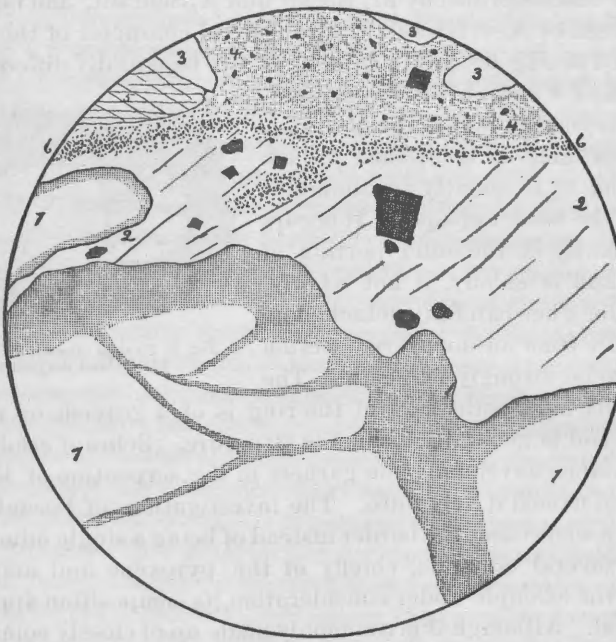

FIG. 7. Part of a border about a grain of pyrope, magnified 80 diameters.

In this case, although the border is not so prominently marked about the whole circumference of the garnet (5 millimeters in diameter) as that represented in Fig. 6, yet there are narrow places along the border where it is distinctly fibrous and grades directly into that represented in Fig. 7 in such a way as to show that both are of the same substance. The uniaxial, negative, strongly dichroic foliated mineral numbered 2 in Fig. 7 is undoubtedly biotite. It extends far into the garnet along fissures and contains besides magnetite small triangular and quadratic sections as well as irregular grains of a yellowish brown isotropic mineral, which in all probability is picotite. The first sight suggests that this deep brown mineral is hornblende, but the absence of all pleochroic phenomena and its regular octahedral form clearly indicate that it cannot belong to the amphibole group. One small pseudomorph after garnet deserves special mention, in that the whole of the middle portion is composed of picotite, which is surrounded by a broad border of magnetite. In the majority of cases, especially where the border is fibrous, the fibers are in direct contact with the clear garnet, but in the section of which Fig. 7 represents a part, where the biotite and picotite are much better developed, the garnet near the border and along fissures is clouded. Besides the biotite and picotite within the compass of the garnet's border, there are traces of calcite and a clear colorless mineral, which, on account of its strong double refraction and the absence of cleavage, is regarded as quartz. It is interesting to note that the quartz almost always occurs in immediate contact with the picotite.

That the shell frequently found about the garnets in peridotitic rocks is composed in most cases essentially of minerals belonging to the pyroxene and amphibole groups has been demonstrated by a number of observers, but as far as I am aware the occurrence of biotite in this connection is here noted for the first time.

It is evident, from the facts represented in Figs. 6 and 7, as already suggested by Lasaulx and Rosenbusch,[1] that the pyrogenic origin of the shell of iron-magnesian silicates frequently enveloping the garnet is generally untenable. The manner in which the enveloping substance is sometimes included in the garnet and penetrates the garnet along fissures clearly demonstrates its secondary origin.

The pyrope, from Kentucky, was carefully analyzed by T. M. Chatard, with the results given in the table of analyses, page 24. It was impracticable to obtain sufficient of the border for chemical examination. The position of the pyrope in the series denoting the order of crystallization is between enstatite, a serpentinous pseudomorph of which it includes, and olivine. Its relation to the primary biotite is not easily determined, from the fact that where the two minerals are found together the biotite is always a secondary product.

Ilmenite is a common and uniformly distributed constituent of the Kentucky peridotite. It is plainly visible in the freshly fractured rock, where it appears in the form of brilliant black grains, varying in size from 1 millimeter to 15 millimeters in diameter. Although subject to considerable alteration it frequently withstands meteoric influ-

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[1] H. Rosenbusch: Mikroskopische Physiographie der petrographisch wichtigen Mineralien. Zweite gänzlich umgearbeitete Auflage, 1885, p. 269.

ences with remarkable persistence, appearing abundantly with the garnet in the soil resulting from the disintegration of the peridotite. It is only by means of the ilmenite and pyrope in the soil, as indicated upon the map, that the limits of the dikes can be approximately determined. The ilmenite is readily distinguished from the magnetite, even under the microscope in reflected light, by the brilliant luster of portions of its pitted surface. It has always been observed in large grains and not in the form of fine, spongy particles like magnetite. Under the microscope the ilmenite is frequently seen surrounded, penetrated, and even completely replaced by a mixed group of yellowish and black grains resulting from its alteration. The black opaque grains are magnetite and the yellowish ones probably octahedrite. The specific gravity of the ilmenite is 4.453 and a chemical analysis of it is given in the table, page 24.

Near the southern end of the eastern dike, at a point indicated upon the map, is a prehistoric embankment which appears to have been the foundation for works to smelt the peridotite, probably on account of the supposed value of the bright ilmenite it contains.

Magnetite is abundantly distributed throughout the whole rock. It rarely occurs in the form of well developed octahedrons, but appears generally in irregular, spongy grains a small fraction of a millimeter in diameter. The magnetite results chiefly from the alteration of the olivine and ilmenite, and is therefore rarely, if ever, observed as veritable inclusions in the primary minerals.

The particles picked out of the rock powder by the magnet were treated to an acidulated solution of sulphate of copper in water, and after their removal examination under the microscope showed that many of the grains were coated with copper, indicating that some of the iron was present in the peridotite in a native state.

Abundantly scattered among the other secondary products in the serpentinous network enveloping the remnants of olivine are yellowish clouded grains ranging in size from .004 to .06 millimeters in diameter. The intensity of the yellowish color varies considerably, with a strong inclination towards brown. Its index of refraction is very high, causing it to rise above the neighboring minerals, but its low grade of translucency scarcely more than allows the observer to discover that the mineral is distinctly doubly refracting without determining certainly its degree. The relation of this mineral to the ilmenite clearly indicates that it results from the alteration of the latter and at once suggests that it is a mineral with much titanium, probably titanite or one of the forms of titanic oxide. This is clearly demonstrated by its chemical reactions. With a very sharp steel point a number of these grains were removed from an uncovered section. In the same way a small particle of ilmenite about half replaced by yellow grains adhering to it was isolated. In both cases the material was dissolved in fused $KHSO_4$, and when the product was moistened with a solution of H_2O_2 it turned distinctly yellow, indicating the presence of titanium. The grains are compact and generally spherical, or at most not more than twice as long as thick. Not infrequently one discovers bounding planes to these grains in the sections that are straight and sharply defined, indicating crystallographic form. Such cases are generally accompanied by a higher degree of transparency and are triangular, square, or diamond shaped. When diamondshaped the grains are most strongly doubly refracting and extinction takes place parallel to the longest diagonal. No trace of cleavage could be discovered, nor could the system of crystallization be determined with certainty, but the facts mentioned render it highly probable that the mineral is octahedrite. The occurrence of octahedrite as an alteration product of ilmenite was observed by the author several years ago in "Schalstein" from Hof in the Fichtelgebirge, Germany.[1] Cohen and Rosenbusch,[2] had previously called attention to the same phenomenon in other localities.

Under the microscope the rock is seen to contain an abundance of carbonate irregularly distributed among the secondary minerals. It is plainly a product of alteration, chiefly of the olivine. It is not affected by warm acetic acid, but effervesces vigorously in ordinary hydrochloric acid. After the calcium has been removed from the solution sodium phosphate yields an abundant crystalline precipitate, showing the presence of magnesia and demonstrating that the carbonate is dolomite. It rarely accumulates in nodules as large as a hazel nut and only at points where the rock is highly altered. The high percentage of lime and carbonic acid present in the peridotite, as shown by chemical analysis No. 4, in the table, page 24, indicates that there is about 14 per cent. of dolomite present and that the carbonate of lime largely predominates in its composition. In some cases, as noted by Dr. M. E. Wadsworth[3] and Prof. R. D. Irving,[4] peridotite is almost completely replaced by dolomite resulting from its alteration.

Next to olivine, serpentine is the most important mineral of the rock, and it occurs in two forms: first in the form of small green scales, which, with dolomite, magnetite, ilmenite, and octahedrite, compose the network in which the remaining olivine is inclosed; frequently, however, the olivine has entirely disappeared, and its place in the meshes is represented by yellowish serpentine, quite unlike the first in its color and inclusions. The first form is bright green of varying intensity, but rarely pleochroic, and it has weak double refraction, yielding between crossed nicols a peculiar bluish aggregate polarization. Its appearance under the microscope is like that of chlorite, but, when isolated and treated with sulphuric acid and cæsium chloride, it did not show the presence of alumina.

[1] Anatas als Umwandlungsproduct von Titanit in Biotitamphibolgranit der Troas. Neues Jahrbuch, Vol. I, 1883, p. 187.

[2] H. Rosenbusch: Mikroskopische Physiographie der petrographisch wichtigen Mineralien. Band II, p. 336; also, Zweite Auflage, Band I, p. 332.

[3] Lithological studies: Memoirs of the Museum of Comparative Zoölogy, Cambridge, Mass., Vol. XI, Part I, p. 139.

[4] Fifth Annual Report United States Geological Survey, 1883–'84, p. 217.

Strongly contrasted with the green foliated serpentine is the yellowish fibrous form which with dolomite fills the meshes. It is often distinctly fibrous, and sometimes between the fibers are small radial aggregates which show a distinct cross between opposed nicols. The fibers are sometimes distinctly dichroic; the ray oscillating parallel to the longest axis is yellow and perpendicular to it pale greenish, but generally it is not perceptibly dichroic. This form of serpentine, although free from the larger inclusions so common in the other, contains great numbers of small black grains not more than .002 of a millimeter in diameter. These black grains are probably the magnetite secreted in a very fine form in the process of serpentinization, for this serpentine is slightly magnetic.

RELATIONS AND ORIGIN OF THE PERIDOTITE.

The relation of the peridotite to the carboniferous sandstones and shales is of paramount importance in determining its age and origin. Although it has been repeatedly spoken of as a dike the evidence has not yet been fully presented to establish its eruptive character. Concerning the relation of the peridotite to its associated rocks only two hypotheses are worthy of consideration: (1) the peridotite may be older than the carboniferous strata and may have formed on the floor of the sea a peak about which the horizontal strata were deposited; (2) the peridotite may have been erupted through the carboniferous strata. If the first hypothesis is correct we would expect to find the adjacent sandstone composed largely of detritus derived from the peridotite and to exhibit no evidence of contact metamorphism. On the other hand, if the second hypothesis is true, there would not necessarily be a correspondence in the composition of the neighboring rocks, and under favorable conditions the sedimentary deposits would be metamorphosed near their contact with the eruptive.

The rocks of the neighborhood are so disintegrated and covered with soil that notwithstanding our careful search we were unable to discover an exposure of the junction between the two rocks. Nevertheless sufficient evidence has been collected to definitely settle the problem under consideration. Very near an outcrop of the peridotite at locality 1 occurs a calcareous sandstone of which mineralogical and chemical analyses have been made. It is composed of quartz with a smaller proportion of triclinic feldspar, bent scales of muscovite, and biotite, all of which are cemented by carbonate of lime. The quartz grains are distinctly subangular and not infrequently contain minute needles of rutile. The sandstone is conspicuously unlike the adjacent peridotite in its composition and clearly indicates that the peridotite was not in its present position at the time the sandstone was deposited. This difference is further emphasized by the chemical analysis, No. 7, page 24. When it is compared with the analysis of the peridotite (No. 4) from the same locality the dissimilarity is so prominent as to dispel at once the thought that they may be genetically connected.

This discordance in the composition of the two rocks stimulated the hope of discovering evidence of contact metamorphism, and in this we were not disappointed, for at locality 3 hardened shale was found near the peridotite under such circumstances that its induration is certainly attributable to the influence of the eruptive mass. The effects produced by the peridotite upon the adjacent sedimentary rocks may be considered first and subsequently those experienced by the peridotite itself near the contact. For convenience the shale may be regarded as made up of two classes of constituents, (1) the grains of sand and (2) the matrix or cement in which they are embedded. Among about a dozen specimens of the shale examined the relative proportions of the sand grains and cement vary greatly. In one case the former predominates, so that the rock may be regarded as a fine-grained sandstone, but generally the earthy cement is in excess and frequently forms almost the whole mass. Some of the clear grains are quartz, but most of them are of orthoclase, microcline, or plagioclase feldspar. The matrix varies greatly, consisting chiefly where least altered of a heterogeneous clayey substance containing a multitude of microlites,[1] numerous small scales of mica, and particles of black organic pigment with a trace of magnetite.

The metamorphic influence of the peridotite is clearly traceable in the distribution of the pigment and the development of a crystalline structure in the cement. The latter becomes more and more micaceous in character as the metamorphism increases, and the parallel arrangement of the foliæ renders the rock more easily split, sometimes even fissile in one direction. The distribution of the pigment is generally uniform throughout the mass, but in a portion of one of the sections it is clearly aggregated into groups, giving the section a mottled appearance, and approaches in character the so-called Knotenthonschiefer so admirably investigated by Rosenbusch.[2] The name spilosite has been used to designate such rocks in the contact zone about basic eruptive masses. The dark spots (Knoten) are not visible in the hand specimens, but may be plainly seen in the section and appear to be completely isotropic. The lighter colored areas among these show between crossed nicols doubly refracting grains, which are chiefly mica associated with feldspar. Chemical analysis No. 9 was made of a fragment of indurated shale in which the microscopic spots were most distinctly observed. Analysis No. 10 is of a fragment of shale included in the peridotite. The size and abundance of the mica scales in the altered shale is in a general way proportional to the intensity of the metamorphic influence. A person is frequently surprised, however, to find small fragments of shale, less than a centimeter in diameter, completely enveloped by the peridotite and yet not extremely metamorphosed. In many cases the small fragments are almost completely altered to micaceous minerals,

[1] These microlites correspond exactly to those so frequently observed in clay-slate and in a number of cases have been demonstrated to be rutile. H. Rosenbusch: Mikroskopische Physiographie der petrographisch wichtigen Mineralien. Zweite Auflage, p. 304.

[2] Die Steiger Schiefer und ihre Contactzone an dem Granititen von Barr-Andlau und Hohwald.

which appear to be of several sorts. A portion is completely colorless and when examined in converging light between crossed nicols is found to be distinctly biaxial, but the hyperbolæ when farthest apart do not quite reach the outer limit of the field of vision. It is strongly doubly refracting, with the peculiar sheen commonly observed in muscovite. The other mica is more or less distinctly colored, being greenish or yellowish bordering upon brown, and is distinctly dichroic light to dark yellowish green. It occurs in irregular scales and fibers, with strong double refraction, and appears to be nearly or altogether uniaxial. The colorless mica is frequently continuous with that which contains considerable coloring matter, and I have frequently been in doubt as to the presence of more than one kind of mica.

The included fragments of shale are always surrounded by a border of colorless mica whose scales are intricately intermingled. Frequently, although not generally, the foliæ have their greatest dimension at right angles to the surface of the inclusion. This border varies in width, but is usually about 3 millimeters in thickness and composed almost exclusively of well developed irregular scales of colorless mica. The same mineral is distributed quite abundantly in the enveloped fragment. It appears also sparingly scattered for a short distance away upon the outside of the border among the serpentine and other alteration products of the peridotite. The brownish colored mica, which is so common in the altered shale adjacent to the peridotite, appears very different in the included fragments, where a higher degree of alteration has taken place. It here appears to be a gray, clouded, translucent mass, which, between crossed nicols, is seen to be made up of scales of mica. This advanced stage of metamorphism in the included fragments is accompanied by the appearance of very interesting bodies which have not been definitely determined. They are pale yellowish in color, translucent to almost transparent, and perfectly isotropic. The diameter of these little balls is generally about .02 of a millimeter and they are remarkably uniform in size and shape. In general appearance they closely resemble the small translucent grains of octahedrite in the adjacent peridotite, but they cannot be octahedrite, for they are soluble in hydrochloric acid. When a flake of mica containing them is heated to a bright red heat they become less translucent and somewhat more earthy in appearance, but the change is not prominent. In the small fragments the globules are usually numerous, scattered throughout the scales of clouded mica, but most abundant and less regular in form near the border of the inclusion, where they sometimes produce a quite distinct band just inside the one of colorless mica. In the fragments where this peculiar isotropic substance is most abundant there is but little well developed mica. Traces of other unimportant minerals occur under such circumstances as to render their determination a matter of great difficulty. Rarely among the scales of clear mica in the border which always surrounds included fragments of shale, may be observed elongated particles of a deep brown mineral, which in ordinary transmitted light resembles hornblende, but is not pleochroic, has weak double refraction and an extinction angle of about 37 degrees. The recent discovery that the Kimberley and other diamond mines of South Africa are upon volcanic necks of peridotite penetrating carbonaceous shale[1] attaches much interest to the peridotite of Kentucky, where similar geologic relations exist. Diamonds have not yet been discovered in Kentucky. The shale in the immediate vicinity of the dikes does not appear to be sufficiently rich in carbonaceous matter to excite much enthusiasm.[2]

An endomorphic effect experienced by the peridotite near its contact with the sedimentary rocks is apparently discernible in a structure which may be regarded as variolitic in character. The peridotite at this point contains many fragments of included shale, but in the hand specimens one sees nothing resembling a variolite. In a few of the thin sections, however, here and there among the olivine and its alteration products may be observed light brown, translucent, homogeneous, compact bodies similar in general appearance to the isolated sphærolites which sometimes occur in fresh andesitic rocks. Lighter colored veinlets run through them and between crossed nicols they are seen to be radially fibrous and show a distinct but not sharply defined black cross. The quadrants are rather intensely but not brilliantly red, yellow, or green, with a peculiar fuzzy appearance. These varioles are seen only in sections containing inclusions of shale and appear to be most abundant in their neighborhood; but, on the other hand, small included fragments of shale are frequently observed without any such structure near them.

The facts which indicate the relation of the peridotite to the adjacent carboniferous strata may be briefly recapitulated. In mineralogical and chemical composition the two rocks are very unlike. The carboniferous shales near their junction with the peridotite are greatly indurated by the development of a crystalline structure, which as it augments obliterates the sedimentary character and gives rise to a schistose arrangement of the particles. Fragments of shale of various sizes are included in the peridotite and have been greatly metamorphosed. On the other hand, the peridotite near its junction with the sedimentary rocks, owing to their influence upon it, has locally developed a variolitic structure such as has been not infrequently observed in diabases and other eruptive rocks near their contact with older formations. These facts demonstrate beyond a doubt that the peridotite is a truly eruptive rock which has been forced up through the carboniferous strata. Peridotites are common rocks, but they are almost always associated with others of a highly crystalline character in regions of great disturbance, and their origin cannot be clearly demonstrated. By many authors they are regarded as eruptive, but by others they are considered to belong to sedimentary formations. In one of the very

[1] H. Carvill Lewis: The Genesis of the Diamond, Science, Vol. VIII, p. 345.
[2] The Genesis of the Diamond, Science, Vol. VIII, p. 392, October 29, 1886.

latest works on lithology[1] they are included among "katog ene" rocks, i. e., rocks which, like sandstone, are formed of material deposited at a level lower than its source. In this country the dunite associated with the corundum deposits of North Carolina has been regarded by Dr. A. A. Julien,[2] who studied the rocks both in the field and under the microscope, as a deposit of olivine sand derived from an earlier eruptive mass. Dr. M. E. Wadsworth,[3] after a critical examination, considered them to be eruptive, and my investigations of the same rocks convince me that Dr. Wadsworth's conclusion is correct. The dunite of North Carolina and the one in Elliott County, Kentucky, are essentially the same in structure and composition, and I believe are also of the same eruptive origin. Certain it is that the one in Kentucky is eruptive, and all the essential phenomena in North Carolina point in the same direction. It is important to note, however, a marked difference in the character of the alteration in the two cases. In the dunite of North Carolina, as well as in a number of undescribed peridotites of Northern California and elsewhere,[4] which like it are found associated with highly contorted and metamorphosed strata, the olivine frequently alters to hornblende. In Kentucky, however, where regional metamorphism is entirely absent, no such alteration has been observed.

CHEMICAL COMPOSITION.

The following table presents in a concise form all of the chemical analyses which have been made of the peridotite, its constituents, and associated rocks:

Chemical analyses of peridotite and associated rocks.

	(1) Olivine.	(2) Pyrope.	(3) Ilmenite.	(4) Peridotite.	(5) Peridotite.	(6) Granite.	(7) Calcareous sandstone near peridotite.	(8) Fine grained fissile sandstone near dike.	(9) Indurated shale near dike.	(10) Fragment of shale included in peridotite.
Water at 110° (H_2O)	0.14	0.17	0.20	8.92	10.90	0.51	0.85	1.94	......	1.40
Water at red heat (H_2O)	0.66	......	......	......	......	......	2.32	5.17	8.78	9.00
Carbonic acid (CO_2)	......	......	......	6.66	5.65	......	6.29	......	0.55	0.88
Silicic acid (SiO_2)	40.05	41.32	0.76	29.81	29.43	60.56	60.78	60.25	41.32	35.53
Titanic acid (TiO_2)	0.07	0.16	49.32	2.20	1.48	1.19	0.03	0.23	0.48	0.95
Phosphoric acid (P_2O_5)	0.04	None	Trace	0.35	Trace	0.30	0.09	0.10	0.08	0.08
Chromic oxide (Cr_2O_3)	0.24	0.91	0.74	0.43	0.14	......	......	......	Trace	......
Alumma (Al_2O_3)	0.39	21.21	2.84	2.01	2.36	16.19	10.51	20.18	20.71	18.23
Ferric oxide (Fe_2O_3)	2.36	4.21	9.13	5.16	......	5.19	3.27	1.53	2.59	2.46
Ferrous oxide (FeO)	7.14	7.93	27.81	4.35	9.06	2.41	......	3.42	5.46	4.81

[1] E. Kalkowsky: Elemente der Lithologie, p. 236.

[2] Proceedings Boston Society Natural History, Vol. XXII, p. 141.

[3] Science, Vol. III, p. 286, April 18, 1884.

[4] Mikroskopische Physiographie der petrographisch wichtigen Mineralien. Zweite gänzlich umgearbeitete Auflage, pp. 412, 413.

Chemical analyses of peridotite and associated rocks—Continued.

	(1) Olivine.	(2) Pyrope.	(3) Ilmenite.	(4) Peridotite.	(5) Peridotite.	(6) Granite.	(7) Calcareous sandstone near peridotite.	(8) Fine grained fissile sandstone near dike.	(9) Indurated shale near dike.	(10) Fragment of shale included in peridotite.
Manganous oxide (MnO)	0.20	0.34	0.20	0.23	....	0.36	0.10	0.10	0.17	30.1
Nickelous oxide (NiO)	(CoO) Trace	.....	....	0.05	0.60	......	......	......	....	......
Lime (CaO)	1.16	4.94	0.23	7.69	6.94	2.09	10.15	0.51	9.91	21.17
Magnesia (MgO)	46.68	19.32	8.68	32.41	31.66	1.30	1.59	3.52	1.91	2.01
Potash (K_2O)	0.21	......	....	0.20	0.65	4.82	2.36	3.17	0.88	1.08
Soda (Na_2O)	0.08	0.07	0.19	0.11	0.78	4.78	1.41	0.39	7.19	2.53
Sulphur (S)	......	......	....	None	*0.20	......	......	......	....	......
Sulphuric acid (SO_3)	......	......	....	0.28	0.30	......	......	......	....	......
Total	99.42	100.58	100.10	100.86	100.15	99.70	99.78	100.51	100.03	100.26
Specific gravity	3.377	3.673	4.453	2.781	2.697	2.633	......	......	....	2.489

* In sulphides.

Analysis No. 5 of the peridotite was made by A. M. Peter and J. H. Kastle in the chemical laboratory of the Geological Survey of Kentucky. All the other analyses were made by T. M. Chatard in the chemical laboratory of the United States Geological Survey.

Although the freshest samples of the peridotite were selected for analysis, the large percentage of water and carbonic acid present indicates a high degree of alteration. As compared with the analyses of other typical peridotites the amount of silica appears very low, but this does not necessarily indicate that any of the silica has been removed, for its apparent decrease is due, at least in large part, to the addition of water and carbonic acid from external sources.

LOOSE FRAGMENTS OF FELDSPATHIC ROCKS FOUND WITH THE PERIDOTITE.

At the localities marked 4 and 5 upon the map loose fragments of highly feldspathic rocks occur upon the surface, mixed with the soil containing garnets and ilmenite. The fragments found at the two places, although somewhat dissimilar, are holocrystalline and granitic in structure, altogether unlike the adjacent sandstones and shales, and it is evident that they belong to the eruptive mass. They deserve special attention and will be noticed separately, beginning with those found upon the hillside at locality 4, a short distance northwest of the site of the old furnace. Several fragments were found at this place, scattered along the border of the dike for a distance of 50 yards. The hand specimen looks very like a rotten syenite and is easily crumbled between the fingers. Notwithstanding the fact of its feeble cohesion the feldspar, which is by far the most prominent mineral of the rock, exhibits numerous bright cleavage and crystal faces. Dark colored minerals are not conspicuous. Among these, ilmenite may be easily recognized by its jet black color and brilliant luster. Under the microscope the rock is seen to be composed chiefly of feldspar. Considerable quartz and ilmenite are present, with a trace of hornblende, sphene, and apatite. The feldspar is of two sorts, orthoclase and plagioclase, readily distinguished by their optical characters. They are generally grown together as perthite and may be completely irregular in their interlockings, but frequently the parallel sheets of each, varying from .005 to .01 millimeter in thickness, join in the plane of the orthopinacoid and are quite regular in outline. The orthoclase is somewhat clouded by kaolinization, but the plagioclase is colorless and transparent, with bright polarization between crossed nicols. The polysynthetic twinning which characterizes the plagioclase is generally parallel to the clinopinacoid, but frequently associated with these lamellæ are others parallel to the orthopinacoid. Cleavage lamellæ of the plagioclase parallel to the base have a very small angle (2 degrees) of extinction. This fact indicates that the plagioclase is not pure albite, but has a considerable admixture of the anorthite molecule and is probably oligo clase. This conclusion is substantiated by a test with hydrofluorsilicic acid, which shows the presence of both calcium and sodium. The feldspar, especially the perthitic form, contains numerous inclusions. Besides apatite and ilmenite, the earlier products of crystallization, the feldspar contains numerous acicular groups of light brown scales, whose character could not be definitely determined. The scales are frequently hexagonal in form, and although all are in a row their hexagonal planes may make any angle with the longer axis of the group. These acicular groups generally lie at an angle of about 45 or 90 degrees to the plane of the perthitic lamellæ.

Quartz occurs in clear, colorless grains, the uniaxial positive character of which can be easily demonstrated. It contains occasional liquid and gas inclusions, but none of the kind so common in the feldspar. Quartz and feldspar are each included in the other and must have crystallized synchronously. The green dichroic mineral regarded as hornblende does not appear with well defined crystallographic features. It has rather strong double refraction, but the angle of extinction could not be sharply determined in the absence of well defined cleavage. Chemical analysis No. 6 in the table is of this feldspathic rock. Its mineralogical and chemical constitution indicates that it belongs rather to the granites than to the syenites, although it is closely related to the latter group.

The other specimen of feldspathic rock collected near the eastern end of the dike at locality 5 is quite unlike the one just described. The only fragment found in this case is very solid and fresh in appearance and somewhat gneissoid in structure. In the hand specimen it appears to be composed chiefly of feldspar and garnet and a smaller proportion of a greenish mineral, but in addition to these the microscope reveals the presence of small quantities of quartz, enstatite, apatite, and other accessory minerals. In structure it is holocrystalline and distinctly granular. None of its constituents, excepting the minute acicular inclusions, has a well defined crystallographic outline. The feldspar is plagioclase with a much larger angle of extinction and broader twinning lamellæ than the oligoclase of the other fragment. Orthoclase, if present at all, is rare and does not appear in perthitic growth with plagioclase. Occasionally the feldspar is bent or broken, as if subjected to great strain since its crystallization. Nearly or quite a third of the rock is formed of garnet, which to the unaided eye looks very like the pyrope of the peridotite. It differs from the latter, however, very prominently under the microscope in containing numerous included microlites. These minute acicular crystals are of a yellowish mineral like rutile, but between crossed nicols are seen to be brilliantly doubly refracting with inclined extinction. The angle of extinction varies from 0 degree to 30 degrees, indicating that the mineral crystallizes in the monoclinic system. Cross sections of the small crystals have a rhombic or elliptical outline. Rarely these inclusions are arranged irregularly, but generally they appear to be nearly equally distributed in three sets. The longer axes of the crystals in each set are parallel, but the longer axes of the different sets make an angle of about 45 degrees with one another. Frequently these minute crystals are associated with cavities, as represented in the annexed figure 8.

The first example looks as though the crystal had been formed by partly filling a cavity, of which *a* represents the portion remaining unoccupied. In the second example, however, the cavity *e* is between *b* and *c*, which are optically parallel, indicating that they are parts of the same crystal and that the cavity has been formed by dissolving away its middle portion. Although these inclusions are numerous in the garnet they are even more abundant in the green mineral, which has not been definitely determined. It has almost as high an index of refraction as garnet and is strongly doubly refracting. It is plainly biaxial, with extinction inclined to the indistinct cleavage. The quartz, enstatite, apatite, and a yellowish brown mineral like rutile present nothing worthy of special mention. The structure and mineralogical composition of this rock fragment closely ally it to the granulites.

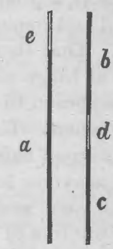

FIG. 8. Included microlites and cavities in garnet.

The presence of the two kinds of fragments of feldspathic rocks intermingled with the soil resulting from the disintegration of the peridotite may be explained in many ways, but from the fact that the dike occurs in nearly horizontal, unaltered, stratified rocks, many scores of miles away from the nearest known outcrops of similar massive terranes, it is highly probable that the fragments are indigenous to the region and were brought to the surface by an eruption. Their striking dissimilarity in composition to the peridotite indicates that they cannot with any considerable degree of probability be regarded as early products of crystallization in the peridotitic magma, but must be looked upon rather as inclusions of the country rock brought up from beneath a vast thickness of unaltered Paleozoic strata. The presence of a number of granitic fragments, nearly in line along the border of the olivine rock, suggests that the granite may have reached the surface by an independent eruption instead of as an inclusion brought up from the depths by the peridotite.

AGE OF THE PERIDOTITE.

Professor Crandall has kindly furnished me the following field notes upon the general geological features of Eastern Kentucky, which have an important bearing upon the age of the peridotite:

The dike is found near the line which marks the eastern limit of the Silurian anticlinal of Ohio and Kentucky, as modified by the final uplift of the Carboniferous series. That the Silurian axis was involved somewhat in this movement is indicated by the conditions as now observed; but there remains a clearly defined anticlinal ridge, with the border of the Coal Measures on its eastward slope, as has been pointed out in various reports on the geology of Eastern Kentucky. The eastward dip is interrupted along a line which is, in a general way, parallel to the border of the coal field. This interruption is more or less prominent as marked by a reduced dip, or by horizontal beds, or even by a reverse dip of the exposed strata. The last condition is more noticeable in Elliott County than elsewhere. The line of change falls but a few miles east of the dike. The reverse and the varying dips eastward and southeast from this line are the result of the upheaval of the Cumberland coal field, a movement which hinged on the Silurian axis along this line. The Silurian axis still remains, a prominent, unmistakable feature, as remarked, but reduced in width eastward and somewhat obscured in the topography as modified by the resulting drainage. That there may have been profound fractures of the rock formations along this line of hinge movement follows as a matter of course. The Elliott County dike may be supposed to add something to the probability of such fractures as the result of this movement. The movement as described may, in turn, throw some light on the occurrence of this outlying dike.

Transverse to the axis of uplift are some minor wave-like undulations, especially southward, and involving Elliott County in part, as noticed in Lesley's report on the outcrop line of the eastern coal field of Kentucky. These undulations have a determinative relation to the drainage, as in the case of the Licking, the Red, and the Kentucky Rivers, and it is not improbable that they may have an important relation to the faults which traverse adjacent parts of the Silurian axis and terminate in the border of the coal field. The most striking modification of the general dip by transverse flexure is found along a belt which extends from the Big Sandy River, south of Louisa, in Lawrence County, to a point opposite to and but a few miles east of the dike. The dip along this belt is to the northward from a ridge of conglomerate rock, which elsewhere falls below the drainage along the border of the coal fields. It is along this slope that the oil and gas developments of Lawrence and Martin Counties are being made. The prominent geological basin centering at Willard is formed by a junction of this northward dip with the general southeast dip, increased by local depression. Willard is about 6 miles in a direct line northeast of the dike.

The dike is found near the juncture of two lines of flexure: one parallel with the axis of uplift of the Coal Measures and the other a transverse or secondary undulation of considerable local prominence. Whether or not these conditions throw light on the occurrence of igneous rock far from any region of great disturbance, they form an interesting, if not a necessary, background to any general view of the dike and its surroundings.

That the eruption of the peridotite occurred since the deposition of the Carboniferous strata with which it is associated is a matter that does not admit of question, but whether or not its extrusion took place at the close of the Carboniferous period synchronously with the plication of the Paleozoic strata of the Appalachian system is difficult to determine.

The very slight disturbance suffered by the strata through which the peridotite reached the surface suggests that its extrusion may not have been connected with the great orographic movements at the close of the Carboniferous age, but rather with the subsequent dislocations, like that of Pine Mountain in Southeastern Kentucky, which, according to Professor Shaler, occurred at a much later date.

SUMMARY.

The rock recently discovered by the State Geological Survey in Elliott County, Kentucky, is a peridotite, which on account of the great predominance of olivine in its composition is closely related to dunite, such as occurs in the corundum region of North Carolina.

Among the interesting features of the peridotite is the occurrence of some of the olivine in well defined crystals. It contains a considerable proportion of pyrope and ilmenite; the former, as in many other peridotites, is surrounded by a fibrous border composed chiefly of biotite.

The peridotite is associated with nearly horizontal Carboniferous sandstones and shales, from which it differs widely in chemical and mineralogical constitution. It not only includes numerous fragments, but has greatly indurated the shale near the contact and has itself suffered endomorphic effects in the production of a sphærolitic structure corresponding to that of variolites. These facts clearly indicate that the peridotite is eruptive and render its occurrence of much importance, for it so rarely happens that peridotites are found under such circumstances that their eruptive character can be fully established.

WASHINGTON, D. C., *April* 26, 1886.

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Washington, D. C., April [illegible]

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[Bulletin No. 39.]

The publications of the United States Geological Survey are issued in accordance with the statute approved March 3, 1879, which declares that—

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

On July 7, 1882, the following joint resolution, referring to all Government publications, was passed by Congress:

"That whenever any document or report shall be ordered printed by Congress, there shall be printed, in addition to the number in each case stated, the 'usual number' (1,900) of copies for binding and distribution among those entitled to receive them."

Except in those cases in which an extra number of any publication has been supplied to the Survey by special resolution of Congress or has been ordered by the Secretary of the Interior, this Office has no copies for gratuitous distribution.

ANNUAL REPORTS.

Of the Annual Reports there have been already published:

I. First Annual Report to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Report of the Director of the United States Geological Survey for 1880–'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 61 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881–'82, by J. W. Powell. 1883. 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882–'83, by J. W. Powell. 1884. 8°. xxxii, 473 pp. 85 pl. and maps.

V. Fifth Annual Report of the United States Geological Survey, 1883–'84, by J. W. Powell. 1885. 8°. xxxvi, 469 pp. 58 pl. and maps.

The Sixth and Seventh Annual Reports are in press.

MONOGRAPHS.

Of the Monographs, Nos. II, III, IV, V, VI, VII, VIII. IX, X, and XI are now published, viz:

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt. U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

V. Copper-bearing Rocks of Lake Superior, by Roland D. Irving. 1883. 4°. xvi, 464 pp. 15 l. 29 pl. Price $1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price $1.05.

VII. Silver-Lead Deposits of Eureka, Nevada, by Joseph S. Curtis. 1884. 4°. xiii, 200 pp. 16 pl. Price $1.20.

VIII. Paleontology of the Eureka District, by Charles D. Walcott. 1884. 4°. xiii, 298 pp. 24 l. 24 pl. Price $1.10.

IX. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. 1885. 4°. xx, 338 pp. 35 pl. Price $1.15.

X. Dinocerata. A Monograph of an Extinct Order of Gigantic Mammals, by Othniel Charles Marsh. 1885. 4°. xviii, 243 pp. 56 l. 56 pl. Price $2.70.

XI. Geological History of Lake Lahontan, a Quaternary Lake of Northwestern Nevada, by Israel Cook Russell. 1885. 4°. xiv, 288 pp. 46 pl. Price $1.75.

The following is in press, viz:

XII. Geology and Mining Industry of Leadville, with atlas, by S. F. Emmons. 1886. 4°. xxix, 770 pp. 45 pl. and atlas of 35 sheets folio.

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The following are in preparation, viz:

I. The Precious Metals, by Clarence King.

— Gasteropoda of the New Jersey Cretaceous and Eocene Marls, by R. P. Whitfield.

— Geology of the Eureka Mining District, Nevada, with atlas, by Arnold Hague.

- Lake Bonneville, by G. K. Gilbert.

— Sauropoda, by Prof. O. C. Marsh.

— Stegosauria, by Prof. O. C. Marsh.

— Brontotheridæ, by Prof. O. C. Marsh.

— Geology of the Quicksilver Deposits of the Pacific Slope, with atlas, by George F. Becker.

— The Penokee-Gogebic Iron-Bearing Series of North Wisconsin and Michigan, by Roland D. Irving.

— Younger Mesozoic Flora of Virginia, by William M. Fontaine.

— Description of New Fossil Plants from the Dakota Group, by Leo Lesquereux.

— Report on the Denver Coal Basin, by S. F. Emmons.

— Report on Ten-Mile Mining District, Colorado, by S. F. Emmons.

— Report on Silver Cliff Mining District, by S. F. Emmons.

— Flora of the Dakota Group, by J. S. Newberry.

BULLETINS.

The Bulletins of the Survey will contain such papers relating to the general purpose of its work as do not properly come under the heads of Annual Reports or Monographs.

Each of these Bulletins contains but one paper and is complete in itself. They are, however, numbered in a continuous series, and may be united into volumes of convenient size. To facilitate this, each Bulletin has two paginations, one proper to itself and another which belongs to it as part of the volume.

Of this series of Bulletins Nos. 1 to 39 are already published, viz:

1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross, with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons. 1883. 8°. 42 pp. 2 pl. Price 10 cents.

2. Gold and Silver Conversion Tables, giving the coining values of troy ounces of fine metal, etc., by Albert Williams, jr. 1883. 8°. 8 pp. Price 5 cents.

3. On the Fossil Faunas of the Upper Devonian, along the meridian of 76° 30′, from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams. 1884. 8°. 36 pp. Price 5 cents.

4. On Mesozoic Fossils, by Charles A. White. 1884. 8°. 36 pp. 9 pl. Price 5 cents.

5. A Dictionary of Altitudes in the United States, compiled by Henry Gannett. 1884. 8°. 325 pp. Price 20 cents.

6. Elevations in the Dominion of Canada, by J. W. Spencer. 1884. 8°. 43 pp. Price 5 cents.

7. Mapoteca Geologica Americana. A catalogue of geological maps of America (North and South), 1752–1881, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.

8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Van Hise. 1884. 8°. 56 pp. 6 pl. Price 10 cents.

9. Report of work done in the Washington Laboratory during the fiscal year 1883–'84. F. W. Clarke, chief chemist; T. M. Chatard, assistant. 1884. 8°. 40 pp. Price 5 cents.

10. On the Cambrian Faunas of North America. Preliminary studies, by Charles D. Walcott. 1884. 8°. 74 pp. 10 pl. Price 5 cents.

11. On the Quaternary and Recent Mollusca of the Great Basin; with Descriptions of New Forms, by R. Ellsworth Call; introduced by a sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert. 1884. 8°. 66 pp. 6 pl. Price 5 cents.

12. A Crystallographic Study of the Thinolite of Lake Lahontan, by Edward S. Dana. 1884. 8°. 34 pp. 3 pl. Price 5 cents.

13. Boundaries of the United States and of the several States and Territories, by Henry Gannett, 1885. 8°. 135 pp. Price 10 cents.

14. The Electrical and Magnetic Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1885. 8°. 238 pp. Price 15 cents.

15. On the Mesozoic and Cenozoic Paleontology of California, by Charles A. White. 1885. 8°. 33 pp. Price 5 cents.

16. On the higher Devonian Faunas of Ontario County, New York, by John M. Clarke. 1885. 8°. 86 pp. 3 pl. Price 5 cents.

17. On the Development of Crystallization in the Igneous Rocks of Washoe, Nevada, by Arnold Hague and Joseph P. Iddings. 1885. 8°. 44 pp. Price 5 cents.

18. On Marine Eocene, Fresh-water Miocene, and other Fossil Mollusca of Western North America, by Charles A. White. 1885. 8°. 26 pp. 3 pl. Price 5 cents.

19. Notes on the Stratigraphy of California, by George F. Becker. 1885. 8°. 28 pp. Price 5 cents.

20. Contributions to the Mineralogy of the Rocky Mountains, by Whitman Cross and W. F. Hillebrand. 1885. 8°. 114 pp. 1 pl. Price 10 cents.

21. The Lignites of the Great Sioux Reservation, by Bailey Willis. 1885. 8°. 16 pp. 5 pl. Price 5 cents.

22. On New Cretaceous Fossils from California, by Charles A. White. 1885. 8°. 25 pp. 5 pl. Price 5 cents.

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22. Observations on the junction between the Eastern sandstone and the Keweenaw series on Keweenaw Point, Lake Superior, by R. D. Irving and T. C. Chamberlin. 1885. 8°. 124 pp. 17 pl. Price 15 cents.
23. List of Marine Mollusca, comprising the Quaternary fossils and recent forms from American localities between Cape Hatteras and Cape Roque, including the Bermudas, by William H. Dall. 1885. 8°. 336 pp. Price 25 cents.
24. The Present Technical Condition of the Steel Industry of the United States, by Phineas Barnes. 1885. 8°. 85 pp. Price 10 cents.
26. Copper smelting, by Henry M. Howe. 1885. 8°. 107 pp. Price 10 cents.
27. Report of work done in the division of Chemistry and Physics, mainly during the fiscal year 1884–'85. 1886. 8°. 80 pp. Price 10 cents.
28. The Gabbros and Associated Hornblende Rocks occurring in the neighborhood of Baltimore, Md., by George H. Williams. 1886. 8°. 78 pp. 4 pl. Price 10 cents.
29. On the Fresh-water Invertebrates of the North American Jurassic, by Charles A. White. 1886. 8°. 41 pp. 4 pl. Price 5 cents.
30. Second contribution to the studies on the Cambrian Faunas of North America, by Charles D. Walcott. 1886. 8°. 369 pp. 33 pl. Price 25 cents.
31. A systematic review of our present knowledge of Fossil Insects, including Myriapods and Arachnids, by Samuel H. Scudder. 1886. 8°. 128 pp. Price 15 cents.
32. Lists and Analyses of the Mineral Springs of the United States; a preliminary study, by Albert C. Peale. 1886. 8°. 235 pp. Price 20 cents.
33. Notes on the Geology of Northern California, by Joseph S. Diller. 1886. 8°. 23 pp. Price 5 cents.
34. On the relation of the Laramie Molluscan Fauna to that of the succeeding fresh-water Eocene and other groups, by Charles A. White. 1886. 8°. 54 pp. 5 pl. Price 10 cents.
35. The Physical Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1886. 8°. 62 pp. Price 10 cents.
36. Subsidence of fine Solid particles in Liquids, by Carl Barus. 1886. 8°. 58 pp. Price 10 cents.
37. Types of the Laramie Flora, by Lester F. Ward. 1887. 8°. 354 pp. 57 pl. Price 25 cents.
38. Peridotite of Elliott County, Kentucky, by Joseph S. Diller. 1887. 8°. 31 pp. 1 pl. Price 5 cents.
39. The Upper Beaches and Deltas of the Glacial Lake Agassiz, by Warren Upham. 1887. 8°. 84 pp. 1 pl. Price 10 cents.

Numbers 1 to 6 of the Bulletins form Volume I; Numbers 7 to 14 Volume II; Numbers 15 to 23 Volume III; Numbers 24 to 30, Volume IV; Numbers 31 to 36, Volume V. Volume VI is not yet complete.

The following are in press, viz:

40. Changes in River Courses in Washington Territory due to Glaciation, by Bailey Willis.
41. Fossil Faunas of the Upper Devonian—the Genesee Section, by Henry S. Williams.
42. Report of work done in the division of Chemistry and Physics, mainly during the fiscal year 1885–'86. F. W. Clarke, chief chemist.
43. On the Tertiary and Cretaceous Strata of the Tuscaloosa, Tombigbee, and Alabama Rivers, by Eugene A. Smith and Lawrence C. Johnson.

In preparation:

— Historic statement respecting geologic work in Texas, by R. T. Hill.
— The Nature and Origin of Deposits of Phosphate of Lime, by R. A. F. Penrose, jr.
— Bibliography of North American Crustacea, by A. W. Vogdes.
— The Gabbros and associated rocks in Delaware, by F. D. Chester.
— Report on Louisiana and Texas, by Lawrence C. Johnson.
— On the subaerial decay of rocks and the origin of the red color of certain formations, by Israel C. Russell.
— Bibliography of North American Geology for 1886, by Nelson H. Darton.

STATISTICAL PAPERS.

A fourth series of publications, having special reference to the mineral resources of the United States, has been undertaken.

Of that series the following have been published, viz:

Mineral Resources of the United States [1882], by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1883 and 1884, by Albert Williams, jr. 1885. 8°. xiv, 1016 pp. Price 60 cents.

Mineral Resources of the United States, 1885. Division of Mining Statistics and Technology. 1886. 8°. vii, 576 pp. Price 40 cents.

Correspondence relating to the publications of the Survey, and all remittances, which must be by postal note or money order (not stamps), should be addressed

WASHINGTON, D. C., April 30, 1887.

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 39

WASHINGTON
GOVERNMENT PRINTING OFFICE
1887

MAP
OF THE
UPPER BEACHES AND DELTAS
OF THE
GLACIAL LAKE AGASSIZ.

Scale, 36 miles to an inch.

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

THE

UPPER BEACHES AND DELTAS

OF THE

GLACIAL LAKE AGASSIZ

BY

WARREN UPHAM

WASHINGTON
GOVERNMENT PRINTING OFFICE
1887

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., June 8, 1886.

SIR: I have the honor to transmit herewith for publication as a Bulletin of the Survey a paper embodying the results of the investigations of Mr. Warren Upham, assistant geologist, upon the upper beaches and deltas of the extinct Lake Agassiz, which, in glacial times, occupied the basin of the Red River of the North.

This is but an initial contribution, embracing only so much of the data gathered as from their degree of completeness and interest warrant present publication as a record of results. The investigation is still in progress, and the general discussion of data and the eduction of conclusions are reserved until its completion. Meanwhile the great mass of carefully determined facts here recorded will, besides their inherent independent value, be of important and immediate service to the students of other extinct and shrunken glacial lakes.

Very respectfully,

T. C. CHAMBERLIN,
Geologist in Charge of Glacial Division.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

UPPER BEACHES AND DELTAS OF LAKE AGASSIZ.

By Warren Upham.

INTRODUCTION.

That part of the extinct Lake Agassiz which lies in Minnesota, so far as it is prairie, was explored by the writer in 1879 and 1881 in connection with the Geological and Natural History Survey of Minnesota, the results of which are partly used in the preparation of this report for the purpose of giving completeness and significance to the observations obtained in the survey to which this bulletin more especially relates.[1]

Further exploration of this lake was begun for the United States Geological Survey by the writer, with Robert H. Young as assistant, in 1885, mapping the upper or Herman beaches in Dakota from Lake Traverse to the international boundary, besides portions of the lower shore lines, with exact determinations of their elevation by leveling. As the Herman beaches and deltas are thus surveyed along the entire extent of Lake Agassiz in the United States, excepting the wooded region of Northern Minnesota, where their exact survey seems impracticable, they are made the subject of the present report, reserving the detailed description of the lower beaches and the inclosed lacustrine area until their exploration within the United States is finished, for which the field work of 1886 will probably suffice.

Discussions of the history of Lake Agassiz and of the causes that have changed the relations of surfaces of level here are mainly deferred to the end of the examination of the whole area of this lake. Observations gathered thus completely may be reasonably expected not only to add much to our knowledge of the conditions attending the glacial

[1] The Geological and Natural History Survey of Minnesota, Eighth Annual Report (1879), pp. 84 to 87, containing a general statement of the exteht of this lake, with notes of its beaches and deltas at a few points, and proposing for it the name Lake Agassiz; and Eleventh Annual Report, pp. 137 to 153, describing and mapping the Herman, Norcross, and Campbell beaches, noting the decrease in the northward ascent of the lake level during its successive stages, and attributing these changed levels to the attraction of the lake by gravitation toward the diminishing ice sheet. This work in Minnesota was done under the direction of Prof. N. H. Winchell, State geologist, with the assistance in 1881 of Horace V. Winchell as rodman in leveling.

period and the recession of the ice sheet but also to shed needed light on the nature and relations of the earth's crust and interior.

The glacial Lake Agassiz is confidently believed to have been formed in the basin of the Red River of the North and of Lake Winnipeg during the final melting and gradual recession of the ice sheet. It thus belongs to the closing epoch of the ice age, when the continental glacier, subdued by a more temperate climate, was yielding its ground between Lake Traverse and Hudson Bay. During this retreat free drainage from the melting ice could not take place, because the descent of the land is northward. As soon as the border of the ice had receded beyond the watershed dividing the basins of the Minnesota and the Red Rivers, it is evident that a lake, fed by the glacial melting, stood at the foot of the ice fields and extended northward as they withdrew along the Red River Valley to Lake Winnipeg, filling this valley and its branches to the height of the lowest point over which an outlet could be found. Until the ice barrier was melted upon the area now crossed by the Nelson River, thereby draining this glacial lake, its outlet was along the present course of the Minnesota River. At first its overflow was upon the nearly level, gently undulating surface of the drift, about 1,100 feet above the sea; but in process of time this cut a channel 125 to 150 feet deep and from 1 to 2 miles wide, in which lie Traverse and Big Stone Lakes, respectively 970 and 962 feet above the sea. From this outlet the plain of the Red River Valley, 30 to 50 miles wide, stretches 315 miles north to Lake Winnipeg, which is 710 feet above the sea. Along this entire distance there is a very uniform continuous descent of a little less than one foot per mile. The drift deposited by the ice sheet upon this area, together with that which may have been dropped by floating ice borne on the waters of the lake, and the silt brought in by glacial rivers and by those of the surrounding land, were here received in a lake, shallow near its mouth, but becoming gradually deeper northward. Beyond our national boundary this lake covered a large area, varying from 100 to 200 miles in breadth at and west of Lake Winnipeg, and its total length appears to have been at least 600 miles. Because of its relation to the retreating continental ice sheet, this lake has been named in memory of Prof. Louis Agassiz, the first prominent advocate of the theory that the drift was produced by land ice.[1]

THE UPPER OR HERMAN BEACH.

Along nearly the whole of the upper shore line of Lake Agassiz, as traced in Minnesota and Dakota, there exists a remarkable deposit of beach gravel and sand, forming a continuous, smoothly rounded ridge, such as is found along any part of the shores of the ocean or of our great

[1] The Geological and Natural History Survey of Minnesota, Eighth Annual Report, for the year 1879, pp. 84, 85.

lakes where the land sinks in a gently descending slope beneath the water level. Usually the beach of Lake Agassiz (Fig. 1) is a ridge 3 to 10 feet above the land next to it on the side away from the lake and 10 to 20 feet above the land adjoining it on the side where the lake lay. In breadth this beach ridge varies from 10 to 25 or 30 rods. It is thus a broad wavelike swell, with a smooth, gracefully rounded surface.

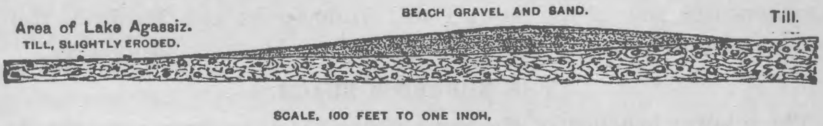

FIG. 1. Typical section across a beach ridge of Lake Agassiz.

Such being a section across the beach, it is to be remembered that this ridge extends along the whole distance that has been explored, with only here and there gaps where it has been cut through by streams and rare intervals—of a quarter or a half of a mile, or, at the longest, 2 or 3 miles—where the outline of the lake shore or the direction of the shore currents prevented such accumulation. It is also deficient on the shores of the strait that occupied the Elk and Golden Valleys in Dakota, but is well developed along the chain of islands east of this strait. There are similar interruptions in the beaches of present lakes and on the sea coast; and, like these modern deposits, the beach of Lake Agassiz varies considerably in its size, having in any distance of 5 miles some portions 5 or 10 feet higher than others, due to the unequal power of waves and currents at these parts of the shore. The usually moderate slope of the land toward Lake Agassiz was favorable for the formation of a beach ridge, and one has been clearly traced as an essentially continuous formation along a distance of 400 miles in Minnesota and Dakota. In calling it continuous, I mean to say that whenever interrupted it is found a little distance farther along, beginning again at very nearly the same height.

The gaps where the beach is not a distinctly traceable ridgelike deposit of gravel and sand cannot exceed one-tenth of its whole course. In a few places the lake undermined its shore, forming a terrace in the till, with no definite beach deposit, the work of the waves having been to erode and carry away rather than to accumulate. In other places—sometimes 2 or 3 miles in length—the area where this ancient lake had its margin is a marsh or shaking bog, full of spring water and rough with hummocks of grass.

Commonly the land upon each side of this beach of Lake Agassiz is till or unstratified clay, containing some intermixture of sand and gravel and occasional stones and bowlders. The material of the beach ridge is remarkably in contrast with this adjoining and underlying till, for it includes no clay, but consists of stratified sand and gravel, the largest pebbles being usually from 2 or 3 to 6 inches in diameter. No bowlders referable to transportation by floating ice have been found in any of the beach deposits of this lake.

When Lake Agassiz stood at its greatest height and formed the upper beach, its outlet was about 75 feet above the present surface of Lake Traverse, or 1,045 feet above the sea. The channel which at this time had been excavated in the drift by its outflow was 40 to 50 feet deep along the distance of about 50 miles, where are now Lake Traverse, Brown's Valley, and Big Stone Lake. This beach is crossed by the Breckenridge line of the Saint Paul, Minneapolis and Manitoba Railway at a point about 1½ miles northwest from Herman, Minnesota.

THE NORCROSS BEACH.

Three lower beaches, of the same character as to form, size, and material with the highest, have been also noted; their course has been traced through long distances and their height has been determined by leveling. At the next epoch after that of the upper or Herman beach, when the lake level was again nearly stationary long enough to form a ridge of gravel and sand upon its shore, the outlet had been eroded about 20 feet deeper than at the time of the upper beach, but was still 55 feet above the present Lake Traverse and Brown's Valley. The beach of Lake Agassiz, when it had this lower level, is crossed by the Breckenridge railway line at Norcross, Minnesota, 5 miles northwest from Herman.

THE CAMPBELL BEACH.

A third series of beach deposits was formed when the outlet of Lake Agassiz had been lowered some 50 feet more, nearly to the level of Lake Traverse. The beach of this third stage of Lake Agassiz takes its name from the township of Campbell (T. 130, R. 46), in the southern part of Wilkin County, Minnesota, which it crosses from southwest to northeast.

THE M'CAULEYVILLE BEACH.

The fourth and lowest beach of Lake Agassiz, while it outflowed to the south, was formed after a further erosion of 15 feet, lowering the outlet to 960 feet above the sea and completing the excavation of its channel to the present beds of Traverse and Big Stone Lakes. My first observation of this beach was 3½ miles northeast from McCauleyville (T. 134, R. 48), in Wilkin County, Minnesota.

Four distinct series of beach ridges of gravel and sand were thus formed by Lake Agassiz at successive stages of height during its process of deepening the channel by which it outflowed southward.

THE RED RIVER VALLEY.

The central part of the basin of Lake Agassiz, within the limits of Minnesota and Dakota, now drained by the Red River, has an exceedingly flat surface, sloping imperceptibly northward, as also from each side to its central line. The Red River has its course along the axial depression, where it has cut a channel 20 to 60 feet deep. It is bordered by only few and narrow areas of bottom land, instead of which its banks usually rise steeply on one side and by moderate slopes on the other to the lacustrine plain, which thence reaches nearly level 10 to 30 miles from the river. Its tributaries cross the plain in similar channels, which, as well as the Red River, have occasional gullies connected with them, dry during most of the year, varying from a few hundred feet to a mile or more in length. Between the drainage lines areas often 5 to 15 miles wide remain unmarked by any watercourses. The highest portions of these tracts are commonly from 2 to 5 feet above the lowest.

This vast plain, 40 to 50 miles wide, lying half in Minnesota and half in Dakota and stretching from Lake Traverse and Breckenridge north to Winnipeg, is the widely famed Red River Valley, the most fertile wheat land of the continent. The material of the lower part of this ancient lake bed, shown in the banks of the Red River and reaching several miles from it, is fine clayey silt, horizontally stratified, but its south end and large areas of each side of this plain are mainly unstratified bowlder clay, which differs from the rolling or undulating till of the adjoining region only in having its surface nearly flat. Both these formations are almost impervious to water, which therefore in the rainy season fills their shallow depressions; but these are very rarely so deep as to form permanent lakes. Even sloughs that continue marshy through the summer are infrequent, but where they do occur they cover large tracts, usually several miles in extent.

On all the area drained by the Red River in Minnesota the glacial drift is so thick that no exposures of the underlying rocks have been found, and they have only few outcrops within this basin in Dakota. The depth of the drift varies from 100 to 250 feet. The prominent topographic features of all this region are doubtless due to the form of the underlying rock surface, upon which the drift is spread in a sheet of somewhat uniform thickness.

Erosion, before the ice age, had sculptured the rocks that are buried and concealed under this universal drift sheet and had formed the broad, nearly level depression of the Red River Valley, which in the United States is 1,000 to 800 feet, from south to north, above the sea. Slopes and terraces of these rocks beneath the drift cause the rise eastward from this valley to the lake-sprinkled plateau, 1,300 to 1,500 feet above the sea, which reaches from Glenwood, Alexandria, and Fergus Falls to the sources of the Mississippi. For example, though the traveler finds no ledge of rock in going from the Red River at Fargo and Moorhead 75 miles east-northeast to Itasca Lake, it yet appears that the form of the surface, marked by two remarkable terraces, is due to that of the bed rock. The flat of the Red River Valley extends from Moorhead to about 6 miles east of Glyndon, with a slight ascent of about 50 feet in these 15 miles. The next 2 or 3 miles rise 200 feet to the top of a terrace, which reaches from south to north the whole length of the Red River Valley in Minnesota, though it is not all the way so distinct nor so high as here. Beyond this ascent the surface is again nearly level, being a sheet of slightly undulating or rolling till, with a rise of perhaps 4 or 5 feet per mile, through 25 miles eastward. Next is a terrace, also reaching a long distance from south to north, which is ascended in 3 or 4 miles, rising about 300 feet, to the White Earth Agency, which thus commands a very extensive western prospect. Thence a more rolling plateau extends, with little change in the average height, 30 miles eastward to Itasca Lake.

In like manner the elevation of the Coteau des Prairies, 1,500 to 2,000 feet above the sea, and the terracelike ascent at the west side of the flat Red River Valley in Dakota, lying at a distance of 20 to 35 miles west of the Red River and stretching from the south bend of the Sheyenne River north to the British line, where it is called Pembina Mountain, are due to the contour of the bed rock, rather than to differences in the thickness of the drift.

The till upon each side of Lake Agassiz has a moderately undulating and rolling surface. Within the area that was covered by this lake it has a much smoother and more even contour, but has been only slightly stratified. The action of its waves gathered from this deposit of till, which was the lake bed, the gravel and sand of its beaches; and corresponding deposits of stratified clay, derived from the same erosion of the till, sank in the deeper part of the lake. But these sediments were evidently of small amount and are not noticeable upon the greater part of this lacustrine area, which consists of a smoothed sheet of till. The position of the thick beds of stratified fine silt and clay in the central depression of the Red River Valley shows that they were not deposited by the waters of Lake Agassiz, which must have spread them more generally over its entire area; but, instead, proves that they were brought by the rivers which flowed into this hollow and along it northward after the glacial Lake Agassiz had been reduced to its present representative, Lake Winnipeg. The occurrence of shells and remains of vegetation in these stratified beds at McCauleyville 32 and 45 feet below the surface, or about 7 and 20 feet below the level of the Red River, and numerous other observations of remains of vegetation elsewhere along the Red River Valley in these beds, demonstrate that the valley was a land surface, subject to overflow by the river at its stages of flood, when these remains were deposited. Even at the present time much of the area of stratified clay is covered by the highest floods, and probably no portion of these stratified deposits is more than 10 feet above the high water line of the Red River and its tributaries.

THE OUTLET OF LAKE AGASSIZ.

The excavation of the remarkable valley occupied by Lakes Traverse and Big Stone and the Minnesota River was first explained in 1868 by General G. K. Warren, who attributed it to the outflow from this ancient lake that filled the basin of the Red River and Lake Winnipeg. He made a careful survey of this valley from Lake Traverse to its mouth, and his maps and descriptions, with the accompanying discussion of geologic questions, are most valuable contributions to science.[1] After his death, in recognition of this work, the glacial river that was the outlet of Lake Agassiz was named River Warren.[2]

The heights of Lakes Traverse and Big Stone are, respectively, 970 and 962 feet above the sea, and the lowest point of the divide between them is only 3 feet above Lake Traverse. These lakes are from 1 to 1½ miles wide, mainly occupying the entire width of this troughlike valley, which is inclosed by bluffs of till about 125 feet high. Lake Traverse is 15 miles long; it is mostly less than 10 feet deep and its greatest depth probably does not reach 20 feet. Big Stone Lake extends in a somewhat crooked course from northwest to southeast 26 miles; its greatest depth is reported to be from 15 to 30 feet. The portion of the channel between these lakes is widely known as Brown's Valley. As we stand upon the bluffs here, looking down on these long and narrow lakes and the valley which extends across the 5 miles between them, where the basins of Hudson Bay and the Gulf of Mexico are now divided, we have nearly the picture that was presented when the melting ice sheet of British America was pouring its floods along this hollow. Then the entire extent of the valley was doubtless filled every summer by a river which covered all the present areas of flood plain, in many places occupying as great width as these lakes. General Warren observed that Lake Traverse is due to a partial silting up of the channel since the outflow from the Red River basin ceased, the Minnesota River at the south having brought in sufficient alluvium to form a dam, while Big Stone Lake and Lac qui Parle are similarly due to the deposits of stratified sand and silt which the Whetstone and Lac qui Parle Rivers have spread across the valley below them.

THE NORTHERN BARRIER.

The northern barrier by which the water of Lake Agassiz was restrained from flowing in the direction of the present drainage to Hudson Bay was supposed by General Warren to have been an elevation of the land much above its present height northeast of Lake Winnipeg.

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[1] "On certain physical features of the Upper Mississippi River," American Naturalist, Vol. II, pp. 497–502, November, 1868. Annual Report of the Chief of Engineers, United States Army, for 1868, pp. 307–314. "An essay concerning important physical features exhibited in the valley of the Minnesota River, and upon their signification," with maps, Report of Chief of Engineers, 1875. "Valley of the Minnesota River and of the Mississippi River to the junction of the Ohio. Its origin considered—depth of the bed-rock," with maps, Report of Chief of Engineers, 1878, and American Journal of Science, (3) XVI, pp. 417–431, December, 1878. (General Warren died August 8, 1882.)

[2] Proceedings of the American Association for the Advancement of Science, Vol. XXXII (for 1883), pp. 213 to 231; also in American Journal of Science, (3) XXVII, January and February, 1884; and Geology of Minnesota, Vol. I, p. 622.

He thought that this elevation was shared by other northern portions of North America and that these regions have recently been depressed at least several hundred feet. The depths of the great lakes and many topographic features of the interior of the continent, besides this channel of Lakes Traverse and Big Stone and the Minnesota River, appeared to him to support this opinion. On the contrary, my belief is that the surface of the continent had nearly the same form then as now and that the continental ice sheet, resting on the land in a solid mass of great depth, formed the northern shore of Lake Agassiz and was the barrier that prevented it from flowing into Hudson Bay.[1]

The four series of beach deposits which mark the shores of Lake Agassiz at as many stages of its height are found to have a gradual ascent northward, as compared with the present level line or the surface which a body of water would have now if confined in this valley. As before stated, these beaches were formed at epochs when the lake level was nearly stationary for a considerable time during the excavation of its channel of outlet at Lake Traverse and southward.

Exploration and leveling along the upper beach in Minnesota extended from the north end of Lake Traverse about 25 miles eastward to Herman, and thence about 140 miles north to Maple Lake. Through this distance it lies from 15 to 30 miles east of the Red River. The ascent of this beach northward is at a rate that increases from 6 inches to 1 foot a mile in its southern portion for about 75 miles. Farther north its rate of ascent increases from 1 foot to 16 inches a mile. In all, the surface of Lake Agassiz in Minnesota at this time of its greatest height ascended northward, above a line now level, 125 feet in these 140 miles, from 1,045 feet, very nearly, above sea at Lake Traverse, to 1,170 feet, very nearly, at the north side of Maple Lake, 20 miles east-southeast from Crookston. Through this distance the upper beach clearly marks one continuous shore line.

Before Lake Agassiz had fallen below the line of this beach in the south half of its explored extent, it had formed a slightly lower parallel beach, three-fourths of a mile to 1½ miles distant, through the northern third of Clay County; and this secondary beach, sometimes double or treble, was noted at several places along the next 30 miles northward. At the northwest side of Maple Lake definite beach ridges were formed when Lake Agassiz had fallen in that latitude successively about 8, 15, 30, and 45 feet from its highest level. Yet all these beaches were accumulated while the lake remained with only very slight depression of

[1] That this lake existed because of the barrier of the receding ice sheet was pointed out by Prof. N. H. Winchell in his First Annual Report of the Geological and Natural History Survey of Minnesota, for 1872, p. 63, and in his Sixth Annual Report, for 1877, p. 31. He also explained in like manner the formerly higher levels of the great lakes, Popular Science Monthly, June, 1873; and the same view is stated by Prof. J. S. Newberry in Report of the Geological Survey of Ohio, Vol. II, 1874, pp. 6, 8, and 51.

level, not sufficient for the formation of any secondary beach ridge, along its southern part for some 75 miles northward from Lake Traverse and Herman.

The Norcross beach in Minnesota has been explored and its height measured through the same distance of 140 miles, in which it ascends northward about 62 feet by a slope that increases slightly from south to north, averaging nearly 6 inches a mile. The surface of Lake Agassiz had fallen at this time from its highest level 20 feet at Lake Traverse, 50 feet in Northern Clay County, and 83 feet northwest of Maple Lake. Its fall in this extent had been thus 63 feet more at the north than at the south. Double and multiple ridges occur along the northern half of this distance and show that the lake level at the time of formation of the Norcross beach fell 5 to 10 feet northward, while it remained without change or with less change than was required to form additional beach ridges southward.

The heights of the Campbell and McCauleyville beaches in Minnesota are known for a distance of 150 miles, in which the northward ascent of the lake level during the Campbell stage was about 37 feet and during the McCauleyville stage 25 feet. The fall of Lake Agassiz from the upper or Herman beach to the McCauleyville beach was 85 feet at its mouth and 185 feet near Maple Lake; and, instead of the northward ascent of the upper beach 125 feet in 140 miles, this had been gradually diminished to 117, 110, 95, 80, 62, 50, 37, and finally 25 feet at the time of the formation of the McCauleyville beach.

In Dakota the same series of beaches are found and they have been traced along the whole or parts of their course, with determination of their elevations, to a distance about 75 miles farther north than in Minnesota. In 224 miles from Lake Traverse to the international boundary the lake level in Dakota at its highest stage, during the time of formation of the first Herman beach, ascended northward about 185 feet, from 1,045 to 1,230 feet above the sea; during the time of the first Norcross beach it ascended 120 feet, from 1,025 to 1,145 feet; during the time of the Campbell beach it ascended 65 feet, from 975 to 1,040; and during the time of the first McCauleyville beach it ascended 35 feet, from 960 to 995 feet above our present sea level. A later McCauleyville beach shows only 25 feet ascent in these 224 miles, or an average of 1⅓ inches a mile.

Comparison of the elevations of these beaches in Dakota and Minnesota at the same latitude reveals another very interesting feature of the levels of this glacial lake, namely, an ascent from west to east similar to that from south to north, but of less amount and diminishing in a similar ratio between the successive stages of the lake. On the latitude of Larimore and Grand Forks the ascent of the lake surface above a line now level was approximately 33 feet, at the time of the first Herman beach, in about 70 miles from west to east, the rate per mile being very nearly half as much as from south to north; and during the time of formation of the later Herman beaches it diminished to 30, 26, and 21 feet. When the first and second Norcross beaches were formed this ascent toward the east was 14 and 11 feet in about 60 miles, and during the Campbell and McCauleyville stages it was reduced to only 6 and 4 feet in about 50 miles; yet it continues through all these stages approximately half as much per mile as the ascent toward the north. The rate of ascent eastward also increased, like that northward, in proceeding from south to north. At the latitude of Wahpeton and Breckenridge, 35 miles north from the mouth of Lake Agassiz, the ascent of the lake level in its highest stage was 10 feet from west to east in 45 miles; at the latitude of Fargo and Moorhead, 75 miles north from the outlet, it was 15 feet in 50 miles; and at the latitude of Grand Forks, 150 miles north from the outlet, it was 33 feet in 70 miles, approximately. The accompanying table shows the relations of these beaches and the changes which took place in surfaces of level here during the existence of this glacial lake.

If the barrier north and northeast of Lake Agassiz had been land, its subsidence to give way for drainage northward in its present course to Hudson Bay would cause the beach deposits of the former lake shores to have the opposite slope, or a descent from south to north and from west to east. These observations are therefore inconsistent with such explanation of the cause of this lake; but they appear to prove that its northern barrier was the receding continental glacier. I have thought that all the differences of the once level lines of Lake Agassiz from our present level line might have been produced by the gravitation of the water of the lake toward the ice sheet. At first this attraction would have been relatively large, because of the nearness of the great mass of ice on the northeast in Minnesota and northward in British America; but as the ice retreated it must have been gradually diminished and reduced to a comparatively small influence by the time the ice sheet had withdrawn so as to permit the northward drainage of the lake.

Among other agencies that have been proposed to account for such changes are (1) effects due to the weighting of the earth's crust by the ice and its removal; (2) the cooling and contraction of the crust by the ice and glacial waters, and the subsequent warming and expansion owing to the amelioration of the climate; and (3) crust changes of unknown origin, having no relationship to the glacial phenomena.[1] These several agencies will receive studious consideration in my final report, when a more extended range of observations will come under review.

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[1] Prof. T. C. Chamberlin, Geology of Wisconsin, Vol. I, 1883, p. 290, and Proc. Am. Assoc. Adv. Sci., Minneapolis meeting, Vol. XXXII, 1883, page 212; also, paper before Philosophical Society, Washington, March 13, 1886.

Mr. G. K. Gilbert, American Journal of Science (3), XXXI, pp. 290-299, April, 1886

AREA AND DEPTH OF LAKE AGASSIZ.

The beaches of Lake Agassiz, as here described in Dakota and from Lake Traverse and Herman north to Maple Lake, in Minnesota, extend through a prairie region very favorable for exploration and leveling. The farther course of the upper beach turns to the east and northeast and lies in a trackless forest, much of which consists of almost impassable tamarack swamps. It is therefore quite impracticable to trace its course exactly through this wilderness; but, from the known elevation of Red Lake (about 1,150 feet above the sea), of the Lake of the Woods (1,062 feet), and of Rainy Lake (about 1,120 feet), the outline of Lake Agassiz when it had its greatest height can be mapped approximately.

From the north side of Maple Lake this outline extends eastward, passing south of Red Lake, across the Big Fork of Rainy River, and along the south side of Rainy Lake, its height above Red and Rainy Lakes being probably about 50 and 150 feet, respectively. Thus Lake Agassiz at this time of greatest height reached along the international boundary farther east than the meridians of Minneapolis and Saint Paul. Its expanse included only few islands, these being of small area and near the shore.

When this glacial lake attained its greatest extent, it probably exceeded Lake Superior, both in length and in area. At the time of the formation of its highest beach the depth of Lake Agassiz above Fargo and Moorhead was nearly 200 feet; above Grand Forks and Crookston, a little more than 300 feet; and above Pembina and Saint Vincent, about 450 feet.

In the following tabulations the figures represent the height, in feet, above sea level, where not otherwise stated.

The letters *a*, *b*, *c*, *d*, represent successive beaches along the northern part of Lake Agassiz, which seem to be merged in a single beach toward its south end.

The columns marked *north ascent* show the ascent of the lake from its south end, which was at Lake Traverse, and those marked *east ascent* show the ascent of the lake from its western to its eastern shore.

The successive elevations of the mouth of Lake Agassiz, situated at its south end (Lake Traverse), were, for the Herman beach, 1,045 feet; for the Norcross beach, 1,025 feet; for the Campbell beach, 975 feet; and for the McCauleyville beach, 960 feet.

Elevations of the crests of the beaches of Lake Agassiz.

[The figures in parenthesis are derived for the boundary line from the nearest observations, chiefly near Walhalla, for which the figures without the parenthesis stand; similarly, the figures in parenthesis for the latitude of Grand Forks are derived from observations near Maple Lake, 15 miles south, for which the figures without parenthesis stand.]

Location.	Herman beach.			Norcross beach.			Campbell beach.			McCauleyville beach.		
		East ascent.	*North ascent.*		*East ascent.*	*North ascent.*		*East ascent.*	*North ascent.*		*East ascent.*	*North ascent.*
(1) On the international boundary line in Dakota, 224 miles north of Lake Traverse. (Only the west or Dakota shore could be examined at the boundary.)	(*a*) 1,226 (1,235)	....	(185)	(*a*) 1,140 near Young (1,155).	....	(120)	1,050	....	65	(*a*) 1,004 (1,006)	....	(35)
	(*b*) 1,212 (1,220)	....	(166)	(*b*) 1,141 (1,143)	....	(108)				(*b*) 992 (994)	....	(25)
	(*c*) 1,197 (1,202)	....	(149)									
	(*d*) 1,182 (1,187)	....	(135)									
(2) On the latitude of Grand Forks, 150 miles north of Lake Traverse, west side, in Dakota.	(*a*) 1,162	....	107	(*a*) 1,092	....	57	1,014	....	31	(*a*) 991	....	21
	(*b*) 1,146	....	93	(*b*) 1,080	....	47				(*b*)	....	....
	(*c*) 1,134	....	80									
	(*d*) 1,121	....	69									
(2) On the latitude of Grand Forks, 150 miles north of Lake Traverse, east side, in Minnesota.	(*a*) 1,180 (1,195)	(33)	125 (140)	(*a*) 1,094 (1,103)	(14)	62 (71)	1,022	6	37	(*a*) 996	4	25
	(*b*) 1,165 (1,178)	(30)	110 (123)	(*b*) 1,082 (1,090)	(11)	50 (58)				(*b*) 989	....	18
	(*c*) 1,147 (1,158)	(26)	95 (106)									
	(*d*) 1,132 (1,141)	(21)	80 (90)									
(3) On the latitude of Fargo and Moorhead, 75 miles north of Lake Traverse, west side, in Dakota.	1,099	....	45	....	....	....	997	....	15	....	....	....
(3) On the latitude of Fargo and Moorhead, 75 miles north of Lake Traverse, east side, in Minnesota.	1,114	15	60	1,065	....	30	1,002	3	18	983	....	13
(4) On the latitude of Wahpeton and Breckenridge, 35 miles north of Lake Traverse, west side, in Dakota.	1,065	....	10	....	....	....	....	....	....	972	....	4
(4) On the latitude of Wahpeton and Breckenridge, 35 miles north of Lake Traverse, east side, in Minnesota.	1,075	10	20	1,045	....	10	992	....	7	....	....	....

THE UPPER OR HERMAN BEACH IN MINNESOTA.[1]

[See the accompanying map, Plate I.]

FROM LAKE TRAVERSE EAST TO HERMAN.

Lake Traverse, elevation 970 feet above the sea.

Bluffs next to Lake Traverse south from the Mustinka River, elevation 1,072 to 1,075 feet above the sea.

Bluffs opposite to these and for 3 or 4 miles northward, on the west side of Lake Traverse, 1,090 to 1,070 feet.

Bluff or ridge forming the highest land between the Mustinka River and the Bois des Sioux River, from Sec. 35 to Sec. 13, T. 128, R. 47 (the west part of Monsen), an island beach ridge of Lake Agassiz during its maximum stage, about 1,050 feet.

Upper or Herman beach in Secs. 2 and 11, T. 126, R. 47 (Walls), 1,060 to 1,062 feet, 4 to 5 miles east from the north end of Lake Traverse, where the steep eroded bluff gives place to the gentle slope of the natural surface, allowing the accumulation of a distinct beach ridge of gravel. This is smoothly rounded, 15 to 20 rods in width, bounded eastward on the side toward the ancient lake by a moderately steep slope which descends 10 or 12 feet, the land 1 to 4 miles distant northeastward within the area that was covered by the lake being 20 to 40 feet below this beach. On the other side this ridge is succeeded by a slight depression 2 to 5 feet deep, beyond which the land soon rises 10 to 15 feet above the beach. The material of the beach is gravel, containing pebbles up to 2 or 3 inches in diameter, but all the surface elsewhere on each side is till.

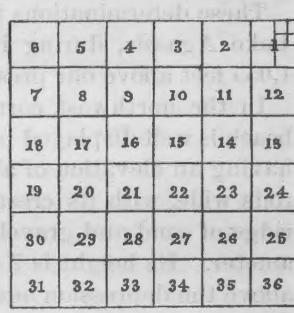

FIG. 2. Map of a township, showing its division in sections.

Beach in Secs. 30 and 32, T. 126, R. 46 (Croke), passing southeastward near the southeast corner of Sec. 30, 1,066 to 1,067 feet.

Beach near the middle of Sec. 9, T. 125, R. 46 (Tarrah), 1,057 feet. Its contour and material and those of the adjoining areas are nearly the same as at the locality already described. The width of the gravel beach here is 25 or 30 rods; the smoothed surface of till which descends thence northward is 10 to 20 feet lower in its first mile; on the south the sheet of till is at first for 40 or 50 rods about 5 feet lower than the top of the beach, but beyond this it gradually rises to a height 10 to 25 and 50 feet above the beach. The average height of its moderately undulating surface, 6 miles to the south at Graceville, is nearly represented by the railroad at the depot there, 1,107 feet.

[1] The townships herein referred to are numbered north from the base line, and the ranges are numbered west from the fifth principal meridian. The method of numbering the sections is shown by Fig. 2, above.

Beach at Dennis W. O'Brien's house, in the SW. ¼ of Sec. 11, T. 125, R. 46, 1,061 to 1,062½ feet. Northward from O'Brien's, as far as the view reaches, across T. 126, R. 46 (Croke), and T. 126, R. 45 (Doleysmount), Lake Agassiz was very shallow, the smooth and nearly level surface of till being 1,045 to 1,035 feet above the sea.

For the next 3 miles eastward the beach is less conspicuous than usual. In the northwest part of Sec. 8, the SE. ¼ of Sec. 5, and through the middle of Sec. 4, T. 125, R. 45 (Leonardsville), this shore line is again distinctly marked by a slight terrace in the till, descending northward in a moderately steep slope 5 to 10 feet, rather than by the usual accumulation of gravel. The top of this terrace is at 1,056 to 1,057 feet. The house of Patrick Leonard is built upon the edge of this terrace at the middle of the east side of section 4.

Beach, low gravel ridge 20 rods wide, 5 feet high above adjacent level, in the southeast part of Sec. 24, T. 126, R. 45 (Doleysmount), 1,060 to 1,061 feet.

These determinations indicate that in Traverse County the surface of Lake Agassiz, during its maximum stage, was very nearly 1,045 to 1,055 feet above our present sea level.

In the northwest corner of Stevens County this upper or Herman beach is well displayed in the NW. ¼ of Sec. 19, T. 126, R. 44 (Eldorado), having an elevation of about 1,063 feet. Through Sec. 18 it is 20 to 25 rods wide, with its crest at 1,063 to 1,066 feet, being a gently rounded ridge of sand and gravel, containing pebbles up to 2 or 3 inches in diameter. Its height is 7 to 10 feet above the land next west and 5 feet above the depression next east. The surface on each side is till, slowly falling westward and rising eastward.

In the southeast part of Sec. 7, same township, the crest of the beach is at 1,067 to 1,070 feet. Here and onward the next two miles, through the NW. ¼ of Sec. 8, the southeast part of Sec. 5, and the western and northern part of Sec. 4, this formation is finely exhibited in a ridge of gravel and sand 20 to 30 rods wide, 15 feet or more above its base westward, where lay the glacial Lake Agassiz, and 8 to 10 feet above the depression eastward, which divides it from the higher, moderately undulating expanse of till beyond. In the east part of Sec. 5 its elevation is 1,065 feet, and through Sec. 4, 1,065 to 1,072 feet.

Sill of Ezra S. Dunning's house, Sec. 3, T. 126, R. 44 (Eldorado), 1,074 feet.

Water in the South Branch of Mustinka River, 5 feet deep, in the NW. ¼ of Sec. 34, T. 127, R. 44 (Logan, Grant County), 1,053 feet.

Upper or Herman beach, in the northwest part of Sec. 27, same township, 1,067 to 1,069 feet; in the SW. ¼ of Sec. 22, 1,067; in the north part of this Sec. 22 and the south part of Sec. 15, forming a broad, smoothly rounded gravel ridge, 1,068 to 1,071 feet.

This beach near the middle of Sec. 15, a third of a mile southwest from Dr. C. O. Paquin's, about 30 rods wide, with a broad, nearly flat top, 1,070 feet, having a descent of about 15 feet on its northwest side to the area of Lake Agassiz and half as much on the southeast, the surface thence rising very gradually in the 1½ miles eastward to Herman. The beach ridge is gravel; the land at each side, till.

Beach, equally well exhibited, close to Dr. Paquin's house, at the southeast corner of Sec. 10 and in the southwest part of Sec. 11, same township, 1,069 to 1,071 feet; and in this Sec. 11, at the railroad, and for 50 rods southwestward, 1,064 to 1,066 feet.

Depression, 40 rods wide, next southeast at the railroad (lowest 20 rods from the top of the beach), 1,060 to 1,063 feet.

Surface of till at the southeastern snow fences of the railroad, about a third of a mile southeast from the beach, 1,073 feet; at the northwest end of the northwestern snow fences, about 25 rods northwest from the highest part of the beach, 1,054 feet; and at the one hundred and eightieth mile post, about a quarter of a mile northwest from the last, 1,049 feet.

Saint Paul, Minneapolis and Manitoba Railway, Breckenridge division, track at Herman, 1,070 feet; at the one hundred and eightieth mile post, 1,051 feet.

FROM HERMAN NORTH TO THE RED RIVER.

Joseph Moses's house, floor of piazza, in the SW. ¼ of the NW. ¼ of Sec. 18, T. 128, R. 43 (Delaware), 1,067 feet; upper or Herman beach here, on which this house is built, 1,066 to 1,067 feet.

H. D. Kendall's house, at the east side of the SE. ¼ of Sec. 12, T. 128, R. 44 (Gorton), on the western slope of this beach, 1,062 feet; top of the beach ridge, about 25 rods east of Mr. Kendall's house, 1,067 feet.

Beach through the next 1½ miles north from Mr. Moses's house, along the west side of Secs. 18 and 7, T. 128, R. 43 (Delaware), 1,066 to 1,068 feet. The beach for this distance is finely exhibited, having a width of about 25 rods, rising 5 to 8 feet above the depression at its east side and 10 to 15 feet above the land west.

L. I. Baker's house sill, in the SW. ¼ of Sec. 6, same township, of same height with the top of the beach ridge, on which it is built, 1,068 feet.

Beach in Sec. 31, T. 129, R. 43 (Elbow Lake), not so conspicuous as usual, 1,066 feet; in (or near) the SW. ¼ of Sec. 19, same township, 1,070 feet; in the SW. ¼ of Sec. 18, at the house of Henry Olson, a gracefully rounded low ridge, as elsewhere, composed of gravel and sand, including pebbles up to 3 inches in diameter, 1,065 to 1,066 feet; at Mrs. John S. Ireland's, in the NW. ¼ of same Sec. 18, 1,070 feet; at Dr. J. M. Tucker's, in the NE. ¼ of the NE. ¼ of Sec. 2, T. 129, R. 44 (North Ottawa), 1,071 feet; about 1 mile north of the last, near the north side of Sec. 35, T. 130, R. 44 (Lawrence), 1,075 feet; and about 1 mile farther north, also 1,075 feet. Through nearly the whole of this distance it is a typical beach ridge of sand and gravel.

Beach about 30 rods west of M. L. Adams's house, in the NE. ¼ of Sec. 26, T. 130, R. 44 (Lawrence), 1,075 feet, being 4 feet above the land adjoining this ridge on the east and about 10 feet above the flat land near on the west; in Sec. 23, same township, 1,076 feet; and near the south side of Sec. 10, same township, 1,069 to 1,074 feet.

Extensive sloughs or marshes occur in Sec. 36 and in Secs. 25 and 24, same township, each being about a mile long, lying on the east side of the beach ridge at Dr. Tucker's and reaching 2½ miles northward; the elevation of these above sea level is about 1,060 feet.

In the north part of Sec. 10 and the south part of Sec. 3, same township, this shore line of Lake Agassiz is not marked as usual by a gravel ridge, but by a somewhat abrupt ascent or terrace in the drift sheet of till, the elevation of the top of which, composed partly of gravel, is 1,085 to 1,079 feet; base of this terrace and land westward, consisting of till, slightly modified on the area of Lake Agassiz, 1,060 to 1,050 feet. This escarpment, the eroded shore line of the lake, passes about 40 rods west of N. S. Denton's house, at the north side of Sec. 10.

Beach in Sec. 34, T. 131, R. 44 (Western), the southwest township of Otter Tail County, near John F. Wentworth's, 1,070 to 1,075 feet; surface at Mr. Wentworth's barn, 1,072 feet.

Beach 25 rods east of Albert Copeland's house, in the SW. ¼ of Sec. 28, same township, 1,070 to 1,066 feet; where it is crossed by the old road from Fergus Falls to Campbell, near the northwest corner of this Sec. 28, 1,072 feet; through the next 2 miles north, finely developed, with nearly constant height, 1,072 feet, being 7 to 10 feet above the depression at its east side and 20 feet above the area westward, which was covered by Lake Agassiz; at Michael J. Shortell's, Sec. 9, same township, 1,073 feet; one mile farther north, 1,078 feet; and at A. J. Swift's, in the SE. ¼ of the NW. ¼ of Sec. 4, 1,076 feet. The beach at Mr. Swift's, and for half a mile farther north, is well exhibited and, as in many other places, is bordered on its east side by a narrow strip of marsh.

Beach in the SW. ¼ of the NE. ¼ of Sec. 33, T. 132, R. 44, 1,076 feet; top of large aboriginal mound, situated on the beach here, 1,082 feet; land 30 rods west, 1,060 feet; lakelet 250 feet in diameter, about an eighth of a mile northeast from the large mound, 1,051 feet.

Red River of the North, near the northeast corner of Sec. 33, T. 132, R. 44, 1,014 feet; on the line between this township and T. 132, R. 43 (Buse), 1,041 feet; at Dayton bridge, in the NE. ¼ of the SW. ¼ of Sec. 20, T. 132, R. 43, 1,064 feet, being 8 feet below the bridge. S. A. Austin's house, foundation, in the NW. ¼ of the SW. ¼ of Sec. 29, same township, 1,147 feet. Old grade for railroad at Dayton bridge, about 1,102 feet.

No noticeable delta was brought into Lake Agassiz by the Red River.

FROM THE RED RIVER NORTH TO MUSKODA.

Beach near the south side of Sec. 21, T. 132, R. 44, 1,077 feet; in this Sec. 21, an eighth of a mile north of the road from Fergus Falls to Breckenridge, 1,079 feet; and for the next mile north, 1,077 to 1,080 feet. This is a typical beach ridge, gently rounded, composed of sand and gravel, containing pebbles up to 3 inches in diameter; its width is 30 to 40 rods, and its height above the very flat area on its west side, which was covered by Lake Agassiz (usually somewhat marshy next to the beach), is about 15 feet. On the east there is first a depression of 4 to 6 feet, succeeded within a fourth of a mile eastward by a gentle ascent, which rises 5 to 10 or 15 feet above the beach. The material on each side of the beach is till, slightly modified by the lake on the west. It is all fertile prairie, beautifully green, or in many places yellow or purple with flowers during July and August, the months in which this survey was made. In August, 1881, no houses had been built on this beach, nor within one mile from it, along its first 11 miles north from the Red River, the first house found near the beach being in Sec. 26, T. 134, R. 45 (Akron), in Wilkin County.

Beach at a low portion, probably in the SE. ¼ of Sec. 5, T. 132, R. 44, 1,075 feet. A lake, nearly a mile long, lies on the flat lowland about one and a half miles west from this low part of the beach. The elevation of this lake was estimated at 1,055 or 1,050 feet; it is only a few feet lower than the general surface around it.

Beach, probably near the north side of this Sec. 5, 1,078 feet. On its east side here and for a half mile both to the south and north is a slough, partly filled with good grass and partly with rushes; its width is about a quarter of a mile and its elevation about 1,070 feet. The land west of the beach descends, within 1 or 2 miles, from 1,060 to 1,050 feet.

Beach a fourth of a mile north from the point last noted, 1,071 to 1,072 feet. This is a typical gravel beach, only 4 feet above the slough on the east and bordered on the west by marshy grassland, which slopes gently down 5 to 15 feet below this beach ridge.

Beach at its lowest portion for this vicinity, within a third of a mile north of the preceding and near the center of Sec. 32, T. 133, R. 44 (Carlisle), 1,070 to 1,068 feet, being only 2 feet above the marsh or slough on its east side. A railroad grade, abandoned, lies a third of a mile east of this. Beach a fourth of a mile farther north, 1,077 feet, and, about one mile north from its lowest portion, 1,075 feet, cut by a ravine, the bottom of which is nearly at 1,063 feet. This ravine is some 30 rods west of the abandoned railroad embankment. Beach a fourth of a mile north-northwest from the last, 1,077 feet.

Railroad grade where it crosses the beach, about a mile northwesterly from the ravine mentioned, 1,077 feet. Beach here, 1,076 feet, being 8 to 10 feet above the slough on its east side and having about the the same height above the marsh next to it westward. The material of the beach, shown by the railroad embankment, which is made of it along a distance of a third of a mile, is coarse gravel, with abundant pebbles of all sizes up to 6 inches in diameter, fully half of them being limestone.

Beach near the west side of Sec. 7, same township, at the west line of Otter Tail County, 1,083 feet. Here it is a smoothly rounded gravel ridge about 15 feet above the edge of the flat area that was covered by Lake Agassiz on the west and 10 feet above a marsh or slough that lies a few rods distant on its east side.

Sill of Rudolph Niggeler's house, in the SE. ¼ of Sec. 26, T. 134, R. 45 (Akron), 1,076 feet. This is on a portion of the beach extending about a third of a mile from south to north; a quarter of a mile to the north its elevation is 1,082 feet. In the northeast part of Sec. 35 and in the north half of Sec. 26 this beach is interrupted by sloughs, which take its place for a quarter of a mile.

Beach in the south half of Sec. 23, same township, 1,079 to 1,080 feet; in the NW. ¼ of this Sec. 23, 1,075 to 1,080 feet.

Through Secs. 14, 10, and 3, same township, the beach does not have its ordinary ridged form, but is mostly marked by a deposit of gravel and sand lying upon a slope that rises gradually eastward. Its elevation here is 1,075 to 1,085 feet. In the southern part of this distance, probably in the SW. ¼ of Sec. 14, the margin of the flat, somewhat marshy area that appears to have been covered by Lake Agassiz is very definite at 1,075 feet, which thus was probably the height of the lake here.

Beach in the SW. ¼ of Sec. 34, T. 135, R. 45 (Tanberg), composed of gravel, nearly flat, 25 to 30 rods wide, 1,084 to 1,087 feet, bordered by a depression of 2 to 5 feet on the east and by an expanse 10 to 15 feet lower on the west.

Beach in the NW. ¼ of this Sec. 34, 1,084 to 1,087 feet. Here the land next east does not present the usual slight hollow dividing the beach ridge from the higher land eastward; instead is a springy belt, mostly 1,089 feet, quite marshy, yet slowly rising 2 to 4 feet above the belt of beach gravel. Occasional hummocks, about 2 feet above the general surface and covered with rank grass about 6 feet high, form part of this belt of marsh and shaking bog. Next to the east is a slough about 1,086 feet, or 3 feet below the springy tract; and this is succeeded by a surface of moderately undulating till, which rises gradually eastward.

Martin E. Renkliv's house sill, in the SW. ¼ of Sec. 22, same township, 1,094 feet. Shore line of Lake Agassiz, an eighth of a mile west of Mr. Renkliv's, on the border of a marshy flat area, not marked by any distinct gravel ridge, about 1,075 feet.

Sloughs, mostly filled with rushes and having areas of water all the year, occupy a width of 1 to 2 miles next west of the shore line and beach of Lake Agassiz and extend nearly continuously 10 miles from south to north from the middle of T. 134, R. 45 (Akron), to the south edge of T. 136, R. 45 (Prairie View). The elevation of this belt of sloughs is 1,080 to 1,050 feet, being considerably lower on its west than on its east border. The highest land westward in the west edge of T. 135, R. 45 (Tanberg), between these marshes and Manston, is about 1,060 feet. Along most of this distance the ordinary beach ridge is wanting.

Saint Paul, Minneapolis and Manitoba Railway, Fergus Falls division, track at Lawndale water tank, in or near the southeast corner of Sec. 33, T. 136, R. 45 (Prairie View), 6 miles northwest from Rothsay and 8 miles southeast from Barnesville, 1,088 feet. Here a sidetrack has been laid, extending about a third of a mile northward, with its northern end some 50 rods east of the main line, to take ballast from the beach, which is well exhibited here and onward, having its typical ridged form. The elevation of its crest is 1,091 to 1,094 feet. It is composed of gravel and sand in about equal amounts, interstratified mainly in level layers, but with these often obliquely laminated. Most of the gravel is quite fine, and the coarsest gravel found here has pebbles only 2 to 3 inches in diameter. About half of it is limestone.

Beach ridge, 1 mile farther north, 1,094 feet; three-fourths of a mile north of the last and close south of a ravine, 1,099 feet.

Beach about 3 miles north from Lawndale water tank, probably in the south part of Sec. 16, T. 136, R. 45 (Prairie View), not ridged, but a belt 25 rods wide, of gravel and sand, on a slope of till that rises eastward, 1,080 to 1,102 feet. Beach, a ridge of gravel and sand, a third of a mile north from the last, 1,105 feet. The beach in Sec. 9 of this township is spread more broadly than usual, its higher parts being 1,095 to 1,107 feet. Here the beach deposits are crossed obliquely by several broad depressions 10 to 15 feet deep, running south-southwest. The depression east of all these banks of gravel and sand is about 1,090 feet above the sea.

Beach, a well marked ridge of gravel of the usual character, in the SW. ¼ of Sec. 4, same township, 1,096 to 1,098 feet, and at John Hart's house, in the NW. ¼ of this Sec. 4, 1,103 feet.

Entering Clay County, the elevation of this upper or Herman beach at the east side of Sec. 33, T. 137, R. 45 (Humboldt), is 1,100 feet above the sea. The land thence for two-thirds of a mile east is low and smooth, not higher than the beach. Beyond this the next third of a mile northeastward, in the north part of Sec. 34, is very rocky, with many bowlders up to 6 and rarely 10 feet in diameter, the contour being moderately rolling 10 to 30 or 40 feet above the beach. Farther eastward here and through the next 15 miles north to the Northern Pacific Railroad, the moderately rolling or smoothly hilly till rises 100 to 250 feet above this beach within the distance of about 10 miles between it and the east line of the county.

Elevation of the beach ridge in the east half of Sec. 28, T. 137, R. 45 (Humboldt), one-fourth to three-fourths of a mile south of Willow River, 1,098 to 1,100 feet. In the 3 miles westward to Barnesville the area that was covered by Lake Agassiz shows here and there bowlders projecting 1 to 2 feet above the surface, which is till, slightly smoothed by the lake.

Saint Paul, Minneapolis, and Manitoba Railway, track at Barnesville, 1,007 feet.

The beach for three-fourths of a mile north from Willow River consists of a belt of gravel and sand, lying on an eastwardly ascending slope of till. Through the next 1½ miles northward, in the NW. ¼ of Sec. 22 and in Sec. 15, T. 137, R. 45 (Humboldt), the shore of Lake Agassiz is not marked by the usual beach of gravel and sand, but instead becomes a belt of marshy and springy land 20 to 50 rods wide, rising by a gentle slope eastward, rough with many hummocks and hollows, in some portions forming a quaking bog, in which horses and oxen attempting to cross are mired.

In the next 2 miles northward, through Secs. 10 and 3, same township, the beach is nowhere well marked as a ridge, but is mainly a belt of gravel and sand, lying on a slope of till, which gradually rises 30 or 40 feet higher at the east. The lack of typical beach deposits on this shore through the north half of this township is probably due to its sheltered situation in the lee of islands on the northwest. The course of the shore currents, determined by the prevailing winds, seems to have been southward, as on the shores of Lake Michigan.

Highest part of southern island in the east edge of Lake Agassiz, in the NE. ¼ of Sec. 5, T. 137, R. 45 (Humboldt), extending northward into T. 138, R. 45 (Skree), 1,117 to 1,122 feet. This island was about a mile long from south to north. Beach on its west side, a well developed ridge of gravel, near the middle of the north line of Sec. 5, 1,095 feet; and for a third of a mile north-northwest from this, 1,094 to 1,096 feet. On the east side of the beach, as it continues northward, is a slough two-thirds of a mile long from south to north and about 30 rods wide, 1,085 feet. This was evidently filled by a lagoon, sheltered on the southeast by the island and separated from the main lake by the beach. Toward the northeast it widened into a shallow expanse of water, 8 to 15 feet deep, about 1½ miles wide, divided from the broad lake on the west by two islands and this beach, or bar, which connected them. Lake Agassiz here appears to have stood at the height of 1,090 to 1,095 feet.

Beach or bar in the north part of Sec. 32, T. 138, R. 45 (Skree), a broad rounded ridge of gravel, with pebbles up to 3 or 4 inches in diameter, 1,103 feet, and through the next half mile, in the south half of Sec. 29, 1,102 to 1,104 feet. Along part of this distance the beach ridge is bounded eastward by a steeper descent than usual, the land next east being 1,085 to 1,090 feet above the sea. This beach or bar continues northward in a typical ridge through Secs. 29 and 20, same township.

Beach or bar at L. Williams's house, in the SW. ¼ of the SE. ¼ of Sec. 20, same township, 1,101 feet; a quarter of a mile farther north, 1,106 feet; three-quarters of a mile north of Mr. Williams's, near the middle of the north line of Sec. 20, 1,110 feet, continuing a very definite ridge through the south half of Sec. 17, 1,109 to 1,110 feet.

Near the middle of this Sec. 17 the beach deposit of gravel and sand ceases at the west side of the northern island, which was situated in the east half of this section and extended also eastward in a long, low projection nearly across the south side of Sec. 16, and northward half way across Sec. 8. Highest part of this island, in or near the NE. ¼ of the NW. ¼ of Sec. 17, about 1,125 feet. The old shore of the north half of this island has no beach ridge nor other deposits of gravel and sand, but is plentifully strewn with large bowlders up to 5 and 10 feet in diameter, and many of these project 2 to 5 feet above the general surface. The lake waves eroded here and deposited the sand and gravel gathered from this till as a beach a little farther south.

North and northeast from this northern island a lower expanse, nearly level and in some portions marshy, resembling the broad flat valley of the Red River, extends 1½ miles to the east shore of Lake Agassiz, its height being 1,075 to 1,090 feet, or 10 to 25 feet below the surface of the ancient lake. The distance between these islands was 2 miles, and the distance from the summit of the first to that of the second, nearly due north, 4 miles. Each of them rose about 25 feet above Lake Agassiz. The strait between them and the mainland eastward was 10 to 20 feet deep and from 1 to 1½ miles wide, excepting a narrow place near the southeast corner of Sec. 16. East of the northern island the main shore of the lake was indented by a bay a third to a half of a mile wide and about 10 feet deep, stretching 2½ miles southeastward from the lake at the northwest corner of Sec. 10 to the west part of Sec. 23, same township. The shore of the lake east of its islands along this bay and northwesterly to the north line of this township lacks the beach deposits which elsewhere distinguish it.

In its continuation northwestward the shore line of the old lake runs diagonally across Sec. 32, T. 139, R. 45 (Hawley), where it again presents the anomalous character of a very springy and marshy belt, 20 to 40 rods wide, rough with hummocks and in many places so deeply miry that it is dangerous for teams. This boggy tract has a gentle descent westward, its lower portion being about 1,085 feet, and its upper border, very nearly level across this entire section, being 1,098 to 1,100 feet, which was almost exactly the height of Lake Agassiz, as shown by its distinct beach of gravel and sand at the south and north. Next eastward rises a moderately undulating slope of till, strewn with abundant bowlders; and rarely a bowlder, 2 to 5 feet in diameter, is seen on the springy land that marks the border of the ancient lake.

DELTA OF THE BUFFALO RIVER.

The delta brought into the east side of Lake Agassiz by the Buffalo River extends about 5 miles southwestward from Muskoda, forming a continuously descending plain of stratified sand and fine gravel, declining from 1,100 feet near Muskoda to 1,073 feet at its southwestern limit in the north part of Sec. 34, T. 139, R. 46 (Riverton). Here and northward along a distance of 3 miles to the Buffalo River, this delta plain is terminated by a steep slope like the face of a terrace; the outer portion of the original delta, beyond this line, has been carried away by the waves and shore currents of the lake when it stood at the lower level marked by the Norcross beach.

Northern Pacific Railroad, track at Muskoda, 1,090 feet. Threshold of church a quarter of a mile southeast from Muskoda depot, 1,113 feet. Beach here and for a third of a mile south to the Buffalo River, as also at the excavation for the railroad, 25 rods north of the church, 1,113 to 1,114 feet. The beach here is 35 rods wide, rising 14 or 15 feet in a gentle swell above the edge of the delta of modified drift on the west and descending the same amount to the depression at its east side. It is made up of interstratified gravel and sand, the former prevailing, including pebbles up to 3 or 4 inches and rarely 6 or even 9 inches in diameter, all water-worn. Half or two-thirds of these pebbles are limestone. No bowlders occur here, nor are they found in any of the beach deposits of Lake Agassiz.

FROM MUSKODA NORTH TO THE WILD RICE RIVER.

Beach in the next 2 miles north of Muskoda, mainly 1,113 to 1,125 feet; at its lowest depression, about 1 mile north of Muskoda, 1,105 feet; at William Perkins's house, in the SE. ¼ of the SE. ¼ of Sec. 30, T. 140, R. 45 (Cromwell), 1,122 feet; an eighth to a third of a mile south-southeast from Mr. Perkins's, 1,130 feet. A nearly or quite continuous depression, from a fifth to a third of a mile wide, lies at the east side of this beach, declining in elevation from 1,118 feet, near Mr. Perkins's house, to 1,100 feet at Muskoda. This distance is about 3 miles.

The surface of Lake Agassiz in its maximum stage was at Muskoda 1,105 feet very approximately above our present sea level. Within 5 to 10 miles northward, its height seems to have been 1,110 to 1,115 feet.

Beach through the north half of Sec. 30, T. 140, R. 45, 1,128 to 1,131 feet, and through the west part of Secs. 19 and 18, same township, 1,125 to 1,130 feet, composed of sand and fine gravel, not generally in a typical ridge, but often with a depression 2 to 5 feet lower eastward and bounded on the west by a descent of about 30 feet within an eighth of a mile. A surface of slightly undulating till rises very gradually from this beach eastward.

In T. 139, R. 46 (Riverton), and in Secs. 35 and 26, T. 140, R. 46, the eroded western border of the delta of Buffalo River marks the shore of Lake Agassiz at the time of the Norcross beach.

In the west part of Sec. 24, T. 140, R. 46, and for 4 miles northward, the Norcross beach lies only 1 mile to a half mile west of the upper beach and is about 50 feet lower. The terracelike area between these beaches is strewn with occasional bowlders up to 6, 8, or 10 feet in diameter and rarely of larger size, much more abundant than upon the average surface of the till in this region, indicating that the surface there has been considerably eroded by the waves of the lake. The largest bowlder seen in Clay County lies about 50 rods west of the upper beach, in or near Sec. 12, T. 140, R. 46. Its dimensions are 15 by 12 by 5 feet and its top is 1,095 feet above the sea. It is gneiss, minutely porphyritic, with white feldspar crystals up to an eighth or a quarter of an inch long.

The elevation of the foot ot the western slope of the upper or Herman beach along the north part of the east line of T. 140, R. 46, is 1,095 to 1,100 feet. Crest of the Norcross beach in Sec. 12, T. 140, R. 46, 6 miles north of Muskoda, 1,080 feet, and along the distance of 3 miles through Secs. 13, 12, and 1, it varies from 1,075 to 1,085 feet. In Sec. 31, T. 141, R. 45 (Keon), its height is 1,085 feet. Like the Herman beach, it is a low, smoothly rounded ridge of gravel and sand, usually having a depression of 3 to 5 feet or more at its east side.

Upper or Herman beach at a high portion in or near the SE. ¼ of Sec. 1, T. 140, R. 46, 1,136 feet. For a mile next south from this point, it is a finely rounded ridge of gravel rising northward from 1,130 to 1,136 feet. The depression at its east side is 4 to 6 feet lower; then the surface gently rises at a quarter to a third of a mile from the beach to 1,135 or 1,140 feet, beyond which eastward this nearly level but slightly undulating expanse of till rises only 5 or 10 feet a mile.

Beach a fourth of a mile north-northeast from the high point mentioned, probably in the NW. ¼ of Sec. 6, T. 140, R. 45 (Cromwell), 1,128 to 1,127 feet. This is an ordinary beach ridge of gravel and sand, with a depression of 2 or 3 feet next east.

Near the south line of Sec. 29, T. 141, R. 45 (Keon), both the Herman and Norcross beaches, here about two-thirds of a mile apart, are intersected by a watercourse. At its north side the upper or Herman beach, near the east line of Sec. 29 and in the NW. ¼ of Sec 28, consists of two well marked ridges of gravel and sand, some 30 rods apart and about 10 feet above the land eastward and between them. These ridges unite in or near the SW. ¼ of the SW. ¼ of Sec. 21, at the height of 1,130 to 1,132 feet.

Beach three-fourths ot a mile farther north, probably near the north line of Sec. 21, a typical gravel ridge, 1,134 feet, 10 feet above the land next east; but a sixth of a mile farther northeast this beach ridge is depressed to 1,123 feet.

A lower beach, contemporaneous with the Herman beach farther south, but formed when the surface of the lake in this latitude had fallen slightly from its highest level, is finely exhibited, at a distance of one-third to two-thirds of a mile west from the upper beach, through the 4 miles from the south side of Sec. 20 to the northeast corner of Sec. 4, same township. The elevation of this secondary beach in the south part of Sec. 20 is 1,115 feet; thence to a stream near the east line of the SE. ¼ of Sec. 17, 1,118 to 1,123 feet; at each side of this stream, 1,118 feet;

northward, in the northwest part of Sec. 16 and in the SW. ¼ of Sec. 9, 1,118 to 1,121 feet; and in the north part of Sec. 9, 1,121 to 1,127 feet.

The elevation of the upper beach in T. 141, R. 45 (Keon), 1,123 to 1,137 feet, shows that the height of Lake Agassiz here, during its maximum stage, was about 1,120 feet. The secondary beach was made by the lake after it had fallen 6 to 10 feet.

Surface of ground at Christian Sether's house, in the SW. ¼ of Sec. 10, 1,129 feet. Upper beach through the west part of this Sec. 10, 1,130 to 1,137 feet, increasing in height from south to north. This is a typical beach ridge of gravel, with a rather abrupt descent on its east side to land 6 or 8 feet lower, which thence ascends with a slightly undulating surface eastward.

Upper beach in Sec. 3, same township, 1,134 to 1,137 feet, 10 feet above the land next east. Secondary beach, parallel with this and about three-fourths of a mile distant to the northwest, in Secs. 4 and 34, 1,123 to 1,127 feet, being thus 10 feet lower than the highest parts of the eastern beach. Extensive sloughs, inclosing lakelets, lie between these beaches in Secs. 34 and 35, T. 142, R. 45 (Hagen), at an elevation of 1,115 to 1,120 feet, but sinking northward to 1,105 feet. The secondary beach continues to the northeast corner of Sec. 26, declining in height northeastward as it approaches the South Branch of the Wild Rice River, being at 1,125 to 1,115 feet.

Upper beach in Sec. 35 and in the south part of Sec. 25, T. 142, R. 45, 1,140 to 1,142 feet. This is a typical beach ridge of sand and gravel, about 30 rods wide, with the land next southeast 5 to 8 feet lower, and divided from the secondary beach northwesterly by a slough about 1 mile wide, this slough being at 1,115 to 1,105 feet.

Beach at B. O. Helde's house, in the south half of the SW. ¼ of Sec. 30, T. 142, R. 44 (Ulen), 1,138 feet. The flat expanse of the Red River Valley reaches east on the South Branch of the Wild Rice River to Sec. 16, T. 142, R. 45 (Hagen), probably being there about 975 feet above the sea, or 160 feet below this upper beach of Lake Agassiz, 4 or 5 miles southeast.

Beach through Secs. 30 and 29, T. 142, R. 44 (Ulen), extending 1½ miles east-northeast from Mr. Helde's to the South Branch of the Wild Rice River, in a low, gently rounded ridge of gravel, 30 rods wide, 5 to 8 feet above the area of till next southeast and about 15 feet above the surface close at its northwest side, 1,138 to 1,142, mostly 1,140, feet.

Beach at Nels Wiger's house, probably in the NW. ¼ of Sec. 28, 1,133 feet; about 40 rods west from this, 1,140 feet.

South Branch of Wild Rice River, in the SW. ¼ of Sec. 21, same township, 1,095 feet.

Beach, a typical gravel ridge, in or near the west half of Sec. 16, a half mile to 1½ miles north of the South Branch, 1,140 to 1,143 feet; surface of till an eighth to a quarter of a mile next east, 1,135 feet. Farther east the slightly or moderately undulating expanse of till has an average ascent of about 10 feet a mile for 15 miles to the base of the high land at the White Earth Agency, which is dimly visible, blue, close to the horizon. Westward the surface gradually descends to the Norcross beach, nearly 60 feet lower, which is the farthest land in sight in that direction, about 3 miles distant, beyond which lies the flat Red River Valley.

Beach, a well defined ridge, in Secs. 9 and 4, T. 142, R. 44 (Ulen), 1,139 to 1,144 feet.

Entering Norman County, an unusually high portion of the beach is found in or near the SE. ¼ of the SE. ¼ of Sec. 33, T. 143, R. 44 (Home Lake), having its crest at 1,149 feet. It holds this elevation for an extent of some 20 rods, on each side of which its height is mostly from 1,139 to 1,145 feet. Its material is coarse gravel, principally limestone, with pebbles up to 4 and 6 inches in diameter. Surface close east of this beach, 1,137 feet. A slight swell above the general descending slope westward, about 2 miles distant, has a height very nearly 1,125 feet. This may be the continuation of the secondary beach that was seen in T. 141, R. 45 (Keon). It hides the view farther west, except from the highest point of the beach (1,149 feet), where the distant belts of timber along the Red and the Wild Rice Rivers are visible.

Beach at J. T. Huseby's house, in the SW. ¼ of the NW. ¼ of Sec. 26, T. 143, R. 44 (Home Lake), 1,147 feet; through 1¼ miles next north, in the NW. ¼ of Sec. 26 and the west part of Sec. 23, forming a broad, low ridge of gravel and sand, 1,145 to 1,149 feet.

In or near Secs. 17 and 16, T. 143, R. 43 (Flom), a prominent massive hill, called "Frenchman's Bluff," of somewhat irregular form, composed of morainic till, rises 150 feet or more above this beach.

Through the W. ½ of the NW. ¼ of Sec. 14, T. 143, R. 44 (Home Lake), the beach is mostly a typical gravel ridge, with its crest at 1,147 to 1,152 feet. In the NW. ¼ of Sec. 11, same township, it curves northeastward and attains an unusually massive development, its crest being at 1,150 to 1,158 feet, rising 15 feet above the land next southeast and 30 feet above the border of the area of Lake Agassiz at its northwest side.

Beach, a well marked gravel ridge near the southwest corner of Sec. 1, same township, 1,156 feet, and an eighth of a mile east-northeast from this, 1,150 feet.

J. G. Aurdal's house, foundation, in the NW. ¼ of the NE. ¼ of Sec. 6, T. 143, R. 43 (Flom), 1,148 feet. This is situated on the beach, which here is a deposit of gravel and sand 8 feet or more in depth, lying upon a slope of till that ascends southeastward.

Anton Johnson's store, foundation, on this beach, in the SE. ¼ of the SE. ¼ of Sec. 31, T. 144, R. 43 (Fosum), 1,142 feet.

Creek flowing northwesterly between the last two, about 1,105 feet.

Wild Rice River, 2 miles north of Johnson's store, approximately 1,075 feet.

Secondary Herman beach, a well marked, broad, smoothly rounded gravel ridge, extending from southwest to northeast, crossed by the township line road at the north side of the NE. ¼ of the NW. ¼ of Sec. 2, T. 143, R. 44 (Home Lake), 1,137 feet. It is about 30 rods wide and rises 5 to 10 feet above the depression at its southeast side.

FROM THE WILD RICE RIVER NORTH TO MAPLE LAKE.

A broad belt of timber borders the Wild Rice River, lying mostly on its north side, in T. 144, R. 43 (Fosum), and T. 144, R. 44 (Wild Rice), and at the time of this survey, in 1881, no road nor bridge afforded a crossing here. Therefore this series of levels was resumed north of the Wild Rice River by starting from Rolette Station of the Saint Paul, Minneapolis and Manitoba Railway, 890 feet above the sea, near the middle of Sec. 17, T. 146, R. 46 (Lockhart), about 1½ miles north of the Lockhart farm. Proceeding eastward from this point, the first observations of the upper beach were in T. 145, R. 43 (Waukon); T. 146, R. 44 (Sundal); and T. 147, R. 44 (Garfield).

This beach is intersected by the Wild Rice River near the middle of T. 144, R. 43 (Fosum), and thence it passes north-northwesterly through the west part of T. 145, R. 43 (Waukon). In Secs. 7 and 6, same township, it is a low smooth ridge of gravel and sand about 25 rods wide, rising 5 to 10 feet. In the west half of this Sec. 6 and in Sec. 36, T. 146, R. 44 (Sundal), the old Pembina trail lies on it.

About 2 miles west of the upper beach, a secondary Herman beach, of similar material and contour, probably 20 feet lower, was observed a few rods east of the stake at the middle of the north side of Sec. 14, T. 145, R. 44 (Strand), having a height of 6 to 8 feet above its base, with a smaller ridge of sand and gravel, 3 feet high above its base, close west of this stake. Again, a half mile farther west, in the northeast corner of Sec. 15, same township, another Herman beach, probably 10 feet below the last, was noted, having a height of 4 or 5 feet above its base.

Traveling northwestward along the Pembina trail, the upper beach ridge was not distinctly observed after leaving Sec. 36, T. 146, R. 44 (Sundal), until it is again occupied by the trail in Sec. 9 of this township. The intervening 3 miles are flat and nearly level. Probably the beach, less noticeable than usual, lies within a half or 1 mile east of the trail here. In the eastern part of Sec. 9 this beach is about 25 rods wide, rising 5 feet from its east side and descending 10 feet to its western base, which was the margin of Lake Agassiz.

Thence the upper beach extends nearly due north through the east edge of Sec. 4, same township, and Sec. 33, T. 147, R. 44 (Garfield). In the east edge of the SE. ¼ of Sec. 28 and the west edge of the NW. ¼ of Sec. 27, T. 147, R. 44, it is a typical ridge of gravel and sand, with its crest 1,166 to 1,173 feet above the sea. There is a gradual descent toward the west. The depression on the east is a sixth to a fourth of a mile wide, sinking 6 to 10 feet below the beach. Farther eastward the land is moderately undulating till, rising 20 to 30 feet above the beach and bearing frequent groves of small poplars, bur oak, and canoe birch.

Water in Sand Hill River, at the ford of the old Pembina trail, in the west part of Sec. 28, T. 147, R. 44, ordinary low stage, July 26, 1881, 1,071 feet.

Even Grödvig's house threshold, at the top of the bluff north of this ford, in the north half of the NW. ¼ of this Sec. 28, 1,136 feet.

When Lake Agassiz stood at its greatest height, the Sand Hill River brought into its margin a delta 6 miles long from south to north and 3 miles wide, reaching from the upper beach to the west side of T. 147, R. 44 (Garfield), and T. 146, R. 44 (Sundal). This westwardly sloping deposit of stratified gravel and sand has about an equal area and thickness with the delta of the Buffalo River at Muskoda. Upon this delta plain dunes have been heaped up by the winds, probably before vegetation had spread over this area after the withdrawal of the glacial lake.

In the south half of Sec. 32, T. 147, R. 44 (Garfield), and in a belt which thence extends approximately north and south, the sand of this delta, as originally deposited, rises eastward with a slope of 25 or 30 feet in 1 mile, from 1,100 to 1,125 or 1,130 feet above the sea. Beneath this plane, however, channels have been eroded by the winds and sandhills 25 to 75 feet above it have been blown up in irregular groups and series, scattered over a tract about a mile wide and extending 3 or 4 miles southward from the Sand Hill River, in Sec. 29, the northeast part of Sec. 30, and in Secs. 31 and 32, T. 147, R. 44 (Garfield), and reaching southward in Secs. 5 and 8, T. 146, R. 44 (Sundal). The most southern of these hills is an isolated group in the east part of the NE. ¼ of Sec. 18, T. 146, R. 44 (Sundal). Another isolated group lies north of the Sand Hill River, in the NW. ¼ of Sec. 16, T. 147, R. 44 (Garfield). These sand dunes are in part bare, being so frequently drifted by the winds as to allow no foothold for vegetation; other portions are clothed with grass or with bushes and scanty dwarfed trees, including bur oak, the common aspen or poplar, cottonwood, green ash, black cherry, and the frost grape.

Elevations of the highest points of these dunes, in order from south to north, are approximately 1,190, 1,180, and 1,200 feet. The highest dune appears to be in or near the east half of the NE. ¼ of Sec. 30, T. 147, R. 44 (Garfield).

Secondary Herman beach, a smoothly rounded ridge of gravel and sand 10 to 15 feet high above the adjacent level, 1,148 to 1,153 feet above the sea, about three-fourths of a mile east of the old Pembina trail, in the west half of Secs. 21 and 16, T. 147, R. 44 (Garfield), extending 1½ miles north from the Sand Hill River to the cluster of dunes in the NW. ¼ of Sec. 16.

Upper Herman beach, the first of the series which was here formed contemporaneously with the single Herman beach farther south, running approximately from south to north through or near the northeast corner of Sec. 4, T. 147, R. 44 (Garfield), a smooth gravel ridge, in some parts hidden by scattered groves, 1,165 to 1,175 feet. Farther east is a large area of woodland. Second Herman beach, in the east part of Sec. 5, same township, and Sec. 32, T. 148, R. 44 (Godfrey), about a mile west from the upper beach, 1,149 to 1,153 feet; this is a ridge of gravel and sand, about 40 rods wide, with very gentle, prolonged slopes toward both the east and the west. Natural surface at the northeast corner of Sec. 32, T. 148, R. 44 (Godfrey), 1,146 feet. Third Herman beach, running north, in the NW. ¼ of Sec. 5, T. 147, R. 44 (Garfield), and the west part of Sec. 32, T. 148, R. 44 (Godfrey), a half or two-thirds of a mile west from the last, 1,130 to 1,135 feet, consisting of a distinct ridge in its southern part, but farther north being a flat area of gravel and sand slightly elevated above the land next east.

Second Herman beach, a broad low ridge of gravel and sand, extending north-northeast through Sec. 28, T. 148, R. 44 (Godfrey), from its southwest corner to its north line, 1,148 to 1,150 feet. The northward continuation of this beach is a low, flattened ridge, the western one of two parallel ridges of gravel below that of the upper beach, extending northeasterly and northerly through or near the west edge of Sec. 10, same township, 1,150 to 1,154 feet. Through the next 3 miles in Sec. 3, same township, and in the east part of Secs. 35 and 26 and the NW. ¼ of Sec. 25, T. 149, R. 44 (Tilden), it is a prominent beach ridge, with its crest at 1,153 to 1,161 feet, somewhat steep on its east side, which descends about 10 feet to a belt of lowland and marsh that divides it from the parallel beach a quarter to a third of a mile east.

The eastern of these parallel beach ridges is only 8 or 10 feet below the average elevation of the upper beach. It probably marks a slight fall in the water surface at this latitude; but, as no corresponding beach formation has been observed in Dakota, it is neglected in the foregoing table of elevations of the beaches of Lake Agassiz. It is clearly continuous 8 miles, the first 4 miles extending northerly and the next 4 miles easterly. These parts are connected in Sec. 25, T. 149, R. 44 (Tilden), by a graceful curve, that portion of this beach and its extent thence eastward being known as the "Attix ridge," from Henry and William Attix, brothers, who have built their houses upon it. In its northward course, nearly through the middle of Secs. 10 and 4, T. 148, R. 44 (Godfrey), its crest is at 1,158 to 1,163 feet; in the west edge of Sec. 36, T. 149, R. 44 (Tilden), and along its curved course to the northeast and east at the west and north sides of Sec. 25 and in the southeast part of Sec. 24, same township, 1,163 to 1,168 feet, and in Secs. 21 and 22, T. 149, R. 43 (Grove Park), 1,171 to 1,173 feet. Slough, a third to a half of a mile wide, extending along the east side of this beach, in Sec. 3, T. 148, R. 44 (Godfrey), and in the southeast part of T. 149, R. 44 (Tilden), 1,155 to 1,160 feet.

Upper beach in the SW. ¼ of Sec. 11, T. 148, R. 44 (Godfrey), forming a plain of stratified gravel and sand a quarter or a third of a mile wide from east to west, 1,168 to 1,173 feet. This beach near the south side of Sec. 11 becomes a distinct gravel ridge of the usual character, about 25 rods wide, with its crest at 1,173 feet, bordered by a slough 20 to 40 rods wide at its east side. About a third of a mile farther southeast and some 50 rods west of the southwest extremity of Maple Lake, in Sec. 14, same township, the elevation of this beach ridge is 1,175 to 1,178 feet.

Maple Lake, water surface July 28, 1881, 1,169 feet.

Upper beach, top of its well marked gravel ridge in the east edge of the NE. ¼ of the NE. ¼ of Sec. 3, T. 148, R. 44 (Godfrey), about 20 rods north of Mr. Horton's, 1,180 feet.

Beyond this point, through its next 2½ miles, curving from a northward to a northeastward and eastward course, this upper beach of Lake Agassiz is magnificently exhibited, forming a massive, gently rounded ridge of gravel and sand about 30 rods across, with its crest 1,178 to 1,186 feet above the sea. It is bordered on its southeast side by a tract of slightly undulating till 10 to 15 feet lower, mostly covered with small timber and brush and holding frequent sloughs and lakelets in its depressions. The top of the beach is not wooded, but small trees and bushes encroach upon its slopes. A road extends along the crest of its curving portion for a distance of about 1 mile through Sec. 36, T. 149, R. 44 (Tilden).

The marsh which borders the northwest side of the northeast part of Maple Lake shows a descent of 5 to 7 feet northwestward, or away from the lake, in its width of 1 to 1½ miles. Maple Lake is prevented from flowing in this direction by a beaver dam near the lake. Creek draining this marsh where it intersects the upper beach near the east line of the NE. ¼ of Sec. 27, T. 149, R. 43 (Grove Park), 1,163 feet. Here the beach skirting the north side of the marsh is a flat deposit of gravel and sand, a fourth to a half of a mile or more in width, highest next to the marsh, above which it rises 5 to 8 feet in a moderate slope. Its elevation in the north half of Secs. 26 and 27 is 1,169 to 1,172 feet, being even 1 or 2 feet lower than the Attix ridge, which lies some two-thirds of a mile farther north, in the south half of Secs. 21 and 22. This belt of beach gravel and sand continues 6 miles in a nearly due east course, and beyond that it extends still eastward along the north side of a great tamarack swamp, which begins in Sec. 34, T. 149, R. 42, and is said to be 8 miles long. Maple Lake and this tamarack swamp hold the same relation to the upper beach ridge, which was a barrier between them and Lake Agassiz and which now wholly or partially obstructs the drainage of these areas.

Third Herman beach, a small ridge of gravel and sand, extending from southwest to northeast, 8 to 10 rods wide and rising 4 or 5 feet, crossed by the Crookston road in the SW. ¼ of Sec. 23, T. 149, R. 44

(Tilden), and seen to reach at least a mile each way from this road, 1,146 to 1,149 feet.

Natural surface at the southeast corner of Sec. 15, same township, 1,134 feet.

Fourth Herman beach, crossed by road to Crookston and Red Lake Falls near the center of the SE. ¼ of this Sec. 15, 1,132 to 1,134 feet. This is a well marked gravel ridge, mainly single, but twofold where it is crossed by this road. The distance of 1 mile here between these third and fourth Herman beaches consists of till, with a nearly smooth surface, which has bowlders up to 3 and rarely 5 feet in diameter quite numerously scattered over it. Southeastward from the third to the first or upper beach the surface mostly is modified drift, with no bowlders.

Four to five miles north from the fourth Herman beach the road to Red Lake Falls crosses the Norcross beach in Sec. 27, T. 150, R. 44 (Lake Pleasant), where it is a belt of gravel and sand about a half mile wide, extending from west-southwest to east-northeast, at an elevation of 1,083 to 1,095 feet.

THE UPPER OR HERMAN BEACH IN DAKOTA.

[See the accompanying map, Plate I.]

FROM LAKE TRAVERSE NORTHWEST TO MILNOR.

From the south extremity of Lake Agassiz, in Sec. 18, T. 125, R. 45 (Leonardsville), Traverse County, Minn., the upper or Herman beach extends northwestward 75 miles to the most southern bend of the Sheyenne River in Ransom County, Dakota, and thence its course is nearly due north, but with slight deflection westward, to the international boundary. The mouth of Lake Agassiz was where now a slough 2 to 3 miles wide, with frequent areas of open water, stretches northward from the northeast end of Lake Traverse. On the west side of this slough and of Lake Traverse bluffs of till rise 100 to 125 feet; their tops and the rolling surface of till which extends thence westward are 1,070 to 1,100 feet above the sea.

The beginning of the upper or Herman beach in Dakota is in Secs. 10, 3, and 4, T. 128, R. 48, nearly 2 miles south from the north line of the Sisseton and Wahpeton reservation. It rises with terracelike steepness 20 or 30 feet above the surface of undulating till which borders it on the northeast. Its material is sand and gravel, with pebbles up to 1½ or 2 inches in diameter, about half of which are limestone. Beyond its steep margin this deposit of beach gravel forms a belt about a mile wide, approximately level, but with frequent short swells and low flattened ridges 5 to 10 or 15 feet above the intervening depressions. Its elevation is 1,060 to 1,070 feet above the sea, or from 90 to 100 feet above Lake Traverse.

For its first 3 or 4 miles the terracelike margin of the beach sweeps with a gentle curve westerly and northerly to a point in the SW. ¼ of Sec. 34, T. 129, R. 48, where it turns quite abruptly, taking a nearly due west course for the next 3 miles to the west side of Sec. 31 of this township.

In the NW. ¼ of Sec. 3, T. 128, R. 48, a third of a mile east of W. J. Allen's house, the ascent at the beach margin is about 10 feet to an elevation of 1,060 feet, approximately. The belt of sand and fine gravel is here about a half mile wide. Occasional hummocks, rising 5 to 10 feet and 50 to 100 feet long, which were observed on this part of the beach, appear to have been heaped up by the wind before the protecting mantle of grass and other vegetation was spread over it. In the SE. ¼ of Sec. 32, T. 129, R. 48, similar dunes, 1,075 to 1,080 feet above the sea, have been excavated for use as plastering sand. Nearly all portions of this beach and even its dunes are now covered with a black soil and plentiful vegetation; but certain species preferring dry and sandy soil, as the dwarf rose, grow in greater abundance on the beach, and especially among its hummocks and hollows, than on the flat or slightly undulating surface of till at each side.

The margin of this Herman beach, marking the shore of Lake Agassiz at its maximum stage, passes in its western course about 60 rods north of the southeast corner of Sec. 32 and turns again to the northwest near the middle of the west side of Sec. 31, T. 129, R. 48. At the latter locality it is a low wavelike ridge of sand and fine gravel, about 1,060 feet above the sea. On the south it is bordered by land 3 to 5 feet lower for a width of one and a half miles. J. R. Grimesey's well, 13 feet deep, at the southwest corner of Sec. 31, on this low tract outside the beach ridge, encountered only very fine stratified sand, irregularly laminated and containing numerous tubular limonitic concretions. Farther to the southwest and west, a gently undulating surface of till, scarcely higher than the beach of Lake Agassiz, stretches away several miles, beyond which the highland of the Coteau des Prairies is seen in the far distance.

The Herman beach crosses T. 129, R. 49, in a diagonal course, entering it a half mile north of its southeast corner and running northwest to the north side of Secs. 5 and 6. In Sec. 23 and the northeast part of Sec. 22, its elevation is about 1,055 feet; but its dunes rise 3 or 4 feet higher. At the middle of the north side of Sec. 16, on the line between Roberts and Richland Counties, it is a ridge of sand and fine gravel about 8 rods wide, rising 4 to 6 feet above the land on each side. Its crest here, and for a mile to the southeast and northwest, is 1,060 to 1,065 feet above the sea. Northeastward the surface falls about 20 feet in the first mile. On the southwest side of this distinct beach ridge, a smooth, slightly undulating tract 1½ to 2 miles wide, extending through this township, consists of sand and fine clayey silt. Its elevation varies from 1.055 to 1,080 feet, attaining the latter height in the northwest part of the township. This belt, with its continuation southeastward, previously described, was doubtless covered by Lake Agassiz before the erosion of its outlet to the level of the Herman beach; but much of its stratified sand and silt may be modified drift deposited by streams from the melting ice sheet. The glacial recession here was from southwest to northeast, and this was probably an avenue of drainage during a short time, till the continued retreat of the ice left a considerable expanse of water, the beginning of Lake Agassiz, between itself and the shore.

In the north part of Secs. 5 and 6, T. 129, R. 49, and in Secs. 31 and 32, T. 130, R. 49, this beach consists of two or three parallel wavelike ridges of gravel and sand, divided by depressions an eighth to a quarter of a mile wide and 5 to 10 feet lower.

This belt reaches north to the Lightning's (or Thunder's) Nest, a massive dune of fine sand, partly bare and now wind blown, but mostly covered with bushes and herbage, situated near the center of Sec. 30, T. 130, R. 49. Its base on the south is 1,060 feet and its top 1,120 feet, approximately, above the sea. It covers a space about a quarter of a mile in extent from southeast to northwest, with nearly as great width, and rises in two summits of nearly equal height. The Lightning's Nest is the most prominent in a series of dunes, elsewhere rising only 10 to 30 feet, mostly grassed, which extends a mile or more to the southeast and is traceable several miles northwest to the east end of a very conspicuous tract of dunes 50 to 100 feet above adjacent level, with summits at 1,100 to 1,150 feet above the sea, which stretches about 4 miles in a west-northwest course in the south part of T. 131, R. 50, 1 to 2 miles south of the Wild Rice River. By winds, eroding and drifting, these sand hills were heaped up from the Herman beach and its associated belt of modified drift, probably soon after the retreat of the ice, though their forms have been constantly changing since that time.

Outside the area of Lake Agassiz, the southwest part of Richland County is till, mostly undulating or moderately rolling, but in part prominently hilly, with rough morainic contour and abundant bowlders. Taylor Lake, approximately 1,050 feet above the sea, 2½ miles west of the Lightning's Nest, is a very beautiful sheet of water, bordered by a sandy shore and a large grove on the north and by a shore of bowlders and morainic hills 50 to 150 feet above the lake on the west. These hills and most of the lakes farther west in this county have no timber. Northeastward the area that was covered by Lake Agassiz is mostly smooth and nearly flat till, with frequent marshy tracts called sloughs, but with only very rare and small lakelets.

Swan Lake, 3 miles long, reaching from Sec. 3 to Sec. 7, T. 130, R. 51, estimated 1,070 feet above the sea, with undulating till 5 to 10 feet higher on the northeast and 10 to 20 feet higher on the south and west.

Herman beach, a ridge of fine sand, 20 to 25 rods wide and about 3 feet high, near the south line of Sec. 36, T. 132, R. 52, extending west-northwest, approximately 1,065 feet. On the north, the exceedingly flat plain of Lake Agassiz, sinking very slowly northeastward, reaches as far as the eye can see. On the south, flat land, covered by Lake Agassiz before the time of this beach, continues 1½ miles, ascending in that distance from 1,060 feet to about 1,080 feet, and moderately undulating till rises beyond to 1,100 and 1,125 feet.

One and a half miles north of this beach the Wild Rice River is crossed by a bridge near the center of Sec. 25, T. 132, R. 52. The stream in its ordinary stage is 1 to 2 rods wide, with a depth of about 3 feet, and is filled with grass and rushes. Its bottom land, a sixth to a third of a mile wide, is about 10 feet higher and is annually overflowed by the high water in spring. Its bluffs rise about 40 feet above the river at low water, the elevation of their top and of the adjoining plain being, approximately, 1,050 feet. These bluffs and the surface from the Herman beach north to Elk Creek are till, but the country about Wyndmere and south to Elk Creek is stratified fine clayey sand. Both formations have a very fertile soil, unsurpassed for wheat and all crops proper to this latitude. Elk Creek is a stream similar to the Wild Rice River, but smaller, and the width and depth of its valley are about two-thirds as great.

Northern Pacific, Fergus Falls and Black Hills Railroad: track at Wyndmere, 1,060 feet; at the Herman beach 1½ miles west of Wyndmere, track 1,064 and crest of the beach 1,065 feet, rising 8 feet above the adjacent land 20 rods away both east and west; surface along the railroad thence westward 8 miles, 1,060 to 1,063 feet, with Star Lake, a third of a mile in diameter on this level area, only 2 or 3 feet below the surrounding land, close north of the railroad, in Sec. 5, T. 132, R. 52; a higher beach of Lake Agassiz, crossed 3 miles east of Milnor, and therefore called the Milnor beach, crest and track, 1,083 feet, 4 or 5 feet above the adjoining land 10 rods away both east and west; another beach ridge formed during the same stage of Lake Agassiz, a third of a mile farther west, crest and grade, 1,084 feet; land close east, 1,079, and west, 1,076 feet; track at Milnor, 1,095 feet.

The Herman beach west and north of Wyndmere has an irregular surface, with frequent hummocks of sand heaped 5 to 10 feet above adjacent hollows. Most of these dunes are now grassed. From near Wyndmere this beach, with frequent small dunes, extends north through the west edge of T. 133, R. 51, and thence westerly to another tract of prominent dunes 50 to 100 feet above adjacent surface, with their tops at 1,100 to 1,150 feet, which extends about 10 miles in a west-northwest course from the southwest part of T. 134, R. 52, to the east part of T. 134, R. 54, terminating about 2 miles east of the Sheyenne River. Like the similar high dunes south of the Wild Rice River, these are mainly covered by herbage, bushes, and small trees; but many portions are now being drifted by the winds, so that they are wholly destitute of vegetation. These dunes mark the course of the Herman beach, here greatly increased in volume by delta deposits from the Sheyenne River.

Morainic knolls and hills, rising 20 to 50 feet, with plentiful bowlders, lie close west of Milnor, extending in a belt from southeast to northwest. They are probably a continuation of the Altamont and Gary moraines of the Coteau des Prairies. Near Lisbon, about 15 miles northwest from Milnor, some of these morainic hills are quite conspicuous, rising 100 feet or more above the surrounding country.

Evidence of a stage of Lake Agassiz 20 or 30 feet higher than that of the Herman beach is found, as already noticed, in many places along the southern part of its boundary in Dakota. The portion of this glacial lake formed earliest by the recession of the ice seems to have reached from Lake Traverse to the Sheyenne River, and its level appears to have been then nearly that of the general surface and the top of the bluffs bordering Lake Traverse. Distinct traces of this stage of the ancient lake have not been recognized in Minnesota, nor along the greater part of its boundary in Dakota, from the Sheyenne River northward.

FROM MILNOR NORTH TO SHELDON.

The highest level of Lake Agassiz, near Milnor, is marked by the Milnor beach, already mentioned, where it is crossed by the railroad. This beach is fine clayey sand, in somewhat irregular and interrupted low ridges and terraces, abutting at the west on undulating till, which gradually rises 10 or 20 feet higher, while on the east a descent of 10 or 15 feet, within about 20 rods, is succeeded by a flat area, which thence sinks very slowly northeastward. The elevation of the Milnor beach at the railroad is 1,084 feet, and at Mr. G. V. Dawson's house, at the middle of the east side of Sec. 22, T. 133, R. 54, 1,092 feet. Its course between these points is north-northwest, and this is continued to the mouth of a former channel of the Sheyenne River, near the center of Sec. 4 in this township, 3 miles east from the most southern bend of the river.

During all the stages of Lake Agassiz the Sheyenne River brought into it much sediment, carrying the clay farther than the sand and gravel, which were laid down near the river's mouth. Extensive areas of these originally flat beds have been changed by wind action to irregular groups and belts of sand hills or dunes, which vary from a few feet to more than a hundred feet in height above the surrounding level. Besides the large tract of these dunes before described east of the Sheyenne River, others of even greater extent and equally conspicuous border the river and reach 2 or 3 miles from it in the northeast part of T. 135, R. 54, and along its next 15 miles.

Watercourses formerly occupied by this stream are found west of the Milnor beach. One of them is marked by a sandy flat, which reaches from the present course of the Sheyenne River, in Sec. 1, T. 133, R. 55, southeastward through T. 133, R. 54, to the vicinity of Milnor. Another runs from near the middle of the SW. ¼ of Sec. 32, T. 134, R. 54, about 1¼ miles east-southeast to the middle of Sec. 4, T. 133, R. 54. This is a channel, 30 to 50 rods wide, about 40 feet below a ridge of coarse gravel, which extends along its northeast side, dividing it from the lower area that was covered by Lake Agassiz and from the present valley of the river. The crest of the ridge is nearly flat, upon a width of 10 to 30 rods, and is 75 to 100 feet above the river, being highest westward. It contains pebbles and cobbles of all sizes up to 6 inches in diameter, about half being limestone and nearly all the others granitic. This ridge or plateau of gravel is a remnant of an old delta plain of the Sheyenne River, apparently deposited before the formation of the Milnor beach, above which it rises some 40 or 50 feet, which suggests that the deserted channel of that depth on its south side was probably eroded during the Milnor stage of Lake Agassiz. Similar gravel occurs on the side and verge of the bluff, 100 feet high, northwest of the Sheyenne River, in the SW. ¼ of Sec. 29, T. 134, R. 54, but a rolling surface of till extends thence northwest.

Sheyenne River in Sec. 32, T. 134, R. 54, 1,037 feet above the sea, and on the west line of the NW. ¼ of Sec. 29, T. 135, R. 54, 1,019 feet. Its bed through these townships is mostly 4 to 6 rods wide, with water 1 to 2 or 3 feet deep, and is strewn in many places with cobbles and bowlders up to 2 or 3 feet and rarely 6 or 8 feet in diameter. Its bottomland near the south bend, about a third of a mile wide, is 15 or 20 feet above the ordinary low stage of water, and during a term of fourteen years preceding this survey in 1885 it had not been overflowed; but driftwood, found by the first immigrants, proves that the river sometimes reaches this height. Bluffs of till here, in the southwest corner of T. 134, R. 54, rise 100 to 125 feet above the stream.

Bluffs of till close west of the Sheyenne River, in Sec. 20, T. 134, R. 54, 1,100 to 1,110 feet; moderately rolling till a quarter of a mile farther west, 1,115 to 1,125 feet; same in Secs. 17 and 18, 1,090 to 1,130 feet; and on the east side of the river, in Secs. 21, 16, and 17, 1,085 to 1,075 feet, descending northeastward. Prominent swell of till west of the Sheyenne River in the SE. ¼ of Sec. 30, T. 135, R. 54, having four aboriginal mounds on its crest, 1,113 feet; top of these mounds, 1,117 feet, very nearly. Highest portions of the area of undulating till seen westward from this Sec. 30, 3 or 4 miles distant, 1,125 to 1,150 feet.

Surface at Charles G. Froemke's house, in the NW. ¼ of Sec. 29, T. 135, R. 54, 1,073 feet; bottom land of the Sheyenne River close west, 1,037 to 1,027 feet; ordinary low water of the river, 1,019 feet.

Portion of area of Lake Agassiz, a strip a fourth to a third of a mile wide, west of the Sheyenne River, in Secs. 32 and 5, a half mile to 2 miles south of Mr. Froemke's, 1,065 to 1,075 feet. Herman beach one-fourth to two-thirds of a mile east of the Sheyenne River here and extending southeasterly toward the western limit of dunes in the east part of T. 134, R. 54, 1,073 to 1,079 feet. Crest of this beach, a low ridge of sand and fine gravel, at J. Altmann's house, near the middle of Sec. 20, T. 135, R. 54, 1,073 feet. Within 10 or 15 rods east there is a descent of about 10 feet. This beach ridge runs north and northeasterly to near the northeast corner of this Sec. 20, and thence it passes eastward about 3 miles, having an elevation of 1,075 to 1,065 feet to where it is intersected by the Sheyenne River, near the northeast corner of Sec. 14. North of the river it continues about a half mile in Sec. 12, its elevation being 1,065 to 1,070 feet, to the west end of a tract of dunes 25 to 100 feet above their vicinity, with summits at 1,100 to 1,150 feet, which extends thence about 15 miles eastward. This Herman beach was sufficient to turn the course of the Sheyenne River along its west and north side for a distance of 8 miles, from Sec. 9, T. 134, R. 54, north and east to Sec. 14, T. 135, R. 54, though it is only a ridge of sand and gravel 5 to 10 feet higher than the smoothed area of till, occasionally covered by 1 to 3 feet of sand, which lies west of it and in which the river has now cut its channel 50 to 60 feet deep.

Rolling surface of till in the south edge of Sec. 9, T. 135, R. 54, 25 to 40 rods north of the Sheyenne River, 1,080 to 1,090 feet. Most of this Sec. 9 is nearly level till at 1,080 to 1,085 feet, with occasional large hollows 20 feet lower. It seems to have been smoothed by Lake Agassiz at the time of the Milnor beach. Westward is slightly undulating till, having an elevation of 1,085 to 1,125 feet for 2 or 3 miles, as far as the surface lies within view.

Herman beach in the NW. ¼ of the NW. ¼ of Sec. 10, T. 135, R. 54, 1,075 to 1,080 feet. This is a deposit of gravel and sand extending along the verge of the plateau of till just described in Sec. 9. Fifteen or 20 rods to the east the elevation is 1,065 feet, and it sinks slowly thence eastward to about 1,050 feet at the west base of the dunes in Secs. 12 and 1 of this township.

Lakelet back of this beach, situated in the east edge of the SE. ¼ of Sec. 4, T. 135, R. 54, about 50 rods long from south to north, 1,060 feet, being 25 feet below the average of the adjacent undulating till. Shallow lakelet, 40 rods across, close east of the beach, a quarter of a mile east from the northwest corner of Sec. 3, also 1,060 feet; adjoining land, 1,065 to 1,070 feet, excepting on the west, where the Herman beach has an elevation of 1,080 feet, with undulating till beyond it a few feet higher.

Herman beach at the middle of the west side of Sec. 34, T. 136, R. 54 (Sheldon), 1,082 feet; surface 25 rods east, 1,070 feet, thence descending slowly eastward. Here and for 1½ miles south, through Sec. 3, this beach is a flattened ridge of sand and fine gravel, 25 or 30 rods wide, with a depression 3 to 6 feet deep along its west side. In the NW. ¼ of Sec. 28, its elevation is 1,080 feet.

Fargo and Southwestern Railroad track at Sheldon, 1,078 feet. Wells in Sheldon village are 10 to 15 feet deep, in sandy clay free from gravel or bowlders 6 to 10 feet, with sand below. These deposits belong to the Herman beach, which is here spread upon a width of about a half mile.

FROM SHELDON NORTH TO THE NORTHERN PACIFIC RAILROAD.

This beach, terracelike, at Hugh McIntosh's house, in the south edge of the NW. ¼ of Sec. 8, T. 136, R. 54 (Sheldon), has its crest 1,083 to 1,084 feet above the sea. His well, near the top of the beach, 22 feet deep, is soil and sandy clay to a depth of 7 feet, then sand 15 feet to water. Till rises to the surface 20 rods farther west. About 30 rods east, on land 10 feet lower, a well 10 feet deep is all caving sand below the black soil, which is 1 or 2 feet deep next to the surface.

From the east base of the beach near Mr. McIntosh's there is a very slight descent eastward to 1,065 feet, approximately, about Island Lake, which lies some 10 feet lower. This lake, nearly round, about a third of a mile in diameter, is crossed by the line between Secs. 9 and 10. Its island, which is said to have an area of 12 acres, lying in Sec. 9, is wooded; but the shores around the lake are destitute of timber, being in part marshy, with grass and rushes, and in part hard sand. The maximum depth of water is only 6 feet, but it has not been dried up during the six years from the first immigration here to the time of this survey.

Maple River in Sec. 32, T. 137, R. 54, about 2 miles northeast from its most southern bend, 1,017 feet. It is 20 to 40 feet wide and 1 to 3 feet deep, with cobbles and bowlders in many portions of its channel.

Herman beach, a sand and gravel deposit extending a quarter of a mile from south to north on the verge of the bluff of till west of Maple River in the northwest part of this Sec. 32, 1,072 to 1,077 feet. In the north edge of the NW. ¼ of this section, the northeast corner of Sec. 31, and the east edge of Sec. 30, it is a plateaulike tract a fourth of a mile wide, with a subsoil of sand and fine gravel, 1,086 feet, from which both east and west a gentle slope falls 5 feet within 20 or 30 rods. In the NW. ¼ of Sec. 20 and the west half of Sec. 17, it is a gracefully rounded ridge, 1,085 to 1,087 feet, with descent of about 5 feet on its west side and 10 to 15 feet within as many rods on the east. The surface east of the Maple River in this T. 137, R. 54, has an elevation of 1,075 to 1,065 feet, declining toward the north and east.

In the east half of T. 137, R. 55, a surface of till, moderately undulating near the beach of Lake Agassiz, but prominently rolling at a distance of 3 miles to the west, rises to 1,150 and 1,175 feet in the vicinity of the Maple River above its south bend.

The Herman beach, a broad flattened ridge of sand and gravel, passes in a north-northeast course through the center of Sec. 8, T. 137, R. 54, its elevation being 1,083 feet. A smoothed surface of till, 1,082 to 1,087 feet, with occasional sloughs in depressions 15 to 20 feet deep, occupies the west half of this Sec. 8; and close east of the beach a flat of till on the east line of the section, at 1,065 to 1,070 feet, was the bed of the lake.

Continuing northeastward, the beach is offset a mile to the east in Secs. 4 and 3, T. 137, R. 54, so that the greater part of Sec. 4 was a bay of Lake Agassiz during its Herman stage, with bottom at 1,080 to 1,065 feet, inclosed on the west, north, and east by beach deposits. The highest portion of the hook or spit east of this bay is in the SW. ¼ of Sec. 3, 1,093 to 1,096 feet. It is composed of sand and fine gravel, with pebbles, mostly less than an inch but occasionally 2 inches in diameter, forming a smoothly rounded swell 30 to 40 rods wide. This cape, projecting south and west a mile into the lake, was accumulated by the southward drift of the beach material along the shore, caused by northern winds, as is also observable at various other places on both the east and west shores of this extinct lake and on both sides of Lake Michigan at the present time.

Herman beach in the west edge of Sec. 26, T. 138, R. 54, 1,094 feet. On the east side of the beach here, near the center of this section, is a slough filled with rushes and containing water all the year; its elevation is about 1,065 feet, that of the land on its east side in the east part of this section being about 1,075 feet. In the NE. ¼ of the NE. ¼ of Sec. 34, the beach is intersected by a sluggish creek, apparently formed by springs within a half mile northwest, its ravine being fully 40 feet below the general level of the beach and the land westward. Again, in the NW. ¼ of the SW. ¼ of Sec. 26, the beach is cut by a dry channel, the outlet in rainy weather from a small slough.

Through the west half of Sec. 23, T. 138, R. 54, the beach is a low, smoothly rounded ridge of sand and fine gravel, about half of which is limestone and the rest granite or other Archean rocks. As in the 3 miles next southward, it is largely composed of fine gravel, and pebbles abound, often covering half the surface of the knolls made by gophers. Most of the pebbles are less than an inch in diameter, but some measure 2 and a few 3 inches. The elevation of this beach ridge is 1,092 to 1,100 feet; on the north line of this section its height is 1,099 feet. A broad depression 3 to 5 feet below the beach borders its west side. Toward the east there is a descent of about 10 feet in 25 or 30 rods, and thence a gradual slope sinks to 1,060 or 1,050 feet within 1 to 1½ miles.

Undulating till in Secs. 22 and 15, T. 138, R. 54, 1,095 to 1,110 feet; crests of prominently rolling till in the west edge of Sec. 11 and the south part of Sec. 10, 1,115 to 1,125 feet; thence northwestward lower undulating till has an elevation of only 1,090 to 1,100 feet for nearly two miles and rises quite slowly beyond.

This somewhat irregular contour has caused considerable diversity in the development of the beach, so that its deposits are massed in unusual amount in some places, while elsewhere they are deficient or wholly wanting. In the SW. ¼ of the SW. ¼ of Sec. 14, T. 138, R. 54, a swell of gravel, with pebbles of all sizes up to 2 inches or rarely 3 inches in diameter, rises to 1,105 feet, extending about 40 rods from south to north; and similar gravel, at 1,095 to 1,105 feet, occurs in the west part of the NW. ¼ of Sec. 23, west of the distinct beach ridge. The northwest part of Sec. 14 is a nearly flat tract, having a subsoil of sand and fine gravel, with an elevation of 1,090 to 1,095 feet. Beach ridge extending south from the east side of a prominent swell of till in the SW. ¼ of Sec. 11, 1,086 to 1,089 feet, having a continuous depression of about 5 feet on its west side and bordered eastward by land 6 to 10 feet below its crest. In the northwest part of this Sec. 11 and the southeast part of Sec. 3 the shore of Lake Agassiz is marked by slight erosion in the rolling and undulating surface of till rather than by the usual beach deposits of gravel and sand.

Beyond this, a conspicuous beach ridge 25 to 40 rods wide, elevated 10 feet above the undulating till on its west side and bordered by a still lower surface on the east, extends from the middle of the SW. ¼ of the SE. ¼ of Sec. 3, T. 138, R. 54, northwestward to near the middle of the north line of the NW. ¼ of this section, where it is interrupted by a drainage gap about 20 feet below its crest. Thence this massive beach ridge continues in a north-northeast course through Sec. 34, T. 139, R. 54, to near the middle of its north line. Its material is sand and gravel, with pebbles up to 1½ inches in diameter. In Sec. 3 its elevation is 1,095 to 1,090 feet, and in Sec. 34, 1,089 to 1,094 feet. It passes onward as a very distinct and typical beach ridge, with the same north-northeast course, through Secs. 27 and 22, T. 139, R. 54, having an elevation of 1,087 to 1,095 feet in Sec. 27 and 1,089 to 1,096 feet in Sec. 22. Its eastern slope in these sections descends 15 to 20 feet.

About a half mile west from this great beach ridge the east edge of Sec. 4 has irregular deposits of beach gravel and sand in swells and bars 5 feet above the general level, and in the east edge of Sec. 33, T. 139, R. 54, a well defined parallel beach begins, having a width of 20 to 25 rods and elevation of 1,092 to 1,094 feet, with a depression 2 to 4 feet lower on the west and descent of about 5 feet on the east. This western Herman beach extends as a continuous ridge 2 miles to the north-northeast, excepting a gap where it is intersected by a small stream in the NW. ¼ of Sec. 27. Its material is sand and gravel, with pebbles up to 2 inches in diameter, about half of which are limestone. Both this and the east beach have a black soil a foot or more in depth, and are scarcely inferior to the adjoining areas of till in productiveness. Farther west a slightly undulating or nearly flat surface of till extends from a half mile to 1½ miles before it rises above 1,095 feet; and the highest of its swells, seen 3 to 6 miles away to the west and northwest, do not exceed 1,150 or 1,175 feet. Western Herman beach on the north line of the NW. ¼ of Sec. 27, 1,095 feet; about 6 rods to the south, 1,097 feet, and northeastward, in Sec. 22, 1,092 to 1,095 feet, to its junction with the eastern or main beach in the east part of this section.

A lower Herman beach, formed after the lake level here had fallen slightly, appears in the northwest edge of Sec. 26, T. 139, R. 54, having its crest at 1,072 to 1,075 feet; passing north-northeast.
west half of Sec. 23, its elevation is 1,075 to 1,080 feet; through Sec 14, 1,080 to 1,087 feet, being highest near the center of this section; and in the east part of Secs. 11 and 2 and northward to the SW. ¼ of Sec. 36, T. 140, R. 54, 1,083 to 1,080 and 1,075 feet. Its maximum development is in Sec. 14, where it is a massive, smoothly rounded ridge of sand and fine gravel, 30 rods wide, with a descent of 15 feet on each side. In Secs. 26 and 23 it is bordered on the west by a continuous depression 4 to 8 feet below it; and, through Secs. 14, 11, and 2 and in the SW. ¼ of Sec. 36, a slough 3½ miles long, mown for its luxuriant marsh hay, having an elevation of 1,067 to 1,072 feet, lies between this and the main beach, a half mile farther west.

Floor of S. P. Gardner's house, in the northwest corner of Sec. 27, T. 139, R. 54, 1,096 feet.

Main Herman beach through the west edge ot Sec. 14, T. 139, R. 54, 1,096 to 1,093 feet, declining northward; in the west part of Sec. 11, 1,093 to 1,095 feet; in Sec. 2, 1,092 to 1,095 feet, changing from a north to a north-northeast course; in the southeast edge of Sec. 35 and the northwest edge of Sec. 36, T. 140, R. 54, 1,092 to 1,096 feet; and in the west part of Sec. 25, where it is cut by the Northern Pacific Railroad, 1,093 to 1,099 feet. At the railroad cut its crest is 1,097 to 1,099 feet and the track is 1,091 feet. Along this distance of 5 miles it is a typical beach ridge of sand and gravel, with pebbles up to 2 inches and occasionally 3 to 6 inches in diameter, about 30 rods wide, rising nearly 25 feet above the slough on the east, and bordered on the west by a continuous depression, mostly about an eighth of a mile wide, 3 to 7 feet below its crest. Slightly undulating till rises beyond to 1,125 and 1,140 feet within 1 or 1½ miles west, which is as far as the surface lies within view.

Northern Pacific Railroad, track at Wheatland, 991 feet; on bridge over creek in the east edge of Sec. 25, T. 140, R. 54, 4 miles west of Wheatland and three-fifths of a mile east of the Herman beach, 1,074 feet; bed of the creek, 1,055 feet; track at summit, 4½ miles west from the Herman beach, same as the natural surface, 1,206 feet; and at Buffalo, a half mile farther west, 1,200 feet.

FROM THE NORTHERN PACIFIC RAILROAD NORTH TO GALESBURG.

Herman beach, a broad, smoothly rounded, continuous ridge of the same material and contour as southward, for the next 4 miles north from the Northern Pacific Railroad, bearing north-northeast, 1,097 to 1,100 feet, very constant in elevation. The descent of its east slope is 15 or 20 feet in about 20 rods, and of its west slope, about 5 feet. Thence westward the surface is undulating till, in swells 10 to 15 feet above the depressions, rising gradually to 1,150 and 1,200 feet above the sea at a distance of 3 to 5 miles, the farthest seen in that direction. In a broad view this area seems an almost flat plain.

Where this beach is cut by the Saint Paul, Minneapolis and Manitoba Railway from Ripon to Hope, near the middle of the line between Secs. 32 and 33, T. 141, R. 53, its crest was 1,096 to 1,099 feet above the sea. It has been excavated here for ballast to a distance of about 30 rods south from the railway. It is mostly gravel; the pebbles seldom exceed 2 inches in diameter; about half is limestone and the remainder granitic. The thickness of this beach deposit is only 8 to 10 feet; its east slope falls 12 or 15 feet, and its west slope, 5 to 7 feet.

On the floor of this excavation, about 10 rods south from the railway, in the upper foot of the till or bowlder clay, under the gravel, numerous bones of a mammoth were found in the year 1884. These included a tusk 11 feet long and 9 inches in diameter (tapering to 6 inches at the smaller end, where it was broken off), three teeth, two vertebræ, and several other bones. They were embedded in the top of the till, and the overlying beach formation has yielded no bones, shells, or other fossils.

Southward from this locality the Herman beach is double for a distance of about 4 miles. The secondary beach ridge east of that already described is similar in size and material. Its south end is in the west part of Sec. 19, T. 140, R. 53, a half mile east from the main beach, and it passes thence north-northeastward through Secs. 18, 7, and the east edge of Sec. 6, having an elevation of 1,081 to 1,084 feet. It becomes merged with the main beach in the SE. ¼ of Sec. 32, T. 141, R. 53. Between these beach ridges is a depression, approximately 1,075 feet, partly occupied by a grassy slough, which is all used as mowing lane, having no area of water or bog.

Herman beach, in the SW. ¼ of Sec. 28, T. 141, R. 53, 1,094 to 1,096 feet, not so distinct as usual, being intersected by Swan Creek and having no well marked depression along its west side. Farther north in this section it is a ridge of the ordinary type, with its crest at 1,096 to 1,098 feet. In Sec. 21 it is narrowed to 8 or 10 rods in width, but continues as a very distinct ridge with a slight ascent northward, from 1,097 to 1,101 feet. Its east slope falls 15 to 20 feet in about 20 rods and there is a depression of 3 to 6 feet on the west. Thence a surface of undulating till, seeming nearly flat in a general view, rises gradually westward to about 1,150 feet at a distance of 2 or 3 miles.

This beach ridge passes onward through Sec. 16 and the south part of Sec. 9, T. 141, R. 53, with an elevation of 1,095 to 1,100 feet; but, having been followed thus continuously in a north-northeast course for more than 15 miles, it ceases in the east part of this Sec. 9. Its north end abuts at 1,100 to 1,105 feet upon a terrace slope of till, which rises about 10 feet higher. This forms the east boundary of a slightly undulating expanse of till, which thence gradually rises to 1,150 and 1,200 feet in 2 to 5 miles west and northwest. From Sec. 9 northward through the east part of Sec. 4 and in the west edge of Sec. 34 and the west part of Secs. 27, 22, and 15, T. 142, R. 53, passing close east of Erie, the Herman shore of Lake Agassiz is marked by such a terrace or escarpment formed by wave erosion, and the usual deposit of beach gravel and sand is absent. The base of the escarpment is at 1,095 feet, approximately, and it rises with a moderate slope 25 to 40 feet.

About a half mile east of this escarpment, however, lies a broad low ridge of beach sand and fine gravel, having an elevation of 1,085 to 1,090 feet. Its course is from the west part of Sec. 10 north-northeast through Secs. 3 and 34 and nearly due north through the east edge of Secs. 27, 22, and 15. The descent eastward is more gentle than usual, falling only 6 to 10 feet in a quarter of a mile, beyond which is a flat area of till. On the west a depression 3 to 5 feet deep, partly occupied by a grassy slough, intervenes between this beach ridge and the wave-cut escarpment. On the north line of Sec. 15 the crest of the ridge is at 1,092 feet; the depression west, 1,088; the base of the escarpment, 1,092, and its top, about 1,115 feet.

Saint Paul, Minneapolis and Manitoba Railway from Ripon to Portland, track at tank and section-house close south of Rush River, 1,096 feet; at Erie, 2 miles farther north, 1,128 feet; summit, about 1 mile north of Erie, 1,133 feet; South Branch of the North Fork of Elm River, bridge, 1,083 feet; bed of creek, 1,064 feet; track at summit 1 mile north, 1,091 feet; at Galesburg, 1,081 feet; North Branch of the North Fork of Elm River, bridge, 1,078 feet; bed of creek, 1,065 feet; track at Clifford, 1,057 feet. At Erie and westward the surface is prominently rolling till, which rises within 3 miles to a height 100 feet above the shore of Lake Agassiz.

In Secs. 10 and 3, T. 142, R. 53, the Herman beach is again well exhibited in its usual character. On the north line of Sec. 10 it is a gently rounded ridge of sand and gravel, with pebbles up to 2 inches and rarely 3 or 4 inches in diameter, half being limestone; its width is about 20 rods; the elevation of its crest is 1,106 feet and the slopes fall 10 feet on the east and 3 feet on the west. For the next mile northward, through the west part of Sec. 3, this beach ridge has a width of 10 to 15 rods; its elevation is mostly 1,105 to 1,108 feet, with a depression 5 to 7 feet deep along its west side; but in a few places the ridge itself is depressed to 1,099 feet. Passing northward this beach in the west half of Sec. 34, T. 143, R. 53, is a very smooth, gracefully rounded, wavelike swell, 30 to 40 rods wide, 1,108 to 1,112 feet in elevation, rising 15 feet above its east base and having a depression of 3 to 5 feet on the west. A well in the NE. $\frac{1}{4}$ of the SW. $\frac{1}{4}$ of Sec. 34, on the top of this beach, went through 12 feet of sand and gravel, going into till below. In the SW. $\frac{1}{4}$ of Sec. 27, the beach continues with the same massive development and nearly north course, its elevation being 1,111 to 1,115 feet. In the NW. $\frac{1}{4}$ of this section it becomes a still broader deposit of gravel and sand, a fourth to a third of a mile wide, with no depression on its west side. Here its course is turned northwestward, entering the SE. ¼ of Sec. 21 with an elevation of 1,109 feet; but it seems not to be distinctly traceable farther. About a half mile west of this beach a plateau of till, 1,125 to 1,128 feet above the sea, extends a third of a mile from southeast to northwest in the SE. ¼ of Sec. 28; but for a mile south and west of this plateau and for 3 miles northwest the surface of slightly undulating till averages only 1,105 to 1,120 feet.

The secondary Herman beach, already described in its course east of the Erie escarpment of till, continues northward with an elevation of 1,095 feet, approximately, through the east half of Secs. 10 and 3, T. 142, R. 53, and Secs. 34 and 27, T. 143, R. 53. In Secs. 22 and 16 this beach turns in a gradual curve to the northwest and west and its crest varies in height from 1,095 to 1,104 feet, being highest in or near the southeast corner of Sec. 16. There it is a ridge of gravel and sand about 30 rods wide, rising 10 to 15 feet above its northeastern base and descending 6 to 10 feet on the southwest to a nearly flat tract of moist mowing land fully a mile wide, with a height of 1,090 to 1,095 feet. Through Secs. 17, 8, and 5 it again curves to the northwest, north, and north-northeast, having an elevation of about 1,100 feet. In the north half of Secs. 5 and 4, T. 143, R. 53, a smooth plain with sand subsoil extends a mile eastward from the east base of this beach ridge, descending in this distance from 1,090 to 1,075 feet.

Continuation of this beach northward nearly through the middle of Sec. 32, T. 144, R. 53, 1,096 to 1,099 feet. It is a typical beach ridge of fine gravel and sand 8 to 10 feet above the land on its east side and having a descent of about 5 feet westward, beyond which the surface of undulating till rises in 1 or 1½ miles to 1,125 and in the next 2 miles to 1,175 or 1,200 feet. A half mile east from this beach and only 20 to 30 rods west of the railroad, there is a parallel beach ridge of similar size and material, 1,090 to 1,092 feet. The former of these beaches, where it crosses the south line of Sec. 20, a fourth to a half mile west of Galesburg, is spread in a broad, nearly flat deposit which rises westward from 1,096 to 1,101 feet. On the west it is bordered by a depression about 8 feet lower.

FROM GALESBURG NORTH TO LARIMORE.

In Sec. 20, T. 144, R. 53, the beach is about a third of a mile wide, its higher western margin being at 1,097 to 1,102 feet. From its crest a slope descends first somewhat steeply and then slowly to the amount of 20 or 25 feet in two-thirds of a mile eastward, having a subsoil of sand and very fine gravel to a depth of 5 to 10 feet, underlaid by till, as is shown by wells at Galesburg. Crest of this beach through the west half of Sec. 17, 1,102 to 1,107 feet; in Sec. 6, T. 144, R. 53, where it is intersected by the North Branch of the North Fork of Elm River, and in Secs. 32 and 29, T. 145, R. 53, 1,115 to 1,125 feet, being 10 to 15 feet higher than on the south and north; in Secs. 20 and 17, about 1,110 feet; in the southwest part of Sec. 8, 1,117 feet; westward through Sec. 7 of this township and through the northeast part of Sec. 12, T. 145, R. 54, 1,112 to 1,117 feet. In the west part of Sec. 7 a slough about an eighth of a mile wide, having an elevation of 1,100 feet, approximately, borders the southwest side of this beach ridge. On the line between Traill and Steele Counties, where the top of the ridge is at 1,114 feet, it is a typical beach deposit about 25 rods wide, composed of sand and gravel, with pebbles up to 2 or 3 inches in diameter. Its course is due west, and the descent from crest to base on the south is 6 or 8 feet and northward 12 or 15 feet, beyond which a very gentle slope sinks toward the northeast. A well on this beach, in the east edge of the NW. ¼ of Sec. 12, T. 145, R. 54, went through sand and fine gravel 13 feet, finding till below. Within a few hundred feet farther west the beach is interrupted for a distance of about 1 mile by an area of till some 15 feet lower, with no beach deposits. It reappears, however, as a typical beach ridge of gravel and sand for a distance of three-fourths of a mile in the NW. ¼ of Sec. 11 and the NE. ¼ of Sec. 10, having an elevation of 1,114 to 1,112 feet, with a slough on its south side 6 to 8 feet lower.

Returning to the vicinity of Galesburg, a slightly higher beach, approximately parallel with the foregoing, remains to be traced. It becomes recognizable in the west edge of Sec. 20, T. 144, R. 53, where the border of the area of rolling till that extends thence westward bears occasional deposits of gravel at 1,115 to 1,120 feet. In the east part of Sec. 18 it is a well developed beach ridge of sand and fine gravel 30 to 50 rods wide, with a depression on the west 4 to 6 feet below its top, which has an elevation of 1,120 to 1,123 feet. The next half mile or more westward in Sec. 18 is very smooth till, 1,120 to 1,125 feet; but within one mile farther west prominent swells of till rise to 1,160 and 1,175 feet. Northward in Sec. 7 this beach, continuing at 1,120 to 1,123 feet, is quite broad, without a distinctly ridged form, and is indented from the east by a large slough, whose elevation is approximately 1,100 feet, including several acres of water free from grass and rushes. Crest of beach in the SW. ¼ of Sec. 6, 1,122 to 1,126 feet. North Branch of the North Fork of Elm River 1,105 feet, dry in summer, in a valley 15 to 40 rods wide. Beach through Secs. 31 and 30, T. 145, R. 53, 1,125 to 1,129 feet; and in the west half of Sec. 19, 1,127 to 1,124 feet, sinking slightly from south to north. The farther course of this shore is not marked by continuous beach deposits; but, following the contour line of 1,125 feet, it must turn west in the SW. ¼ of Sec. 18, T. 145, R. 53, and extend through Secs. 13 to 16, T. 145, R. 54, to the South Branch of Goose River.

Highest ground crossed by road on the line between Traill and Steele Counties at the west side of Sec. 18, T. 145, R. 53, 1,125 feet.

Natural surface at the southwest corner of Sec. 3, T. 145, R. 54, a dozen rods west of the South Branch of Goose River, 1,104 feet. This stream, about 1,070 feet, is 8 to 20 feet wide and mostly 1 to 2 feet deep. Its bottom land, 5 to 10 feet above this stage of low water, varies from 20 to 100 rods in width and is inclosed by bluffs rising 30 to 50 feet, increasing in height southwestward. The valley has no timber, the largest wood growth being willows 5 to 8 feet high and 2½ inches or less in diameter. With the aid of these, however, beavers construct dams and were living on this stream when this survey was made in 1885, one of their dams then occupied being found by my assistant in the west edge of Sec. 10, T. 145, R. 54.

Floor of Henry Bentley's barn in the southwest corner of the SE. ¼ of Sec. 6, T. 145, R. 54, on the Herman shore of Lake Agassiz, 1,123 feet. This is a moderate slope, ascending 10 or 15 feet, eroded in till, which from its top stretches westward about 2 miles in a nearly level expanse. From the south side of Sec. 6, such a low escarpment, with its top at 1,120 to 1,123 feet, extends due north, or a few degrees west of north, about 5 miles.

E. W. Palmer's house, in the northwest corner of the SW. ¼ of Sec. 2, T. 145, R. 55, 1,145 feet. Well here, 27 feet deep: soil and hard cemented gravel and sand, 2 feet; sand with occasional layers of fine gravel, 22 feet; and darker clayey quicksand, 3 feet, with water.

This is on the west part, nearly at the crest, of an unusually high beach of this glacial lake, similar in elevation with the Milnor beach, farther south. Including its slopes, it has a width of 60 rods, the nearly flat crest being 40 rods across and in elevation 1,142 to 1,147 feet. The depression on the west falls about 5 feet. In the north part of Sec. 2 the beach deposits have an irregular contour, not lying as usual in a continuous ridge; their highest portions vary from 1,145 to 1,152 feet. Southward from Sec. 2 this shore line is not marked by a continuous beach formation, but is interrupted by wide depressions where the surface is till. Beach gravel and sand appear, however, in some amount at Mr. Thomas Ward's, in the southwest corner of Sec. 11, T. 145, R. 55; also, in the southwest part of Sec. 23, nearly 2 miles farther south. Within 1 to 3 miles west from these sections an area of undulating and rolling till rises to 1,200 and 1,250 feet.

Near the middle of the north half of Sec. 23, T. 146, R. 55, the elevation of this beach is 1,142 to 1,144 feet. It is a ridge of gravel and sand, extending a quarter of a mile from southeast to northwest, with crest 15 feet above the surface on each side. Toward the east it descends in a long slope, but more steeply westward. In Sec. 14 this shore line curves westerly, the crests of its somewhat irregular beach deposits being about 1,135 feet, with a descent of 10 to 15 feet in 25 rods east. Through Sec. 11 they range from 1,135 to 1,147 feet, being highest in the SE. ¼, where the descent eastward is 20 feet or more. These beach deposits are sand and gravel, with pebbles up to 1½ or 2 inches in diameter, massed in flattened hillocks or swells, mostly ridged lengthwise with the shore and occasionally inclosing hollows without outlet. The formation has a width of a quarter of a mile or more in its northward course through the west part of the east half of Sec. 11. An undulating surface of till rises slowly to the west, while on the east a very smooth expanse of till sinks slowly toward the Red River.

Herman beach ridge, 30 rods wide, in or near the east edge of the SE. ¼ of Sec. 2, T. 146, R. 55, 1,125 feet. Irregular accumulations of the higher beach a quarter of a mile farther west, approximately, 1,140 feet. These upper deposits and those described in the last two paragraphs seem to have been formed while the level of this margin of Lake Agassiz was held above its Herman stage by the barrier of the retreating ice sheet, still remaining unmelted within a few miles east, and by that of the high area on the south in Ts. 144 and 145, R. 54.

Crest of the Herman beach, a definite ridge 25 to 30 or 40 rods wide, through the east half of Sec. 2, T. 146, R. 55, 1,122 to 1,135 feet, 10 to 15 feet above the land east and with a depression of 6 to 8 feet on the west. In the south part of Sec. 35, T. 147, R. 55, the beach ridge is merged in a flat, eastwardly sloping area of sand and fine gravel at 1,135 to 1,120 feet, underlaid by till at the depth of a few feet. The beach ridge reappears in the north part of this Sec. 35 at 1,125 to 1,130 feet.

North Fork of the Middle Branch of Goose River, where it intersects the Herman beach in the southeast part of Sec. 26, T. 147, R. 55, approximately, 1,085 feet. Its bottomland is 30 to 80 rods wide, bordered by bluffs rising 30 to 40 feet.

Through Secs. 26 and 23, T. 147, R. 55, the Herman shore is marked by swells and flattened ridges of sand and fine gravel at 1,130 to 1,143 feet, occupying a width of an eighth to a third of a mile, with a depression of several feet along their west side. Four sloughs, elevation about 1,120 feet, lie within the east part of these beach deposits, or on their east border, in the SE. ¼ of Sec. 23. In the south part of Sec. 14, this massive but irregular beach has an elevation of 1,132 feet on the east side of a large slough.

In the middle of Sec. 14, T. 147, R. 55, the beach assumes a definitely ridged form and extends thus northward along the east side of Golden Lake, which owes its existence to this barrier. Crest of beach, through the center and north part of Sec. 14, 1,132 to 1,137 feet; in Sec. 11, east of Golden Lake, 1,132 to 1,141 feet; and at Golden Lake post office, in the east edge of the SW. ¼ of Sec. 2, 1,138 feet. An eighth of a mile north from the south end of this lake the action of its waves has eroded the greater part of the beach ridge. The material of the beach exposed by an excavation near the post office is coarse gravel, with very abundant pebbles up to 3 and occasionally 4 to 6 inches in diameter.

Golden Lake, water July 28, 1885, 1,122 feet above the sea; highest level reached by this lake in recent years, 1,128 feet. It is a beautiful sheet of water, 1¼ miles long and a quarter to a third of a mile wide. Its west shore is moderately undulating till, with the highest swells 20 to 30 feet above the lake. In a few places its grassed bluffs rise steeply from the water's edge 10 to 20 feet. Farther west the rolling surface of till, seen for a distance of 3 or 4 miles, rises to 1,225 or 1,250 feet. This lake has no trees on its margin, excepting two small cottonwoods, each about 25 feet high, on its northwest shore; bushes grow in several places, mostly on the east; but the greater part of the lake border, like all the surrounding country, is prairie.

Beach ridge through the north part of Sec. 2, T. 147, R. 55, 1,138 to 1,132 feet. In the south half of Sec. 35, T. 148, R. 55, it has been mostly eroded by a lake which borders this beach on the east from the north part of Sec. 2 to the north part of Sec. 35, having a length of 1 mile and a width of an eighth to a fourth of a mile. The elevation of this lake is 1,104 feet. It has no trees nor bushes, excepting a few willows 4 to 6 feet high near the middle of its west side, and is wholly surrounded by hard grassy shores. Crest of beach west of the north part of this lake, 1,140 to 1,142 feet, and through the south half of section 26, 1,137 to 1,142 feet, similarly bordered on the east by two lakelets, which have approximately the same height as the preceding, 1,104 feet. The land east of these three lakes is flat, 1,113 to 1,117 feet near them, with a very gentle slope descending thence eastward.

More diffuse and irregular beach deposits in north to south swells and short massive ridges of gravel and sand, inclosing occasional hollows with no outlets, some of which hold small ponds and sloughs, extend from the north edge of Sec. 26 northward through the west half of Sec. 23, T. 148, R. 55, with an elevation of about 1,135 feet. The depression on the west is some 5 feet lower and on the east there is a descent of 10 feet from the crest to the base of the beach. Fingal's Creek in the northwest corner of section 23, where it intersects the beach, about 1,110 feet. Undulating and rolling till within 3 or 4 miles westward rises to 1,250 feet.

Herman beach through the west part of Sec. 14, T. 148, R. 55, 1,142 to 1,147 feet, being mainly a somewhat typical ridge, with short swells of beach gravel and sand on its east side 10 to 15 feet lower, inclosing hollows, but few or no sloughs. Two lakes at 1,110 feet, approximately, lie close east of this beach near the center and in the NW. ¼ of this section. They are bordered on the east by land 10 feet higher, from which a very gentle descent sinks toward the Red River.

Continuation of this beach ridge northward through the east edge of Sec. 10, T. 148, R. 55, 1,142 to 1,146 feet, 3 to 5 feet above the depression on its west side. On the east, three lakelets at 1,120 feet, approximately, lie in the west edge of the NW. ¼ of Sec. 11, each being about 20 rods long from south to north and 15 rods wide. Crest of beach ridge, 30 to 40 rods wide, extending nearly due north through the east edge of Sec. 3, 1,144 to 1,150 feet; east base about 1,125 feet; depression on the west, 5 to 10 feet, nearly level upon a width of 40 rods; beyond is an ascent of undulating and rolling till to 1,250 feet within 2 or 3 miles. In the SW. ¼ of the SW. ¼ of Sec. 36, T. 149, R. 55, this Herman shore is marked by irregular swells and massive short ridges of gravel and sand, with occasional inclosed sloughs. This is succeeded by a half mile of the ordinary continuous single ridge, 1,147 to 1,150 feet.

Watercourse intersecting the beach near the northwest corner of Sec. 36, T. 149, R. 55, about 1,115 feet; bottomland 10 to 15 feet higher, a third of a mile wide, bordered by bluffs rising about 25 feet above it. Some portions of this creek are very shallow or dry, with scarcely any channel, but other portions are pools 6 to 9 feet deep and 20 feet wide, extending 10 to 20 rods or more.

Magnificent beach ridge, passing north-northwest through the east part of Secs. 26 and 23, T. 149, R. 55 (Lind), 1,147 to 1,150 feet. A road, which was formerly an Indian trail, runs on its top here and for several miles northward. This beach is composed of the usual sand and gravel, thickly filled with pebbles up to 2 and rarely 4 inches in diameter. It forms a broad wavelike ridge, 30 to 40 rods wide, including the slopes. On its west side is a depression of 5 to 10 feet, 20 to 60 rods wide, which is moist grass land, excepting a small reedy slough in the south edge of Sec. 11. Farther west undulating and rolling till rises to 1,175 feet within a quarter or a third of a mile and attains a height of 1,250 to 1,300 feet within 3 to 5 miles. On the east side of this upper Herman beach there is a very smooth slope descending 25 or 30 feet in as many rods. Next is a nearly level belt 20 to 60 rods wide, increasing in width from south to north, succeeded by a lower Herman beach ridge rising 8 to 10 feet, with its crest at 1,127 to 1,130 feet, or 20 feet below the upper beach. These parallel Herman beaches are very finely developed thus for nearly 6 miles, passing north through Secs. 23, 14, 11, and 2, T. 149, R. 55, and the southwest part of Sec. 35, T. 150, R. 55. High portion of the upper beach in the south edge of Sec. 14, 1,153 feet, and depression west, 1,142 feet; crest onward through this section, 1,153 to 1,149 feet. In the north part of Sec. 11 and the south edge of Sec. 2, it is a few feet lower, is irregular in height and outlines because of intersecting watercourses, and has a less continuous and shallower depression on its west side. In Sec. 2, however, both beach ridges are finely displayed, having the same contour as southward. Crest of upper beach in Secs. 2 and 35, 1,152 to 1,155 feet; depression on the west, 8 to 15 feet, partly occupied by a long slough. The northwest part of Sec. 35, in the course of these beaches, is lower smooth till, with no deposits of sand and gravel.

Goose River, near the north line of the NW. ¼ of Sec. 35, and the Little Goose River, in the north part of Sec. 15, T. 150, R. 55, where they cross the ancient lake shore, are in valleys about 30 feet deep, eroded in till. Each consists of pools 5 to 7 feet deep and 10 to 20 feet wide, alternating with other portions so narrow that one may step across them.

In the east part of the west half of Sec. 26 and the southwest corner of Sec. 23, T. 150, R. 55, the upper Herman shore is offset a third of a mile east from the remainder of its course and consists of massive irregular swells of till, partly overspread with gravel and sand, 1,152 to 1,160 feet. Among them are hollows 4 to 6 feet deep without outlet, and their entire belt, a quarter of a mile wide, is crossed by depressions as low as 1,145 feet. Through Sec. 22 this shore bears a typical beach ridge of sand and gravel, 40 or 50 rods wide, 1,157 feet, with depression of 10 to 15 feet on the west; descent of eastern slope, 20 to 25 feet in 30 or 40 rods. In Sec. 15 this upper beach, 1,152 to 1,157 feet, has a quite irregular form, chiefly due to erosion by the Little Goose River and its small tributaries. It is again exhibited in its ordinary type through Sec. 10, being a ridge 25 or 30 rods wide, with crest at 1,155 to 1,157 feet, 15 to 20 feet above its east base, and with a narrow depression of 4 to 8 feet on the west; through the west part of Sec. 3, T. 150, R. 55, and the west edge of the SW. ¼ of Sec. 34, T. 151, R. 55, 1,157 to 1,159 feet, excepting gaps cut by small watercourses; and in the east edge of the NE. ¼ of Sec. 33, 1,154 to 1,157 feet. Thirty rods west from the northeast corner of this Sec. 33, its elevation is 1,155 feet, with slopes descending 12 feet eastward and 8 feet westward.

Lower Herman beach, a half mile to three-fourths of a mile east of the foregoing, in the west edge of Secs. 14 and 11 and the east edge of Sec. 3, T. 150, R. 55, 1,130 to 1,135 feet, from which there is a descent of 5 feet to its west base and 10 feet to the east. From the SE. ¼ of Sec. 34, T. 151, R. 55, this beach passes northeasterly to Larimore.

Upper Herman beach, a well defined ridge, running north through the east part of Sec. 28, T. 151, R. 55, 1,155 to 1,159 feet; thence north-northwesterly through Secs. 21 and 16, 1,157 to 1,160 feet, and through the southwest part of Sec. 9, the northeast of Sec. 8, and the SE. ¼ of Sec. 5, 1,157 to 1,162 feet. Where it is crossed by the Saint Paul, Minneapolis and Manitoba Railway from Larimore to Devil's Lake, in the south part of the NE. ¼ of Sec. 5, its crest was 1,162 feet, 4 feet above the track, and it holds the same height for about 50 rods northeastward. Two-fifths of a mile east from this beach the railroad crosses a second beach deposit whose crest and the track are the same, 1,146 feet.

SHORE WEST OF THE ELK AND GOLDEN VALLEYS.

Through Sec. 32, T. 152, R. 55 (Elm Grove), the upper beach runs northwesterly, its elevation being 1,160 to 1,163 feet. Its material is coarse gravel, with pebbles up to 6 inches in diameter, in part accumulated as a ridge 10 or 15 feet above the land at its base northeast and 5 to 8 feet above its southwest base, and in part lying on the flank of swells of very stony till, the crests of which are only 5 to 10 feet higher than the beach. This till or morainic drift contains a multitude of granitic and limestone bowlders up to 1½ feet in diameter, but few or none of larger size. In the rolling till which rises thence westward to

1,250 or 1,300 feet within 2 or 3 miles, are many granitic bowlders up to 5 feet or more in diameter, exceeding the usual proportion in the till of this region.

In the north edge of Sec. 32 and the south part of Sec. 29, T. 152, R. 55, this beach is the terracelike border of a nearly level tract of sand and gravel an eighth of a mile or more in width, at an elevation of 1,171 to 1,173 feet. The bordering slope is beach gravel, with its base at 1,155 to 1,158 feet; but the slow descent thence eastward is till, somewhat eroded by wave action and having many small and large granitic bowlders up to 4 or 6 feet in diameter strewn on the surface or partially covered by the soil. In the NE. ¼ of Sec. 30 this upper Herman beach is typically developed, being a gracefully rounded ridge of sand and gravel, 25 or 30 rods wide; crest, 1,165 to 1,166 feet; foot of eastern slope, 1,150 feet; depression west, usually 2 to 5 feet, beyond which is a slowly ascending area of smooth undulating till.

Upper beach through Sec. 19, T. 152, R. 55, a low rounded ridge of sand and gravel about 25 rods wide; crest, 1,166 to 1,168 feet; base of its east slope on the north line of this section, 1,158. In the SW. ¼ of Sec. 18, this beach is cut by the South Branch of the Turtle River; its elevation in this section south of the stream is 1,167 to 1,168 feet. There is no considerable valley here and the creek runs only in spring or after unusual rains, being reduced to stagnant pools during the rest of the year. Within 2 miles southeast, however, it becomes a living stream, fed by almost ice-cold springs; and thence to the secondary Herman beach, near Larimore, it has cut a valley 50 to 90 feet deep.

Elm Grove, comprising about 5 acres, is on this creek, a third of a mile east of the upper Herman shore line, which continues north-northwestward through the southwest part of Sec. 18, T. 152, R. 55, and the northeast edge of Sec. 13, T. 152, R. 56 (Niagara), to the west side of Little Elm Grove, 10 acres or more in extent, in the east part of Sec. 12. Along this distance of 1½ miles the surface presents a very favorable slope, from 1,150 to 1,200 feet elevation, on which a beach ridge or definite beach deposits would usually be found well developed; but the waves and currents of Lake Agassiz could not act very efficiently here, because this area lay in the lee of islands and a wave-formed bar or beach several miles to the east, which are the eastern boundary of the Elk Valley. Consequently deposits of beach sand and gravel are scanty on the upper western shore of Lake Agassiz here and for 40 miles northward along the extent of the Elk and Golden Valleys, east of which a narrow chain of islands and bars rose above the surface of Lake Agassiz during its highest Herman stage. Between the South Branch of Turtle River and Little Elm Grove the beach formation consists only of a thin covering of sand and gravel spread on the sloping area of till, elevation from 1,160 to 1,175 feet. Several of the small grassy channels eroded here, dry excepting in spring and times of excessive rain, are almost completely paved with stones up to 1 or 2 feet in diameter, but few stones occur upon the adjoining surface of till.

From the Little Elm Grove the highest western shore of Lake Agassiz (consisting of a similar slope of till ascending gently westward, with inconspicuous deposits of beach gravel and sand, not accumulated in any distinct ridge, but probably recognizable almost continuously) extends northward through Secs. 12 and 1, T. 152, R. 56, and Secs. 31 and 30, T. 153, R. 55 (Agnes), to the central part of Bachelors' Grove, which it passes through in the west half of Sec. 30. This grove borders the head stream of Turtle River for 1½ miles, with an average width of about a quarter of a mile, thus comprising approximately 250 acres. It is dense woods, chiefly elm and basswood in its east half, but nearly all bur oak for the west half. Much bur oak is also found along several miles of this stream next westward, but it is not seen from the margin of Lake Agassiz, being hidden in the valley, 40 to 50 feet deep, which the stream has eroded in that area of undulating and rolling till.

Surface at M. S. Wallace's house, in the middle of the west edge of Sec. 32, T. 153, R. 55, 1,146 feet. Bridge over the North Branch of Turtle River on the east line of the SE. ¼ of Sec. 30, 1,150 feet; channel (dry August 5, 1885), 1,142 feet. There is no valley here, only a trenchlike channel in the flat expanse of Lake Agassiz, 8 feet deep.

Herman beach, for the first mile or more north from Bachelors' Grove, passing through the NW. ¼ of Sec. 30 and the west edge of Sec. 19, 1,165 to 1,170 feet. This is mostly a well defined beach ridge, 20 to 30 rods wide, composed of sand and gravel, with pebbles up to 2 inches in diameter. It rises slowly to a height of 10 or 12 feet above the flat land on the east and is bordered on the west by a depression of 1 to 3 feet, beyond which a smoothly undulating and rolling surface of till rises to an elevation of 1,200 and 1,250 feet at a distance of 3 miles. In the NW. ¼ of this Sec. 19 the beach deposit becomes complex, consisting of several irregular ridges rising 5 to 8 feet above their bases, 1,167 to 1,170 feet above sea level, with inclosed hollows, and the depression close west occasionally sinks to 1,155 feet.

Surface at Michael McMahon's house, 40 rods west from the center of Sec. 13, T. 153, R. 56 (Oakwood), 1,176 feet. Rounded hill of till a half mile northeast, about 1,205 feet; swells of till in the southwest part of Secs. 12 and 2, 1,195 to 1,210 feet.

Through these Secs. 13 and 12, the southwest part of Sec. 1, and in Sec. 2, T. 153, R. 56, to the grove on the north line of this section at the junction of the north and south branches of Lost Creek, and thence northeast and north through Sec. 35, T. 154, R. 56 (Elksmount), the Herman shore, between 1,160 and 1,170 feet, is not marked by any considerable deposits of gravel and sand. Farther north this shore is distinguished not only by a noticeable change in the topographic features along a nearly level line at 1,170 feet, dividing the very flat area of the glacial lake from the undulating and rolling till on the west, but also by occasional beach deposits. Through the south half of Sec. 26 a somewhat typical beach ridge of sand and gravel, 15 to 25 rods wide, with a depression of 3 to 6 feet on its west side, runs north and northwest, its crest being at 1,175 to 1,170 feet, declining from south to north. On the east its slope falls 5 to 10 feet in 10 to 20 rods; and thence a more gentle descent, with surface of sand and fine gravel, sinks to 1,155 feet within an eighth of a mile. In the NW. ¼ of this Sec. 26 the beach ridge ceases and is succeeded northward by an expanse of nearly flat till, which along the north line of this section sinks eastward from 1,175 to 1,155 feet.

Elk Valley, for 12 miles from Elm Grove and McCanna north to Forest River, is nearly constant in elevation, which is 1,155 feet on its west border and 1,135 feet near its east side, its average width being about 4 miles.

Surface at Frank Hamilton's house, in the center of the NE. ¼ of Sec. 15, T. 154, R. 56, 1,178 feet.

Upper Herman beach, a definite and massive ridge of sand and fine gravel, 25 to 40 rods wide, for a half mile south from the South Branch of Forest River, in the west part of the NW. ¼ of Sec. 14, T. 154, R. 56, 1,173 to 1,178 feet, passing north and northwest, with a descent of 12 to 15 feet on the east and a depression of 4 to 8 feet on the west.

Beyond this branch of the Forest River, in the north half of Sec. 10, the beach ridge, similar in outline, with its crest at 1,174 to 1,179 feet, is the site of an abandoned railway grade, on account of which its material is well exhibited. It is sand and gravel, and three-fourths of the pebbles, mostly less than 2 inches in diameter, are dark gray slaty shale. Twenty miles to the south-southeast the same shale in small grains makes fully two-thirds of a stratum of sand that extends from 20 to 60 feet in depth in the well at the Sherman House, Larimore. Pebbles of it were also observed in kamelike deposits of gravel and sand near Balaton, Lyon County, in Southwestern Minnesota. During the further exploration of the western shore of Lake Agassiz this shale was discovered in place and is found to be the bed rock, of cretaceous age, which forms the conspicuous escarpment of Pembina Mountain, though even there it is generally covered and concealed by drift.

Natural surface at the northwest corner of Sec. 3, T. 154, R. 56, on the line between Grand Forks and Walsh Counties, 1,181 feet.

The upper Herman shore passes north-northwesterly through this corner of Sec. 3 and the east part of Sec. 33, T. 155, R. 56 (Medford), to the Middle Branch of Forest River (farther east formerly called Salt River), which it reaches near the center of the east half of Sec. 28. It has only scanty deposits of beach gravel and sand, nowhere forming a ridge; instead, the surface is mainly till, very flat east of this shore, but undulating or rolling westward.

The South and Middle Branches of Forest River occupy valleys 25 to 40 feet deep and 20 to 30 rods wide. They are bordered with groves, or at least a continuous line of trees, along the greater part of their course.

In the NW. ¼ of Sec. 28 and the west part of Sec. 21, T. 155, R. 56, the highest shore line of Lake Agassiz is very distinctly marked, at 1,183 to 1,185 feet, by being the upper edge of a flat slope of till, probably with scanty deposits of gravel and sand, which sinks 20 to 30 feet in the next half mile eastward. Farther east, for the width of 3 or 4 miles across the Elk Valley, the surface elevation is 1,160 to 1,125 feet.

Just west of this shore line a knolly belt of morainic drift, bearing a marvelous profusion of bowlders, occupies a width of 25 to 50 rods, generally forming a single series of hillocks rising 15 to 30 or 35 feet. These are strewn with bowlders of all sizes up to 5 feet and rarely 8 feet in diameter, so plentiful that they cover a third or even half of the surface. A few masses of limestone were observed; but fully 99 per cent. of the bowlders are archean granite and gneiss. This is the most eastern portion of a semicircular moraine, which appears to have been accumulated on the eastern boundary of a lobe of the ice sheet during a pause in its retreat. From Secs. 21 and 28 this moraine continues, with nearly the same features, south and southwest to the SE. ¼ of Sec. 32, and thence west-southwest by Pilot Knob in the NW. ¼ of Sec. 5, T. 154, R. 56, to the west side of Sec. 1, T. 154, R. 57, and perhaps beyond. Its hills and knobs rise 25 to 75 feet above the general level of the adjoining smoothly undulating till, their tops being 1,250 to 1,300 feet above the sea. To the north, northwest, and west it reaches, with similar development, in a great curve convex to the northeast, along an extent of 5 or 6 miles, to a cluster of prominent morainic hills rising 50 to 75 feet, situated in Secs. 2 and 3, T. 155, R. 57. This moraine matter was doubtless englacial; among its multitude of both large and small rock fragments a half hour's search failed to discover any marked with striæ or having surfaces planed by glaciation. On the west the area inclosed by this curving moraine is very smooth, only slightly undulating till, at 1,185 to 1,250 feet, ascending slowly westward.

Another distinct morainic series, similar in its very knolly contour, in its material (excepting a larger proportion of gravel, half of which is the cretaceous shale before described), and in the great abundance of bowlders, nearly all granitic, branches from the preceding in the north part of Sec. 8, T. 155, R. 56, and sweeps northeast and north through the west half of Sec. 4, and thence northwest and west through Secs. 32, 29, and 19, T. 156, R. 56 (Vernon), and Secs. 13 to 16, T. 156, R. 57 (Norton), to a group of morainic hills about 75 feet high, a mile northwest of Galt post office. Between this curved moraine and the nearly parallel northern part of the preceding, 4 miles distant to the south, the surface is very smooth undulating till, rising slowly toward the west.

These moraines, with their east base at 1,185 to 1,170 feet above the sea, formed the west shore of Lake Agassiz at its highest stage for nearly 7 miles between the Middle and North Branches of the Forest

River. The North Branch intersects this shore line near the center of Sec. 20, T. 156, R. 56, close to the southwest end of Ramsey's groves, which extend thence about a mile along this watercourse in the north part of Sec. 20 and the SE. ¼ of Sec. 17. The stream in these sections has no valley, only a channel 20 to 30 feet wide and 10 feet deep.

Elevation of road at the southeast corner of this Sec. 20, 1,177 feet.

Golden Valley, on the north line of Secs. 4 and 5, T. 156, R. 56, 1,185 to 1,195 feet, showing an ascent of 10 feet from east to west in its width of 2 miles. About the same transverse slope, raising the west side of this valley 10 or 15 feet above its east side, is found along its whole extent of 20 miles or more, from the Middle and North Branches of Forest River to the Middle and North Branches of Park River. In the north half of T. 156, R. 56, and thence northward, the width of this valley varies from 1¾ miles to only 1 mile. It is flat and consists mainly of clay, free from gravel; but wells find gravel intermixed with the clay, probably till, at a depth of a few feet, and about 20 feet from the surface they sometimes encounter a water-bearing stratum of gravel, chiefly made up of cretaceous shale.

Natural surface at the southwest corner of Sec. 27, T. 157, R. 56 (Garfield), 1,191 feet. Highest part of Golden Valley south of the South Branch of Park River, along the north line of Secs. 27, 28, and 29, in this township, 1,199 feet on the east to 1,211 feet on the west. Surface at school-house on the west side of the NW. ¼ of Sec. 21, 1,207 feet.

South Branch of Park River at the Garfield bridge, near the middle of the north line of Sec. 21, T. 157, R. 56, 1,170 feet, approximately; bottomland about a quarter of a mile wide, 10 to 15 feet above the stream; crest of the south bluff rising to the flat belt of the Golden Valley, 1,191 to 1,209 feet, ascending westward; of the north bluff, 1,189 to 1,205 feet.

Golden Valley, on the north line of Sec. 5, T. 157, R. 56, 1,195 to 1,205 feet; 2 miles farther north, on the north line of Sec. 29, T. 158, R. 56 (Lampton), 1,198 to 1,208 feet. In this northern part of the valley limited tracts of its flat area are strewn with abundant bowlders up to 2 feet and less frequently 3 or 4 feet in diameter. They are probably where swells of till rose nearly to the surface of the water in this strait of Lake Agassiz, so that its fine portions were swept away by waves and currents, to be deposited elsewhere in the valley as clayey silt, leaving the masses of rock which could not be thus removed. Approaching the Middle Branch of Park River, the surface of Golden Valley continues very smooth and flat, but it ceases to have a continuous ascent from east to west, some portions along the center being depressed a few feet. Such a shallow hollow holds a slough about a mile long from south to north and a half mile wide in its broadest part, at 1,193 feet, extending from the north edge of Sec. 20 through the west part of Sec. 17, T. 158, R. 56, in which a small area of water remains throughout the year. On each side of this slough and for miles south and north, this valley is a great hay meadow.

The west border of the Golden Valley was the most western shore of Lake Agassiz in its highest stage, but it is only very scantily marked by deposits of beach gravel and sand, because of its sheltered position on the western and leeward side of this narrow strait. From the middle of Sec. 20, T. 156, R. 56, this shore line extends in a quite direct course a few degrees west of north 11 miles through the west part of Secs. 17, 8, and 5, in this township, Secs. 32, 29, 20, 17, 8, and 5, T. 157, R. 56, and the east edge of Secs. 31 and 30, T. 158, R. 56. For the next 3 miles, in the east edge of Secs. 19, 18, and 7, T. 158, R. 56, it runs nearly due north. Thence it turns to a northwesterly course through Sec. 6 of this township, passing a mile west of Edinburgh post office and through Sec. 31, T. 159, R. 56. In this vicinity the Golden Valley terminates.

Bushes and trees clothe the slope on the west side of the Golden Valley along its northern part, extending to the south line of T. 158, R. 56; but this ascent farther south, also the entire extent of the Golden Valley, the drift hills forming its east border, and the vast plain of the Red River Valley, are prairie, excepting that narrow belts of timber border the water courses.

Smoothly undulating till rises slowly from the west side of the southern part of the Golden Valley; but in Sec. 30, T. 158, R. 56, rounded hills of till attain a height about 100 feet above the valley, or 1,300 feet above the sea. Thence northward a smooth slope ascends 50 to 60 feet, or in some portions only 30 or 40 feet, within the first quarter or half of a mile to the west, succeeded beyond by a moderately rolling surface with less ascent.

A terrace of beach sand and gravel, containing pebbles and cobbles up to 6 inches in diameter, extends a third of a mile from southeast to northwest, with a width of 5 to 30 rods, in the NW. ¼ of Sec. 33, T. 158, R. 56, abutting on the west flank of the rolling and hilly deposits of till which make the east border of the Golden Valley. It was formed by currents entering this strait of Lake Agassiz from the north, eroding the bordering hills in the east edge of Secs. 20 and 29, and thence sweeping this sand and gravel southward. It marks the highest stage of Lake Agassiz, having an elevation of 1,213 to 1,195 feet, declining from north to south, and also sinking 1 or 2 feet from west to east in its width of 100 to 500 feet, being thus slightly higher along its verge than where it rests upon the adjoining hilly till.

Natural surface at the quarter-section stake on the east side of Sec. 8, T. 158, R. 56, 1,203 feet; at Edinburgh post office, near the center of Sec. 5, 1,202 feet.

Middle Branch of Park River a half mile south of Edinburgh, approximately, 1,185 feet; crest of the south bank of the very small valley of this stream, rising to the flat Golden Valley, 1,192 feet on the east to

1,215 feet on the west. The Golden Valley here shows thus a transverse ascent of more than 20 feet in its width of about 1 mile. On the north line of Secs. 5 and 6, T. 158, R. 56, the east edge of this valley has an elevation of 1,210 feet, and its west edge, 1,220 feet. About a half mile farther north, the height of this belt, where it is crossed by a tributary of the Middle Branch, is 1,220 to 1,235 feet, from east to west, being thus above the highest level of Lake Agassiz. Elevation of this tributary at a bridge of a road that runs very crookedly through bushes and small woods in Sec. 32, T. 159, R. 56, 1,204 feet; and at a bridge a few rods north of the middle of the east side of Sec. 29, 1,175 feet.

BEACHES AND ISLANDS EAST OF THE ELK AND GOLDEN VALLEYS.

Returning about 45 miles south to Larimore, we have yet to describe the beaches of Lake Agassiz and its islands of rolling and hilly till which divided the strait of the Elk and Golden Valleys in Grand Forks and Walsh Counties from the main body of this glacial lake.

Saint Paul, Minneapolis and Manitoba Railway track at Larimore, 1,134 feet above the sea.

The upper or first and the second Herman beaches before described, respectively $4\frac{3}{5}$ and $4\frac{1}{5}$ miles west of Larimore, are 1,162 and 1,146 feet above the sea. Third Herman beach, a third of a mile east of Larimore depot, crest, 1,133 feet; another beach belonging to the same stage of Lake Agassiz, a third of a mile farther east, crest, 1,134 feet, with descent in thirty or forty rods east 11 feet, and in the same distance west 9 feet. Fourth Herman beach, consisting of four small beach ridges crossed by the railway $1\frac{1}{2}$ to 2 miles east of Larimore, crests, 1,123 to 1,118 feet, with intervening hollows 3 to 5 feet deep. A nearly level tract reaches 4 miles westward from Larimore along the railway to Devil's Lake, averaging 1,130 feet and varying only 2 or 3 feet above and below this level. Beneath the rich black soil here and elsewhere, all about Larimore, are stratified sand and fine silt free from gravel. The beach ridges near this town are consequently composed wholly of sand, quite in contrast with their usually coarser material.

Well at the Sherman House, Larimore, L. C. Neal, proprietor, dug 20 feet and bored 40 feet lower: soil, 2 feet; fine sandy and clayey silt, without coarse sand, gravel, or stones, 5 feet; fine yellowish sand, with less clay, being mainly siliceous, 13 feet; and dark sand, very soft to bore through, two-thirds cretaceous shale in particles up to a twentieth of an inch in diameter, 40 feet, with much water. Hard blue till was found at the bottom. This is the deepest well in the town. All the other wells are said to obtain their supply of water at a depth of about 20 feet, in the upper part of this sand chiefly derived from shale. The origin and manner of deposition of these beds of sand and silt deserve further observations and study.

The beach seen two-thirds of a mile east of Larimore passes north and north-northwesterly through the east half of Secs. 7 and 6, T. 151, R. 54, and the west half of Secs. 31 and 30, T. 152, R. 54, into the southeast corner of Sec. 24, T. 152, R. 55. North of the South Branch of Turtle River it is not a typical ridge, but a series of massive rounded swells of sand 10 to 15 feet high, with their crests at 1,135 to 1,140 feet.

A parallel beach ridge a third to a half mile west of the foregoing, mostly massive, with typical wavelike form, has an elevation of 1,133 feet close east of Larimore; 1,144 feet at a cemetery close north of the South Branch of Turtle River in or near the southwest corner of Sec. 31, T. 152, R. 54; chiefly 1,137 to 1,140 feet in its course thence north-northwesterly through Secs. 36 and 25, the west edge of Sec. 24, and the east half of Sec. 14, T. 152, R. 55; 1,142 to 1,145 feet in the west half of Sec. 11 and 1,143 to 1,147 feet in the east edge of Sec. 3 of this township. Along the west edge of Sec. 11, a duplication of this beach ridge, of the same massive size, lying a half mile farther west, extends a mile south from the North Branch of Turtle River, its crest being at 1,142 to 1,145 feet; but thence southward the general elevation is about 1,130 feet to the tract of this height crossed by the railway west of Larimore, excepting that the South Branch of Turtle River has eroded a valley 40 to 75 feet deep. The distance of one and a half miles from Larimore north to this stream is a gradually descending smooth slope, but its northern bluff rises steeply to a height a few feet above that of Larimore.

North Branch of Turtle River in the north half of Sec. 11, T. 152, R. 55, 1,085 to 1,075 feet; bottomland, an eighth of a mile wide, 10 to 15 feet above the stream; crest of bluffs a quarter to a third of a mile apart, about 1,135 feet.

Saint Paul, Minneapolis and Manitoba Railway at McCanna, 1,140 feet; on bridge over the North Branch of Turtle River, 1,132 feet, 17 feet above the stream; summit, in the northeast corner of Sec. 22, T. 153, R. 55, grade and natural surface, 1,164 feet; Orr, 1,098 feet.

Lower Herman beach, running northwesterly in the northeast part of Sec. 24, T. 152, R. 55, 1,127 to 1,128 feet, with depression of 2 to 3 feet on its west side; in Sec. 13, 1,127 to 1,132 feet; in the west part of Sec. 12 and the northeast part of Sec. 11, 1,130 to 1,135 feet, being in these sections the easternmost in a succession of three beach ridges, the two others of which are 10 feet higher; at E. C. D. Shortridge's house, in the center of Sec. 2, 1,137 feet, forming a broad flat swell of sand and fine gravel, with a depression of 3 to 5 feet on its west side; in the west part of Sec. 36, through Secs. 26 and 23, and the southwest edge of Sec. 14, T. 153, R. 55, a continuous, well defined beach ridge, 1,140 to 1,149 feet, with a descent of 10 to 15 feet on the east and a depression of about 5 feet on the west; in the east edge of the NE. ¼ of Sec. 15 and through the SE. ¼ of Sec. 10, a deposit of sand and fine gravel, with nearly level top 20 to 30 rods wide, 1,145 to 1,149 feet, from which a slope falls 10 or 15 feet in 20 to 30 rods eastward, while on the west it is bordered by a slough 5 to 20 rods wide, which is partly permanent water and partly mowing land. It is to be noted that the northern two-thirds of the beach here described for a distance of 8 miles corresponds in elevation with the two beaches close east of Larimore and their continuation northward to the North Branch of Turtle River, marking the third Herman stage of Lake Agassiz; but that the southern part records a slightly lower level of the lake, when it had fallen about 10 feet, or to its fourth Herman stage.

On the west side of this beach a smoothly undulating broad swell of till, which was an island in Lake Agassiz, lies in the west part of Sec. 26 and the east edge of Sec. 27, T. 153, R. 55, with nearly level top of several acres, at 1,182 to 1,190 feet. An aboriginal burial mound, raised 4 feet and 50 feet across, is situated on the highest part of this area, 15 rods east-northeast from the quarter-section stake between these sections. Such localities, overlooking an extensive and beautiful panorama, were frequently chosen for this use, as is shown by many mounds on hill-tops and on the margin of bluffs bordering deeply eroded valleys throughout the Northwest. A lower tract of somewhat roughly rolling till, with plentiful bowlders, reaches a third of a mile southeasterly from this swell to the south edge of Sec. 26. Thence a broad ridge of beach gravel and sand, belonging to the second and third Herman stages of Lake Agassiz, with an elevation of 1,153 to 1,151 feet, sinking southward to 1,145 feet, extends south-southeasterly through the east half of Sec. 35 and continues with the same course to Larimore, as before described.

North of this island the upper Herman beach is represented in the east part of the SE. ¼ of Sec. 22 and in the west half of the SW. ¼ of Sec. 23, T. 153, R. 55, by a wide tract of gravel and sand deposits, in irregular ridges and swells rising 4 to 8 feet, mostly trending from north to south, with their crests at 1,164 to 1,170 feet. Next to the north it is a well defined beach ridge, with crest rising from 1,163 to 1,168 feet in its course of a half mile from south to north through the east edge of the NE. ¼ of Sec. 22.

In the SE. ¼ of Sec. 15, T. 153, R. 55, the plain that descends slowly toward the Red River on the east is divided from the Elk Valley on the west by a low swell of till, having an elevation of 1,157 to 1,160 feet, destitute of beach deposits. This is succeeded in the north part of this section and the south part of Sec. 10 by a second island which rose above the highest level of the glacial lake, having a length of 1 mile from south to north and averaging a quarter of a mile wide, its elevation in the SW. ¼ of the NE. ¼ of Sec. 15 being about 1,187 feet, on the line between these sections about 1,175 feet, and near the center of Sec. 10, at the north end of this irregular ridge, about 1,180 feet. Its material is till, partially overspread in its south half by gravel, which seems to have been brought by the currents and waves of Lake Agassiz from the erosion of its northern portion.

The beach of Lake Agassiz during its highest stage extends north from the north end of this island into the SW. ¼ of Sec. 3, T. 153, R. 55, where it is a ridge about 20 rods wide, with an elevation of 1,165 to 1,172 feet, composed of coarse gravel and sand, inclosing plentiful rock fragments, chiefly granitic, of all sizes up to 6 inches in diameter, most of which are only slightly water-worn. Its eastern slope descends 15 to 20 feet in as many rods, and on the west an equal descent takes place within 8 or 10 rods. The steep western slope of this beach or bar, forming the east rim of the strait that filled the Elk Valley, was due to storms on the broad lake, rolling its waves upon the bar and carrying the sand and coarse gravel upward and over its crest. Turning northwestward, this beach passes into the NE. ¼ of Sec. 4, where it consists of irregular accumulations of gravel and sand, occupying a width of an eighth to a fourth of a mile, with their crests at 1,155 to 1,162 feet. In the north edge of Sec. 4 it again becomes a definite beach ridge of the same material and contour as in Sec. 3, and thus passes northeast and north through Sec. 33, T. 154, R. 55, with its crest mostly at 1,165 to 1,172 feet, its lowest part, about 1,162 feet, being near the center of this section. The two islands before described, this beach or bar, and the long island next northward are together commonly called "The Ridge," being the eastern limit of the Elk Valley, which averages 4 miles wide, 1,150 to 1,140 feet above the sea in its eastern and central portions, but rising with a transverse slope to 1,160 feet on its western border.

A third island above the highest stage of Lake Agassiz, 3 miles long from south to north and a quarter to a half mile wide, reaches through the central part of Secs. 28 and 21, the west half of Sec. 16, and into the southwest corner of Sec. 9, T. 154, R. 55. It is till, with somewhat uneven surface, bearing frequent bowlders. Highest points of this in Secs. 28 and 21, 1,185 to 1,195 feet; intervening gaps, about 1,170 feet; summit, near the center of the SW. ¼ of Sec. 18, 1,223 feet, and lower summit, about a half mile to the north, 1,218 feet, each bearing a flat round earthwork about 1 foot higher; lowest depressions intervening, about 1,195 feet; depressions in the northwest part of Sec. 16, 1,185 feet, and highest points in the southwest corner of Sec. 9, 1,194 and 1,195 feet. Beach deposits occur on the east flank of this island in Sec. 21 at 1,155 to 1,165 feet, and from 1,155 feet a smooth slope of sand and fine gravel falls slowly eastward along the east side of this highland through the greater part of its extent.

In the southeast part of Sec. 8, T. 154, R. 55, irregular accumulations of beach gravel, with crests at 1,170 to 1,175 feet, 10 to 15 feet above the adjoining depressions of till, extend northward from the island just described; and in the north part of this Sec. 8 the beach sinks within an eighth of a mile from 1,172 to 1,161 feet and changes to a broad, smooth ridge, which thence passes northward through Sec. 5 of this township, in which it is intersected by the Forest River, with valley a half mile wide and 60 to 75 feet deep, and through the west half of Sec. 32, T. 155, R. 55, near the center of which it has three aboriginal mounds on its top. The material of this beach ridge is fine gravel and sand. Elevation of its crest on the line between Secs. 8 and 5, 30 to 40 rods east of the quarter-section stake, 1,161 feet; an eighth of a mile north, at the verge of the south bluff of Forest River, 1,155 feet; for the first half mile from the bluff north of this river, 1,152 to 1,157 feet; and at the mounds in Sec. 32, 1,156 to 1,159 feet. These mounds lie in a line bearing north-northeast; top of most southerly mound, 1,162 feet, about 6 feet above the adjacent ground; elevation of the middle one, some 20 rods away, 1,166 feet, and of the most northern, again about 20 rods from the last, 1,167 feet, each being 8 feet higher than its base.

Another beach ridge, 20 rods wide, with descent of 10 feet on each side in as many rods, formed during the same stage of Lake Agassiz, lies a half to three-fourths of a mile west from the foregoing, in the NE. ¼ of Sec. 6, T. 154, R. 55. This is the highest land between the main Forest River and its South Branch. It consists of sand and fine gravel, of which a considerable proportion (about a sixth) is cretaceous shale. The maximum elevation of this ridge, 1,157 to 1,164 feet, is maintained for 50 or 60 rods, from which it sinks to 1,150 feet at each end.

From the north side of Sec. 32, T. 155, R. 55, an island of rolling and hilly till above the highest level of Lake Agassiz, far larger than any of those already described, extends, with the exception of two short gaps, 20 miles northward, varying in width from a half mile to a little more than 1 mile in its southern quarter and from 1½ to 2½ miles through the remainder of its extent. This hilly tract, commonly denominated "the mountains," forms the east border of the Golden Valley. In the north part of Sec. 36, T. 156, R. 56, it has a depression to about 1,180 feet, which probably was a strait of the glacial lake in its highest stage, an eighth of a mile wide and a few feet deep. Again, in the center of T. 157, R. 56 (Garfield), it is intersected by the South Branch of Park River, which has a valley a quarter to a half of a mile wide and about 75 feet deep. The stream, in its course of 1½ miles through this belt, descends about 50 feet, from 1,165 to 1,115 feet, approximately. It seems almost certain that a depression slightly lower than the Golden Valley on the west originally extended across this rolling and hilly area where it is cut by this South Branch of Park River; but the erosion of its valley has undermined and removed portions of adjoining hills and ridges, so that its inclosing bluffs now rise 50 to 100 feet, their highest points being about 1,225 feet above the sea, or 25 to 30 feet above the east edge of the Golden Valley. All these bluffs and two plateaus left in the midst of the valley are till, yellowish near the top and dark bluish below.

Elevation of "the mountains" in their southern and narrower portion, through the west part of T. 155, R. 55, and the northeast corner of T.

155, R. 56, 1,190 to 1,225 feet; through the east half of T. 156, R. 56, 1,200 to 1,250 feet; in the south part of T. 157, R. 56, 1,200 to 1,260 feet; and through the north half of this township and the south half of T. 158, R. 56, 1,200 to 1,275 feet, being highest in Sec. 28 of the township last named, near the northern end of this hilly tract.

The east border of "the mountains" in Sec. 20, T. 155, R. 55, falls somewhat steeply to about 1,135 feet, and thence a flat slope, with no beach ridges, sinks slowly eastward. In the NW. ¼ of the NE. ¼ of Sec. 7 in this township a well defined beach ridge 10 to 15 rods wide, composed of sand and gravel, with pebbles up to 2 or 3 inches in diameter, extends 25 rods south from an eastern spur of the hilly till; crest of this spur, about 1,195 feet; of the beach, 1,172 feet, with depression of 3 to 6 feet on the west. Irregular beach accumulations, 10 to 20 feet lower, continue southward nearly a half mile. The east half of Sec. 6, T. 155, R. 56, has a descent of nearly 100 feet to about 1,100 feet. It is till, with no noteworthy beach deposits. No stream has flowed through the depression in Sec. 36, T. 156, R. 56, and no considerable watercourse crosses the gentle slope of till, overspread with much beach gravel at 1,175 to 1,155 feet, which lies within the next mile east.

In Sec. 30, T. 156, R. 56, the eastern border of this rolling and hilly area falls 75 feet or more within a third of a mile, to about 1,100 feet. Its material is till, with scanty deposits of beach gravel and sand, not distinctly accumulated in ridged form. About half way down this slope, it shows in some places a more abrupt escarpment, with steep descent of 15 or 20 feet. The same features continue through Sec. 19, except that a series of distinct beach deposits is observable about 25 rods east from the crest of the slope, at 1,170 to 1,175 feet, probably formed during the second Herman stage of Lake Agassiz. A little farther north, the upper Herman beach is probably represented, 15 to 30 rods north-northeast from the southwest corner of Sec. 18, in a bank of coarse gravel at 1,182 feet, with a small coulée on its west side. A descent of 125 feet takes place within a half mile on the east side of "the mountains," near where it is cut by a large but short ravine, in the SE. ¼ of Sec. 12, T. 156, R. 56, falling from 1,180 to 1,050 feet, approximately, with no well marked shore lines observable. A grove lies at the east base of this slope, a third of a mile south of the ravine. In the NW. ¼ of this Sec. 12 and the west edge of the SW. ¼ of Sec. 1, a well developed beach, in part consisting of two parallel low ridges, has an elevation of 1,170 to 1,177 feet; and in the east edge of Sec. 2, continuing northward, its elevation is 1,177 to 1,184 feet. Its eastern slope falls to 1,170 feet within 10 or 20 rods. Through Sec. 36, T. 157, R. 56, it is not very distinct; but 10 to 25 rods north from the quarter-section stake between Secs. 36 and 25 it is represented by a broad bank of gravel and sand, with crest at 1,187 to 1,190 feet, from which a slight depression falls 1 or 2 feet on the west.

Saint Paul, Minneapolis and Manitoba Railway track at Park River depot, 998 feet; natural surface at the southeast corner of Sec. 23, T. 157, R. 56, on the road from Park River to Garfield, 1,178 feet.

Crest of the upper Herman beach crossed by this road 10 rods west from the point named, 1,187 feet; same 20 rods southeast and northwest from the road, 1,192 feet; depression on the west 3 to 8 feet and descent on the east 10 to 15 feet in as many rods. This is a typical beach ridge of sand and gravel, with pebbles up to 2 or 3 inches in diameter, mostly limestone and granite. The cretaceous shale before mentioned is very rare in the till of "the mountains" and in the beaches formed along their east side, indicating that the east limit of this shale is the Pembina Mountain and the western ascent of the Golden Valley, and that the glacial currents by which the drift here was deposited came only from the north and northeast, with no intermixture of currents from west of north.

Highest beach on verge of south bluff of the South Branch of Park River, in the SE. ¼ of Sec. 23, T. 157, R. 56, 1,188 to 1,192 feet, with a basin shaped hollow on its west side 20 feet lower, which changes southward to a depression of about 5 feet. The river bluff is here freshly undermined, showing the depth of the beach sand and gravel to be 5 to 10 feet, lying on till. Lower beach, a quarter of a mile farther east, extending from northwest to southeast, in the SW. ¼ of Sec. 24, 1,167 to 1,170 feet.

Lower Herman beach, a massive ridge of gravel and sand, extending in a curved course convex toward the east from the NE. ¼ of Sec. 2, T. 157, R. 56, through the southeast part of Sec. 35, T. 158, R. 56, crest, 1,160 to 1,165 feet; through the northeast edge of Sec. 36 and the southwest corner of Sec. 25, 40 to 50 rods wide, with slightly undulating surface, 1,160 to 1,167 feet; near the middle of the east side of the SE. ¼ of Sec. 26, 1,165 to 1,166 feet; and at the quarter-section stake on the north side of this Sec. 26, 1,163 feet.

Near the west line of Sec. 23, T. 158, R. 56, two Herman beaches abut upon the east flank of the north end of "the mountains," and extend thence north-northwesterly 2 miles to the Middle Branch of Park River. The eastern one, a well defined ridge of sand and fine gravel, passes close west of the quarter-section stake between Secs. 15 and 10. The elevation of its crest is 1,161 to 1,166 feet, with increase in height from south to north; the descent on the east is 15 or 20 feet in as many rods, and the depression on the west is 3 to 8 feet deep and 10 rods wide. The other beach ridge is 40 or 50 rods farther west, parallel with the preceding and similar in form and material; its crest, rising slightly northward, is at 1,173 to 1,176 feet. Another distinct beach ridge, but of smaller size, runs in a parallel course through the east part of the SW. ¼ of Sec. 9, with its crest at 1,185 to 1,187 feet. These appear to represent in succession the fourth, third, and second Herman beaches of the series observed northwest of Maple Lake in Minnesota and east and west of Larimore.

Upper Herman beach, northward from the north end of "the mountains," forming in the N.W. ¼ of Sec. 21 and the west part of Sec. 16, T. 158, R. 56, a massive, broad ridge, composed of sand and gravel, with pebbles up to 4 or even 6 inches in diameter, crest, 1,197 to 1,207 feet, rising highest northward, where the beach deposit overlies the eastern slope of a wavelike swell of till that rises to 1,212 feet. Small beach ridge, belonging to this stage, in the east edge of the SE. ¼ of Sec. 8, 1,202 to 1,207 feet. Surface at Evan Edwards's house, in the west part of the SW. ¼ of Sec. 9, 1,197 feet, consisting of sand and gravel of this beach to a depth of 10 feet, underlaid by till, yellowish in its first 6 feet and dark bluish below. Summit of a smoothly rounded hillock, probably till, but having few or no bowlders, in the east edge of the NE. ¼ of Sec. 8, about 1,230 feet; train of beach gravel and sand extending thence 30 rods southward, 1,217 feet, with descent of 15 or 20 feet on each side.

Continuing beyond the Middle Branch of Park River, this highest beach is well developed in a broad ridge running due north through the west part of Sec. 4, T. 158, R. 56, with its crest at 1,202 to 1,208 feet. On the east the surface falls 30 or 40 feet, and more slowly beyond, while toward the west a descent of 10 feet is succeeded by a flat surface of till, which rises slowly from the foot of the beach ridge to a swell, 1,215 to 1,225 feet, a half mile away, forming the east boundary of the Golden Valley. This beach is sand and gravel, with pebbles up to 6 inches in diameter. About half of them are limestone; nearly all of the remainder are archean granite, gneiss, and schists; scarcely 1 in 200 is cretaceous shale. Through the west edge of Sec. 33, T. 159, R. 56, the elevation of this excellent beach ridge is 1,202 to 1,205 feet, and in the southwest edge of Sec. 28 and the middle of the east edge of Sec. 29, 1,202 to 1,197 feet, decreasing in height and size northward. For a half mile through the SW. ¼ of Sec. 33, a slight secondary beach ridge, 4 to 9 feet lower, lies about 30 rods east from the foregoing; its crest is at 1,198 to 1,195 feet, sinking a few feet from south to north; it is divided from the higher beach by a continuous depression about 3 feet deep.

Very massive beach ridge, composed of sand and gravel, with pebbles and rock fragments, the largest only slightly water-worn, up to 6 inches in diameter, passing a few degrees west of north through the center of Sec. 20, T. 159, R. 56, crest in the south half of the section, 1,208 to 1,215 feet; in the north half, 1,215 to 1,223 feet. On the east is a descent of 20 to 30 feet within 25 to 40 rods, and on the west 10 or 12 feet from the highest part of the beach within 10 rods to a nearly level area of till, 1,211 feet, which sinks 40 rods farther west to a long slough, about 1,205 feet, parallel with the beach and one-sixth of a mile wide. Beyond this an undulating surface of till, partly covered with bushes and small trees, rises to 1,250 or 1,275 feet within 2 miles, and then in smooth massive swells to 1,450 or 1,500 feet within the next 2 to 4 miles. These are part of a plateau, thence rising more slowly westward, whose boundary for the next 50 miles or more to the north and northwest is the conspicuous escarpment called Pembina Mountain.

The north end of this massive beach bears on its crest an artificial embankment 100 feet long from east to west and 20 feet wide, raised 2 feet above the natural surface, its top being 1,225 feet above the sea. This is 10 rods south from where the beach is cut to 1,210 feet by a wide gap, as of some ancient watercourse. In the south edge of the SW. $\frac{1}{4}$ of Sec. 17, T. 159, R. 56, on the south bank of the North Branch of Park River, about 10 rods east from the ford of the "Half-breed road," this beach has an elevation of 1,220 feet.

North Branch of Park River at this ford, 10 to 15 feet wide and a few inches deep, 1,203 feet. Surface at Garder, a mile east, 1,175 to 1,170 feet. Lower Herman beach, passing from south to north along the east side of Secs. 20 and 17, T. 159, R. 56, a third of a mile west of Garder, about 1,185 feet.

FROM GARDER NORTH TO THE TONGUE RIVER.

Secs. 17, 8, and 5, T. 159, R. 56, rise from 1,190 and 1,200 feet on their east side to 1,220 and 1,225 feet on the west, including, therefore, the upper Herman shore of Lake Agassiz; but they present no considerable deposits of beach gravel and sand. A swell of till, sprinkled with very abundant bowlders, nearly all archean granite and gneiss, up to 5 feet in diameter, extends from south to north across the line between Secs. 8 and 5, having its crest at 1,215 feet, from which there is a steep descent of 10 or 12 feet to the west. Sloughs and pools of water, permanent through the year, lie in the west part of Sec. 5, about 1,190 feet above the sea.

The South Branch of Cart Creek in Secs. 31 and 32, T. 160, R. 56, is bordered by a belt of timber a half mile wide; but it has only a small channel a few feet below the general surface and is dry through the greater part of the year. Its alluvial gravel, like that of the Middle and North Branches of Park River, is mostly cretaceous shale, derived from the gorges eroded in this rock at the sources of these streams in the Pembina Mountain.

Along the western border of Lake Agassiz here and northward into Manitoba extends a prominent wooded bluff, the escarpment of a treeless plateau which from its crest stretches with slow ascent westward. This escarpment, commonly called the second Pembina mountain, is a very marked feature in the topography for at least 50 miles. It is caused by the outcrop, mostly overspread by glacial drift, of a continuous belt of nearly horizontal cretaceous shale, several hundred feet thick, usually so hard and enduring that it is popularly termed "slate." Its course coincides nearly with the west line of Ts. 159 and 160, R. 56. Thence it continues in an almost straight course, a few degrees west of north, through Secs. 31 and 30, T. 161, R. 56; Secs. 24, 13, 12, and 2, T.

161, R. 57; Secs. 35, 26, 22, 15, 10, 9, and 4, T. 162, R. 57; Secs. 33, 28, 21, 16, 9, and 4, T. 163, R. 57; and Secs. 33, 32, and 29, T. 164, R. 57, to the international boundary, beyond which it soon turns more to the northwest. The base of the ascent is about 1,225 feet above the sea and its crest approximately 1,500 feet, northward to the Pembina River, beyond which the base sinks to 1,150 and 1,100 feet and the crest to 1,400 and 1,300 feet. The width occupied by the slope varies from a quarter to a half of a mile.

Natural surface at the quarter-section stake on the north side of Sec. 32, T. 160, R. 56, 1,178 feet above the sea. Secs. 32, 29, and 20 of this township are mostly till, smoothed by this glacial lake, the depressions having been filled by leveling down the higher portions, where many bowlders partially embedded testify to considerable erosion. A broad ridge of beach sand and fine gravel, 3 to 5 feet high, extends from south to north through the center of Sec. 29, its crest being at 1,180 to 1,182 feet. This is the third in the series of four Herman beaches observed near Maple Lake, near Larimore, and in T. 158, R. 56. The higher beaches are probably also recognizable 1 to 1½ miles farther west, near the base of the "second mountain," which is 1,220 to 1,230 feet above the sea; but it is impracticable to trace their course and determine their exact elevation, because woods reach from the base of this escarpment a half mile east, where these beaches belong.

Fourth Herman beach, a broad low swell of sand and gravel, extending north-northwesterly through the east half of Sec. 20, T. 160, R. 56, 1,166 to 1,172 feet; through Secs. 17 and 8, an eighth to a quarter of a mile wide, 1,161 to 1,173 feet, having in some places a depth of at least 10 feet, as shown by wells. On the north line of Sec. 20 and again in the north part of Sec. 17, it is intersected by branches of Cart Creek, which occupy valleys about 40 feet deep and an eighth to a quarter of a mile wide. Brush and scattered trees grow in these valleys and on the area between them. Toward the east a descent of 30 or 40 feet is made within the first half mile; westward there is only a slight ascent, to about 1,200 feet, in 1 mile; then a more considerable slope, covered with woods, rises 20 to 40 feet to the base of the "second mountain," on or near the township line.

In the west part of Sec. 8 and again near the northeast corner of Sec. 6, T. 160, R. 56, this beach is intersected by the headstreams of Willow Creek, in valleys about 35 feet deep. On the north line of Secs. 5 and 6 of this township, the fourth and third Herman beaches are merged in an undulating tract of gravel and sand a half mile wide, which rises from 1,160 feet on the east to 1,184 feet on the west. A well on the west part of this belt found the beach deposit 6 feet thick, underlaid by till, which forms the slightly ascending surface next west.

Base of second Pembina Mountain in the east half of Sec. 31, T. 161, R. 56, 1,235 at the south to 1,220 feet northward, coinciding nearly with the upper Herman shore of Lake Agassiz. William Crombie's well, 24 feet deep, near the center of Sec. 30, situated about 50 feet above the Tongue River, a few rods back from the verge of its north bluff, was soil, 2 feet; gravel, nearly all cretaceous shale, 8 feet; underlaid by gravel, nearly all granite and gneiss, with scarcely any intermixture of shale, containing pebbles and cobbles up to 4 inches in diameter, 14 feet, yielding a permanent supply of water. This well is close to the base of the "mountain," at an elevation of about 1,230 feet. Its bed of granite gravel appears to be the upper beach, the overlying shale gravel being a delta deposit brought by Tongue River.

Surface at Young post office, in the northeast corner of the SW. ¼ of Sec. 32, T. 161, R. 56, 1,192 feet. The well here, 14 feet deep, is wholly stratified gravel and sand, being a beach deposit of the second and third stages in the Herman series. Third beach, about an eighth of a mile east of Young post office, a broad ridge of sand and fine gravel, a few feet above the land on its west side, crest, 1,187 feet. Fourth and lowest Herman beach, of similar form with the last, but larger, running a few degrees west of north through the west edge of Sec. 33, 1,173 to 1,175 feet, with depression of 1 to 5 feet on its west side and descent of 25 feet within 30 or 40 rods east. About a third of a mile east from the crest of the last is another parallel beach ridge, belonging to the Norcross stage of this glacial lake.

Tongue River at bridge near the center of the south half of Sec. 28, T. 161, R. 56, about 1,110 feet; bottomland, 10 feet higher; top of bluffs, about 1,150 feet. Gavin's Creek in the south half of Sec. 20, about 1,140 feet; valley 40 feet deep, a sixth of a mile wide.

Lowest Herman beach, a massive ridge of sand and fine gravel, in the NE. ¼ of Sec. 29 and the east part of Secs. 20 and 17, T. 161, R. 56, 1,175 to 1,180 feet.

DELTA OF THE PEMBINA RIVER.

The largest tributary to the Red River in Dakota is the Pembina River, which has cut a valley about 400 feet deep and a mile wide in the plateau of the second Pembina Mountain. During the recession of the ice sheet this stream appears to have been much larger than now, being the outlet of glacial lakes in the basins of the Souris and Assiniboine Rivers.[1] From the bend of the Souris, or Mouse River, eighteen miles southwest of its mouth, the river discharging the waters of these lakes ran southeasterly to the Pembina River. Pelican Lake, eleven miles long from northwest to southeast and about a mile wide, occupies a part of the channel of this stream; and a distinct water-course of similar width, called Lang's Valley, eroded 150 to 200 feet below the general level, extends eleven miles between this lake and the Souris River. The highest portion of Lang's Valley is 1,364 feet above

[1] Ninth Annual Report of the Geological and Natural History Survey of Minnesota, p. 342; and Hind's Report of the Assiniboine and Saskatchewan Exploring Expedition, 1859, pp. 118 and 168.

the sea, and is bordered by bluffs that rise 160 feet. It is a channel similar to that of Lakes Traverse and Big Stone and Brown's Valley, eroded by the River Warren. The delta deposited in the margin of the glacial Lake Agassiz by the Pembina River, thus swollen by a great affluent from the melting ice fields beyond the present limits of its basin, extends twelve miles from south to north and has a maximum width of seven miles, with a maximum thickness exceeding two hundred feet. About five sixths of this delta of fifty square miles or more lie south of the Pembina River, reaching nearly to the Tongue River.

Its elevation in the northwest part of Sec. 17, T. 161, R. 56, is 1,200 feet; thence northward it rises slowly in two miles to 1,225 feet in the east part of Sec. 6; and in Secs. 31 and 30, T. 162, R. 56, it varies from 1,220 to 1,227 feet. From this crest of the southern part of the delta it slopes slowly east and northeast to 1,080 and 1,090 feet at its eastern border, in Secs. 25, 24, and 13, which coincides nearly with the east line of this T. 162, R. 56. Deep valleys, with frequent tributary ravines, have been eroded in it by several small streams. Westward the delta reaches to the base of the "second mountain," the belt a half mile to one mile wide next beyond the crest, only about 5 feet lower, being a very flat, beautiful prairie, which rises slowly, like the crest, from south to north. The elevation of this belt in Sec. 18, T. 161, R. 56, is 1,190 to 1,195 feet, and at Mr. Henry Goff's house, in the middle of the east edge of Sec. 36, T. 162, R. 57, 1,221 feet. Farther west there is an ascent to about 1,240 feet at the base of the "second mountain." Wells on this area penetrate only beds of sand and gravel, easy to dig and needing to be curbed to prevent caving. A large proportion, probably half, of the gravel is cretaceous shale. Water is obtained at depths varying from twenty-five to sixty feet.

Natural surface at the northwest corner of Sec. 30, T. 162, R. 56, 1,227 feet.

The part of the Pembina delta thus far described is divided from its central and higher part by a depression about a mile wide, through which a portion or the whole of the river flowed during much of the time in which this delta was formed. In the southwest corner of Sec. 18, T. 162, R. 56, this depression is 1,205 feet above the sea, being 20 feet lower than the area on the south. It extends eastward with a slow descent and rises westward to 1,215 feet close east of the Little Pembina River in Sec. 15, T. 162, R. 57. This stream flows through the escarpment of the "second mountain" in the SE. ¼ of Sec. 22, about a mile south from this lowest part of the divide on its east side. It there turns abruptly from its eastern course and thence flows north-northwest along the base of the "second mountain" to its junction with the Pembina River; thus leaving the depression just described, which would seem to be its more natural course, and taking in its stead a channel that is eroded through a portion of the delta 50 feet higher.

The most elevated point of this delta, as it now remains, is about 1,270 feet above the sea, near the northwest corner of Sec. 11, T. 162, R. 57, east of the Little Pembina and south of the Pembina River, nearly 300 feet above the junction of these streams, 1½ miles distant toward the northwest. Sec. 12 of this township and the west part of Sec. 7, T. 162, R. 56, slope from 1,225 on the south to 1,215 feet on the north; their southern part is the highest land crossed between the depression before mentioned and the Pembina River by the line dividing these townships. The level of Lake Agassiz in its highest stage here was 1,220 or 1,225 feet above the sea, being 50 feet below the top of the Pembina delta, as is shown by the beach line of this level, 1,226 feet, in the central part of this Sec. 7, where an eastward descent begins. This is the east verge of the nearly flat area of the delta in Secs. 12 and 7. Like all of this vast delta deposit, the material here is sand and gravel, covered by a fertile soil. A small proportion of the pebbles of this gravel is limestone; a large part is cretaceous shale; but more was derived from archean formations of granite and gneiss.

Second Herman beach, a ridge of the usual form, crossed by the road near the east side of the NE. ¼ of Sec. 7, T. 162, R. 56, descending from 1,212 feet to about 1,200 feet in a distance of a third or half of a mile from south to north.

William Roadhouse's well, 110 feet deep, in the NW. ¼ of Sec. 9, T. 162, R. 56, at elevation of 1,184 feet, is all stratified sand and gravel, with pebbles up to 6 inches in diameter, fully half cretaceous shale. Water comes in coarse sand at the bottom, filling the lowest 2 feet. Another well of the same description, but 137 feet deep, is a mile farther east, at Wellington Stewart's house, in the SW. ¼ of Sec. 4, 1,192 feet above the sea.

Crest of the first Pembina mountain in the north part of Sec. 33, T. 163, R. 56, nearly two miles southeast from Walhalla, a few rods west from the summit on the Olga road and 5 feet higher, 1,196 feet. This is a beach accumulation, belonging to the third Herman stage. On the west and southwest the undulating delta plateau, mostly covered with bushes and occasional trees, is 10 to 30 feet lower for a width of 1 to 1½ miles, averaging about 1,175 feet.

Northeast from the crest of the Olga road a short descent is made to a prairie terrace 30 to 60 rods wide, varying in elevation from 1,182 to 1,169 feet, but mainly within 2 feet above or below 1,175. In general the verge of this terrace is its lowest portion. Thence a very steep descent of 169 feet is made on the road from 1,173 to 1,004 feet, this being the very conspicuous wooded escarpment called the "first mountain." It is the eroded front of the great Pembina delta, the eastern part of which, originally descending more moderately, has been swept away by the waves and shore currents of the ancient lake during its Norcross, Campbell, and McCauleyville stages. From the north part of this Sec. 33 the "first mountain" extends southeast to Secs. 13 and 24, T. 162, R. 56, before mentioned, and northwest across the Pembina River, passing close southwest of Walhalla and onward to Secs. 10 and 3, T. 163, R. 57. Its highest part is intersected by the Pembina River, above which it rises on each side in bluffs of gravel and sand 200 to 250 feet high, with their crests a half mile to 1 mile apart.[1]

Surface at Bellevue Hotel, Walhalla, 994 feet above the sea; at the post office, Mr. G. D. Loring's store, 968 feet; Pembina River, at the bridge, a third of a mile east of Walhalla, 934 feet.

Highest part of the Pembina delta north of Pembina River, in Secs. 25 and 26, T. 163, R. 57, 1,210 to 1,230 feet, rising slowly from east to west; in the west half of Sec. 26 and the east edge of Sec. 27, it is depressed to 1,225 and 1,220 feet; but beyond this it rises to 1,235 and 1,240 feet, next to the foot of the "second mountain." From this upper portion the delta slopes down gradually toward the northeast and north, extending only 2 to 4 miles beyond the Pembina River.

Natural surface at the quarter-section stake on the north side of Sec. 26, T. 163, R. 57, 1,191 feet.

Third Herman beach, crest 5 rods south of this stake, 1,197 feet, from which there is a descent in 5 rods south to 1,192 feet and in 15 rods north to 1,180 feet. This beach curves thence to the northwest and north, and in the opposite direction runs east-southeast 2 miles to near the center of Sec. 30, T. 163, R. 56, where its elevation is approximately 1,192 feet. Other shore lines of the Herman group were not noticed north of the Pembina River.

In the gravel of this delta, as seen in the bluffs of Pembina River near Walhalla and at noteworthy springs 2 miles to the south, on the south side of the river in the southwest corner of Sec. 32, the pebbles of some beds are mainly cretaceous shale, of others mostly limestone, and of others granite, gneiss, and dark trappean rocks. In the aggregate, these three classes have a nearly equal representation. White quartz and moss agate are frequent and bits of silicified wood occur rarely; but no banded agates were found. Numerous pieces of

[1] The first Pembina mountain was visited by D. D. Owen in 1848. He describes it as follows: "Pembina Mountain is, in fact, no mountain at all, nor yet a hill. It is a terrace of table land, the ancient shore of a great body of water that once filled the whole of the Red River Valley. On its summit it is quite level and extends so for about five miles westward to another terrace, the summit of which I was told is level with the great buffalo plains that stretch away towards the Missouri, the hunting grounds of the Sioux and the half-breed population of Red River."—Report of a Geological Survey of Wisconsin, Iowa, and Minnesota, 1852, p. 178.

Both the first and second Pembina mountains were examined in 1857 by Palliser, who says of the flat Red River Valley and the Pembina delta: "This plain, no doubt, had formed at one time the bed of a sheet of water, and the Pembina Hill, consisting of previously deposited materials, was its western shore."—Journals, detailed reports, &c., presented to Parliament, 19th May, 1863, p. 41.

lignite, rounded by water wearing, from 2 to 4 inches in diameter, noticed in this delta gravel at the springs, have caused some to look for workable beds of this kind of coal in the vicinity; but the proportion of these fragments is no greater than in the glacial drift generally throughout this region and for hundreds of miles to the south.

Surface at the iron post set on the international boundary on the north side of the fractional Sec. 27, T. 164, R. 57, about a quarter of a mile east from the line between Secs. 27 and 28, 1,018 feet above the sea; top of this post, 1,022 feet.[1]

Smooth surface of till on the top of the "second mountain" in the SE. ¼ of Sec. 32, T. 164, R. 57, 1,268 to 1,311 feet above the sea; shallow lakelet in the SW. ¼ of this Sec. 32, 30 rods long from northwest to southeast, 1,309 feet; natural surface of the northeast corner of Sec. 6, T. 163, R. 57, 1,321 feet.

Base of "Heart Mound,"[2] a peculiar hillock of cretaceous shale, with very steep sides and smoothly rounded top, situated near the center of this Sec. 6, T. 163, R. 57, about 1,360 feet; and its top, about 1,390 feet. Some have erroneously supposed it an artificial mound. Glacial drift, containing granitic bowlders up to 4 or 5 feet in diameter, thinly covers its northeast side; but the other sides and crest of this knob show very clearly that it is an outlier of the cretaceous beds that form higher land about a mile westward, and, indeed, make the whole length of the second Pembina Mountain, being left thus isolated from the surrounding area by erosion.

The lowest exposure of this shale observed is 3½ miles south from Heart Mound, at the "fish trap," a rude weir of brush and poles, on the Pembina River, in the northeast corner of the NW. ¼ of Sec. 30, T. 163, R. 57. Here the river falls 7½ feet in 40 rods, its elevation being estimated about 1,050 feet. The southwestern bluff rises steeply from the

[1] The section on the boundary within the next 2 miles west is described by Dr. G. M. Dawson as follows: "The eastern front of Pembina escarpment is very distinctly terraced, and the summit of the plateau, even at its eastern edge, thickly covered with drift. The first or lowest terrace, which is about one-third from the prairie level toward the top of the escarpment, * * * does not seem to preserve exactly the same altitude. On the boundary line its height above the general prairie level was found to be about 90 feet; a second terrace, 260 feet; and that of the third level, or summit of the plateau, about 360 feet. The surface of the first terrace, which is here wide, is strewn with bowlders, as is also that of the second terrace and plateau above. These are chiefly of Laurentian gneiss and granite, but a few smaller ones of limestone occur. The banks of ravines cutting the top of the plateau and draining westward into the Pembina River show, in some places, a great thickness of light-colored, yellowish, marly drift, with few bowlders embedded in it."—Report on the Geology and Resources of the Region in the Vicinity of the Forty-ninth Parallel, from the Lake of the Woods to the Rocky Mountains, 1875, p. 219.

[2] Commonly called by English-speaking people in its vicinity "The Indian Mound," but more properly named as above, in accordance with the usage of the French voyageurs and immigrants, who, probably translating the aboriginal name, call this mound and the area of prairie around it La Baie du Cœur.

fish trap to a height of 150 feet, and at the time of my visit, in August, 1885, was newly exposed by slides, being shown to be a hard, fissile, dark gray shale, nearly horizontal in stratification to a height of 100 feet, capped by glacial drift. In the shale, crystals of selenite, 2 or 3 inches long, are frequent, and the same mineral occurs in its crevices and seams. No fossils were found; but the formation may be with confidence referred to the cretaceous series, and with much probability to its Fort Pierre subdivision.[1] The thickness of this shale, seen at the Heart Mound and the fish trap of Pembina River, is at least 300 or 400 feet; but it probably exceeds this, for there is no indication that these exposures mark its upper and lower limits. Its eroded eastern edge forms the long, high escarpment of the second Pembina Mountain, as the eroded border of the Pembina delta forms the almost equally notable "first mountain." Till, or bowlder clay, containing frequent granitic bowlders, up to 5 or even 8 feet in diameter, covers the shale, so that it is rarely seen excepting in the sections cut by streams.

[1] This reference has been confirmed during the field work of 1886 by the discovery, in the shale at this locality and in its continuation southward on the headstreams of Park River, of *Scaphites Nicolletii* (Morton), *Scaphites nodosus* (Owen), *Baculites ovatus* (Say), and *Baculites compressus* (Say); two species of *Inoceramus*, one of which is *I. altus* (Meek), or near that species, besides other lamellibranchs not yet identified; and the teeth of fishes, apparently *Pachyrhizodus latimentum* (Cope) and *Lamna mudgei* (Cope), or a smaller species, with a vertebral bone, perhaps belonging to one of these.

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ADVERTISEMENT.

[Bulletin No. 40.]

The publications of the United States Geological Survey are issued in accordance with the statute approved March 3, 1879, which declares that—

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

On July 7, 1882, the following joint resolution, referring to all Government publications, was passed by Congress:

"That whenever any document or report shall be ordered printed by Congress, there shall be printed, in addition to the number in each case stated, the 'usual number' (1,900) of copies for binding and distribution among those entitled to receive them."

Except in those cases in which an extra number of any publication has been supplied to the Survey by special resolution of Congress or has been ordered by the Secretary of the Interior, this Office has no copies for gratuitous distribution.

ANNUAL REPORTS.

Of the Annual Reports there have been already published:

I. First Annual Report to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Report of the Director of the United States Geological Survey for 1880–'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 61 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881–'82, by J. W. Powell. 1883. 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882–'83, by J. W. Powell. 1884. 8°. xxxii, 473 pp. 85 pl. and maps.

V. Fifth Annual Report of the United States Geological Survey, 1883–'84, by J. W. Powell. 1885. 8°. xxxvi, 469 pp. 58 pl. and maps.

The Sixth and Seventh Annual Reports are in press.

MONOGRAPHS.

Of the Monographs, Nos. II, III, IV, V, VI, VII, VIII, IX, X, and XI are now published, viz:

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt. U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

V. Copper-bearing Rocks of Lake Superior, by Roland D. Irving. 1883. 4°. xvi, 464 pp. 15 l. 29 pl. Price $1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price $1.05.

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— Flora of the Dakota Group, by J. S. Newberry.

BULLETINS.

The Bulletins of the Survey will contain such papers relating to the general purpose of its work as do not properly come under the heads of Annual Reports or Monographs.

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8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Van Hise. 1884. 8°. 56 pp. 6 pl. Price 10 cents.

9. Report of work done in the Washington Laboratory during the fiscal year 1883–'84. F. W. Clarke, chief chemist; T. M. Chatard, assistant. 1884. 8°. 40 pp. Price 5 cents.

10. On the Cambrian Faunas of North America. Preliminary studies, by Charles D. Walcott. 1884. 8°. 74 pp. 10 pl. Price 5 cents.

11. On the Quaternary and Recent Mollusca of the Great Basin; with Descriptions of New Forms, by R. Ellsworth Call; introduced by a sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert. 1884. 8°. 66 pp. 6 pl. Price 5 cents.

12. A Crystallographic Study of the Thinolite of Lake Lahontan, by Edward S. Dana. 1884. 8°. 34 pp. 3 pl. Price 5 cents.

13. Boundaries of the United States and of the several States and Territories, by Henry Gannett, 1885. 8°. 135 pp. Price 10 cents.

14. The Electrical and Magnetic Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1885. 8°. 238 pp. Price 15 cents.

15. On the Mesozoic and Cenozoic Paleontology of California, by Charles A. White. 1885. 8°. 33 pp. Price 5 cents.

16. On the higher Devonian Faunas of Ontario County, New York, by John M. Clarke. 1885. 8°. 86 pp. 3 pl. Price 5 cents.

17. On the Development of Crystallization in the Igneous Rocks of Washoe, Nevada, by Arnold Hague and Joseph P. Iddings. 1885. 8°. 44 pp. Price 5 cents.

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18. On Marine Eocene, Fresh-water Miocene, and other Fossil Mollusca of Western North America, by Charles A. White. 1885. 8°. 26 pp. 3 pl. Price 5 cents.

19. Notes on the Stratigraphy of California, by George F. Becker. 1885. 8°. 28 pp. Price 5 cents.

20. Contributions to the Mineralogy of the Rocky Mountains, by Whitman Cross and W. F. Hillebrand. 1885. 8°. 114 pp. 1 pl. Price 10 cents.

21. The Lignites of the Great Sioux Reservation, by Bailey Willis. 1885. 8°. 16 pp. 5 pl. Price 5 cents.

22. On New Cretaceous Fossils from California, by Charles A. White. 1885. 8°. 25 pp. 5 pl. Price 5 cents.

23. Observations on the Junction between the Eastern Sandstone and the Keweenaw Series on Keweenaw Point, Lake Superior, by R. D. Irving and T. C. Chamberlin. 1885. 8°. 124 pp. 17 pl. Price 15 cents.

24. List of Marine Mollusca, comprising the Quaternary fossils and recent forms from American localities between Cape Hatteras and Cape Roque, including the Bermudas, by William H. Dall. 1885. 8°. 336 pp. Price 25 cents.

25. The Present Technical Condition of the Steel Industry of the United States, by Phineas Barnes. 1885. 8°. 85 pp. Price 10 cents.

26. Copper Smelting, by Henry M. Howe. 1885. 8°. 107 pp. Price 10 cents.

27. Report of work done in the division of Chemistry and Physics, mainly during the fiscal year 1884-'85. 1886. 8°. 80 pp. Price 10 cents.

28. The Gabbros and Associated Hornblende Rocks occurring in the neighborhood of Baltimore, Md., by George H. Williams. 1886. 8°. 78 pp. 4 pl. Price 10 cents.

29. On the Fresh-water Invertebrates of the North American Jurassic, by Charles A. White. 1886. 8°. 41 pp. 4 pl. Price 5 cents.

30. Second contribution to the studies on the Cambrian Faunas of North America, by Charles D. Walcott. 1886. 8°. 369 pp. 33 pl. Price 25 cents.

31. A systematic review of our present knowledge of Fossil Insects, including Myriapods and Arachnids, by Samuel H. Scudder. 1886. 8°. 128 pp. Price 15 cents.

32. Lists and Analyses of the Mineral Springs of the United States; a preliminary study, by Albert C. Peale. 1886. 8°. 235 pp. Price 20 cents.

33. Notes on the Geology of Northern California, by Joseph S. Diller. 1886. 8°. 23 pp. Price 5 cents.

34. On the relation of the Laramie Molluscan Fauna to that of the succeeding Fresh-water Eocene and other groups, by Charles A. White. 1886. 8°. 54 pp. 5 pl. Price 10 cents.

35. The Physical Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1886. 8°. 62 pp. Price 10 cents.

36. Subsidence of fine Solid particles in Liquids, by Carl Barus. 1887. 8°. 58 pp. Price 10 cents.

37. Types of the Laramie Flora, by Lester F. Ward. 1887. 8°. 354 pp. 57 pl. Price 25 cents.

38. Peridotite of Elliott County, Kentucky, by Joseph S. Diller. 1887. 8°. 31 pp. 1 pl. Price 5 cents.

39. The Upper Beaches and Deltas of the Glacial Lake Agassiz, by Warren Upham. 1887. 8°. 84 pp. 1 pl. Price 10 cents.

40. Changes in River Courses in Washington Territory due to Glaciation, by Bailey Willis. 1887. 8°. 10 pp. 4 pl. Price 5 cents.

Numbers 1 to 6 of the Bulletins form Volume I; Numbers 7 to 14, Volume II; Numbers 15 to 23, Volume III; Numbers 24 to 30, Volume IV; Numbers 31 to 36, Volume V. Volume VI is not yet complete.

The following are in press, viz:

41. Fossil Faunas of the Upper Devonian—the Genesee Section, by Henry S. Williams.

42. Report of work done in the division of Chemistry and Physics, mainly during the fiscal year 1885-'86. F. W. Clarke, chief chemist.

43. On the Tertiary and Cretaceous Strata of the Tuscaloosa, Tombigbee, and Alabama Rivers, by Eugene A. Smith and Lawrence C. Johnson.

In preparation:

— Historic statement respecting geologic work in Texas, by R. T. Hill.

— The Nature and Origin of Deposits of Phosphates of Lime, by R. A. F. Penrose, jr.

— Bibliography of North American Crustacea, by A. W. Vogdes.

— The Gabbros and associated rocks in Delaware, by F. D Chester.

— Report on Louisiana and Texas, by Lawrence C. Johnson.

— Bibliography of North American Geology for 1886, by Nelson H. Darton.

— On the subaërial decay of rocks and the origin of the red color of certain formations, by Israel C. Russell.

STATISTICAL PAPERS.

A fourth series of publications, having special reference to the mineral resources of the United States, has been undertaken.

Of that series the following have been published, viz:

Mineral Resources of the United States [1882], by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

DEPARTMENT OF THE INTERIOR

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1887

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

CHANGES IN RIVER COURSES

IN

WASHINGTON TERRITORY

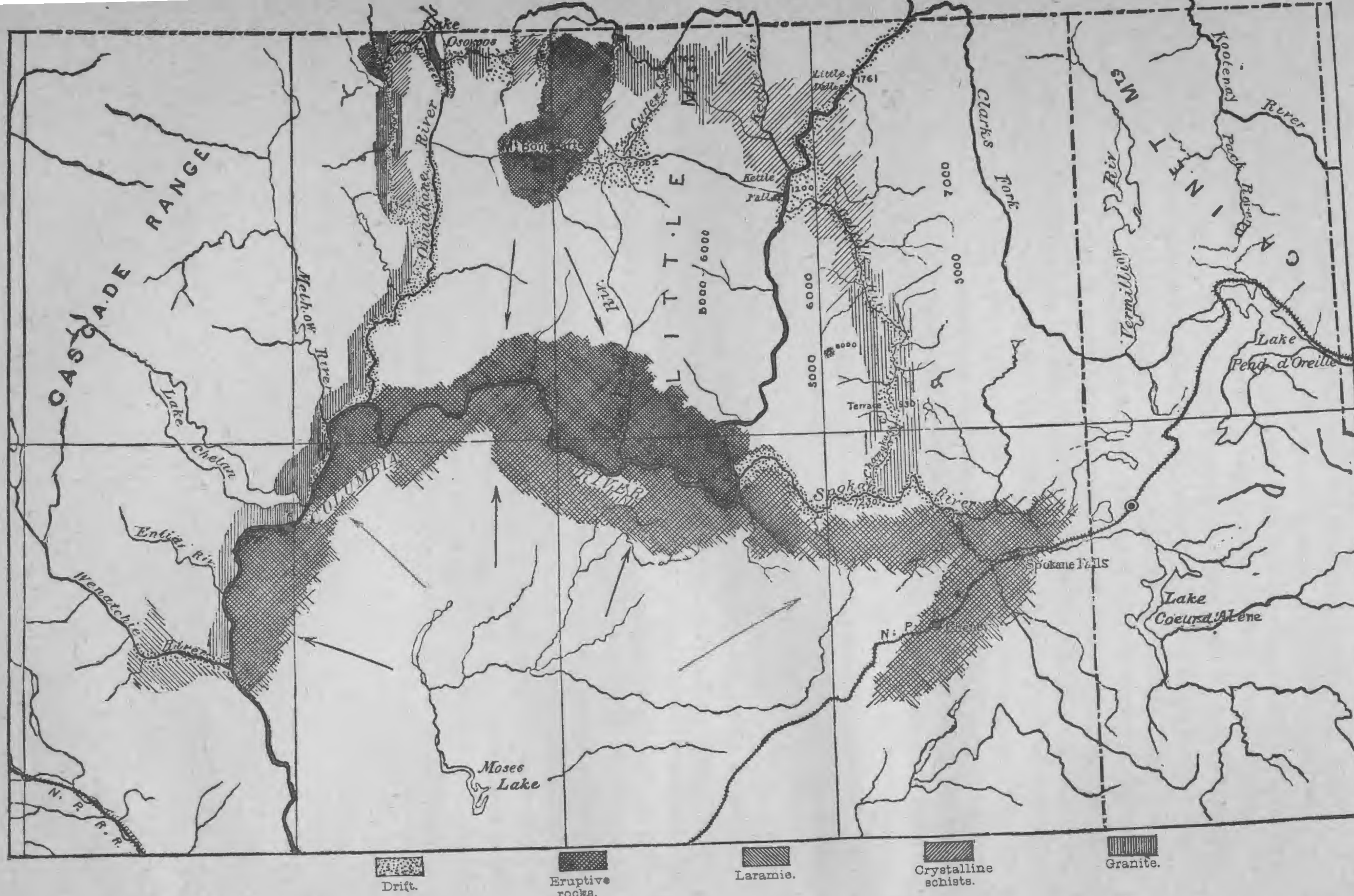
DUE TO GLACIATION

BY

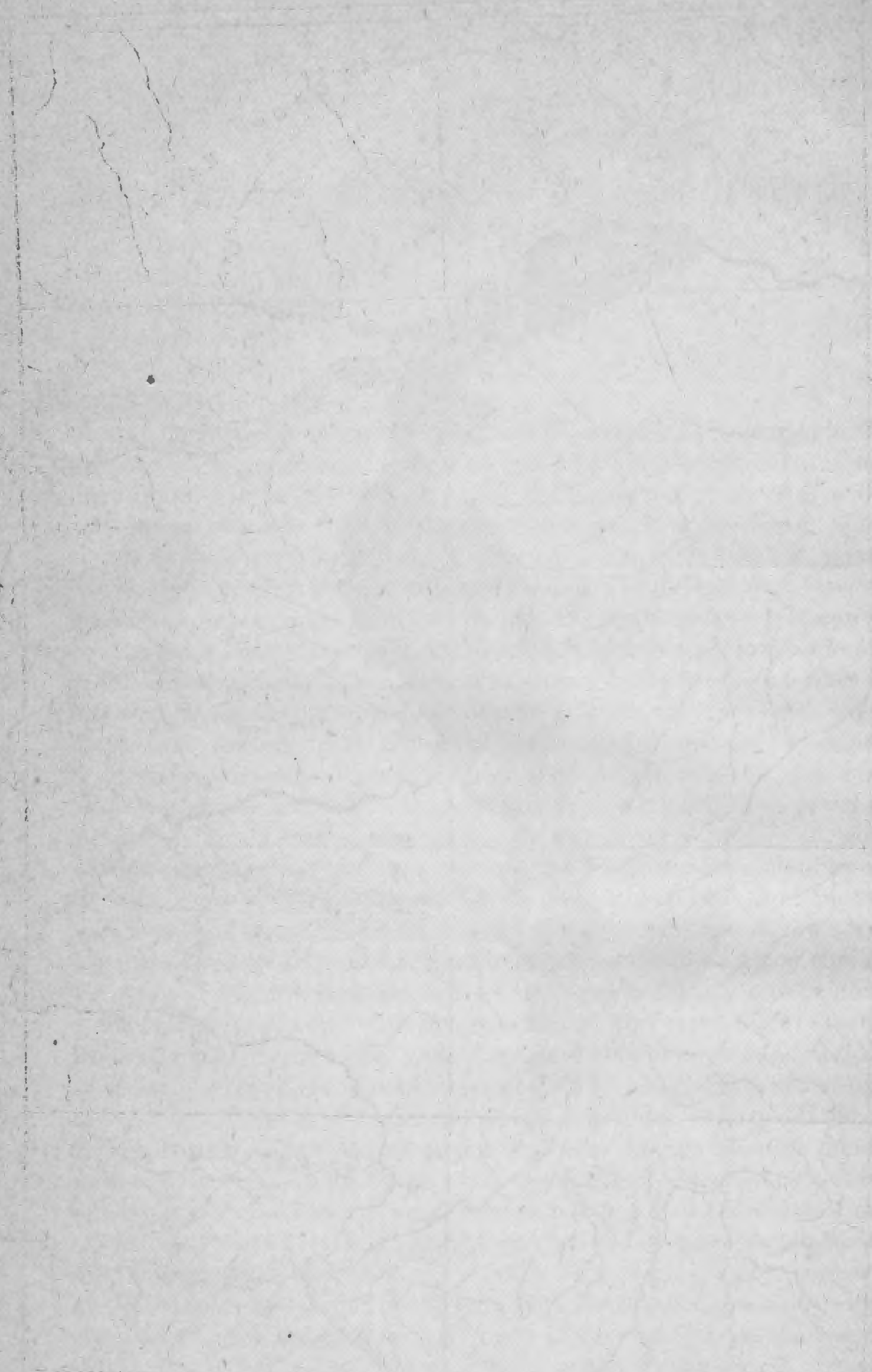
BAILEY WILLIS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1887

ILLUSTRATIONS.



MAP OF EASTERN WASHINGTON TERRITORY.



CHANGES IN RIVER COURSES IN WASHINGTON TERRITORY DUE TO GLACIATION.

By Bailey Willis.

Drainage lines in Eastern Washington Territory are broadly characterized by an aspect of youth, but they are divisible, according to age, into preglacial and postglacial channels. The general slope of the region presented in Plate I is southward; such streams as the Wenatchie, Methow, Okinakane, and San Puel strike the eye as members of a possibly consequent and unmodified system, determined by processes of subaërial erosion only. Of these, the last named alone enters the area of the volcanic flow of the Columbia River plain; the other valleys are carved upon the older surface of granite and crystalline sedimentary rocks. These valleys are also broader and more advanced in their development than the cañon of the Columbia, which crosses their direction nearly at right angles, and, cutting through the northern corner of the great flow from the Spokane River to the Okinakane, meanders along the contact of the basalt with the granite thence to the Wenatchie. The sudden northwestward turn of the river at the Spokane and its relation to the western limits of the eruptive rocks suggest that its course was determined by southward and by northward and westward *volcanic flows, as indicated by arrows on Plate I, the line of least elevation* of the cooled surface having lain near the edge, i. e., at the contacts of different coulées and of the earlier rocks with them.

If this be true, an older Columbia Valley lies beneath the great plain, and the converging lines of its watershed should be elsewhere apparent outside the area of the flow. Such channels are found traversing the Cabinet Mountains, but they are no longer occupied by the greater rivers. The Clark's Fork, below Lake Pend d'Oreille, the Columbia, from Kettle Falls to the Spokane, flow through clean cut, rock bottomed cañons, parallel with valleys of equal depth, gentler declivity, and wider expansion, such as those of Colville, Vermilion, and Pack Rivers. The suggestion lies close at hand that the latter belonged to the older system and are sections of valleys now overflowed by basalt in their lower courses. Their abandonment by the great rivers is the result of the much later causes of the glacial period, when valleys were filled with drift and rivers were driven to seek new channels across the lowest gap in their watersheds.

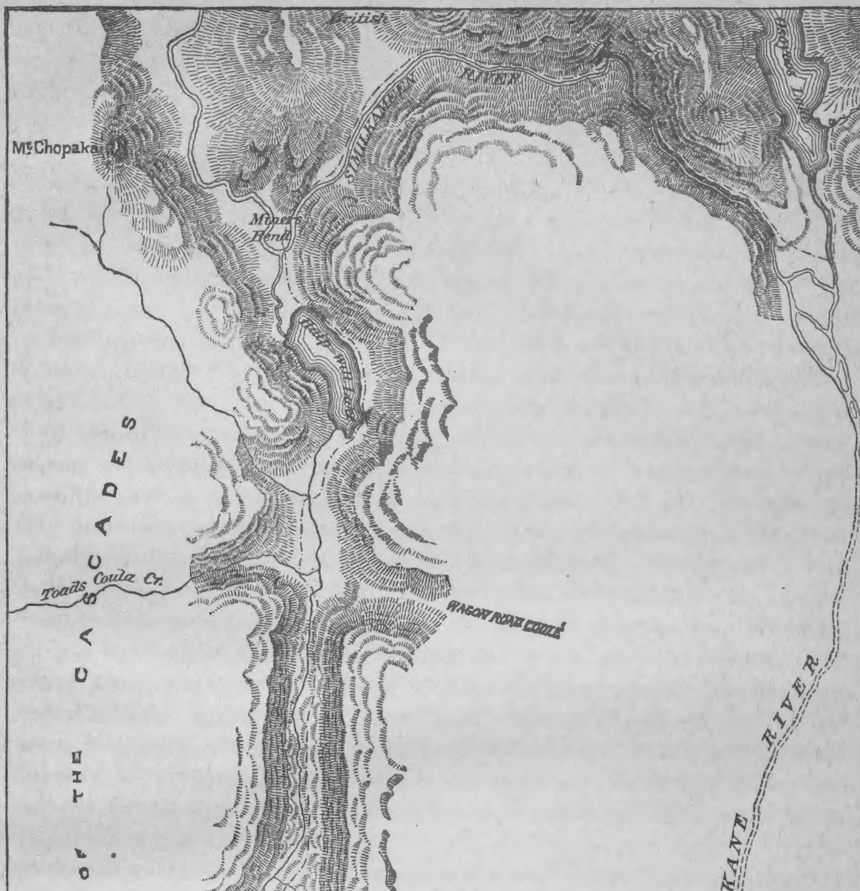
Through the kindness of Prof. T. C. Chamberlin I am able to give here the unpublished results of his observations of the glaciation of the region about Lake Pend d'Oreille.

The rugged crest of the Cabinet Mountains northeast and northwest of the lake is traversed by a depression a mile wide, known as the Pack River or Kootenay Pass. Gentle slopes descend northward to Bonney's Ferry and southward to the lake; the broad valley of the Kootenay extends far into British Columbia on the one hand and the level gravel plains of the Spokane spread in the opposite direction.

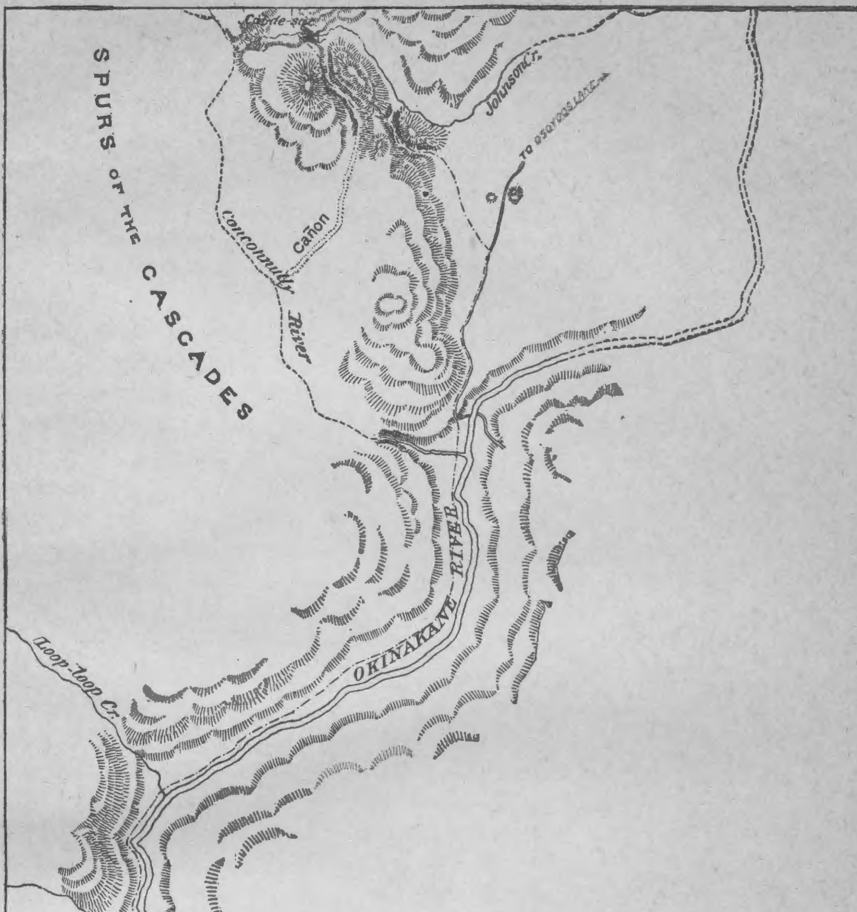
The Kootenay enters upon its placid northward flow from a cañon 50 miles long, one of the deepest and most abruptly walled of the Northwest; the Clark's Fork also descends to Lake Pend d'Oreille by a cañon and leaves it to traverse another, so wild that no one has passed through it. Of these channels, that of the ancient river, which flowed northward or southward through Pack River Pass, is certainly very much the oldest. During the ice age it was occupied by a glacier, which, descending from the north, filled the basin of Lake Pend d'Oreille and spread its moraine before the valleys on either hand. The lakelets that lie along the base of the Rocky Mountains are the products of its morainal dams, and from it sprang the great gravel stream of the Spokane and the Cœur d'Alene plains. Roches moutonnées and glacial striæ are abundant in Pack River Pass and about Lake Pend d'Oreille, but they are wanting on the surfaces of volcanic rocks about Spokane Falls, and there is no evidence that the ice reached so far.

Professor Chamberlin was not equipped for trips into less accessible districts; the western limits of this glacier are therefore undetermined, but the facts observed by him in the vicinity of Lake Pend d'Oreille are paralleled elsewhere in Northern Washington Territory, and similar topographic conditions suggest analogous causes.

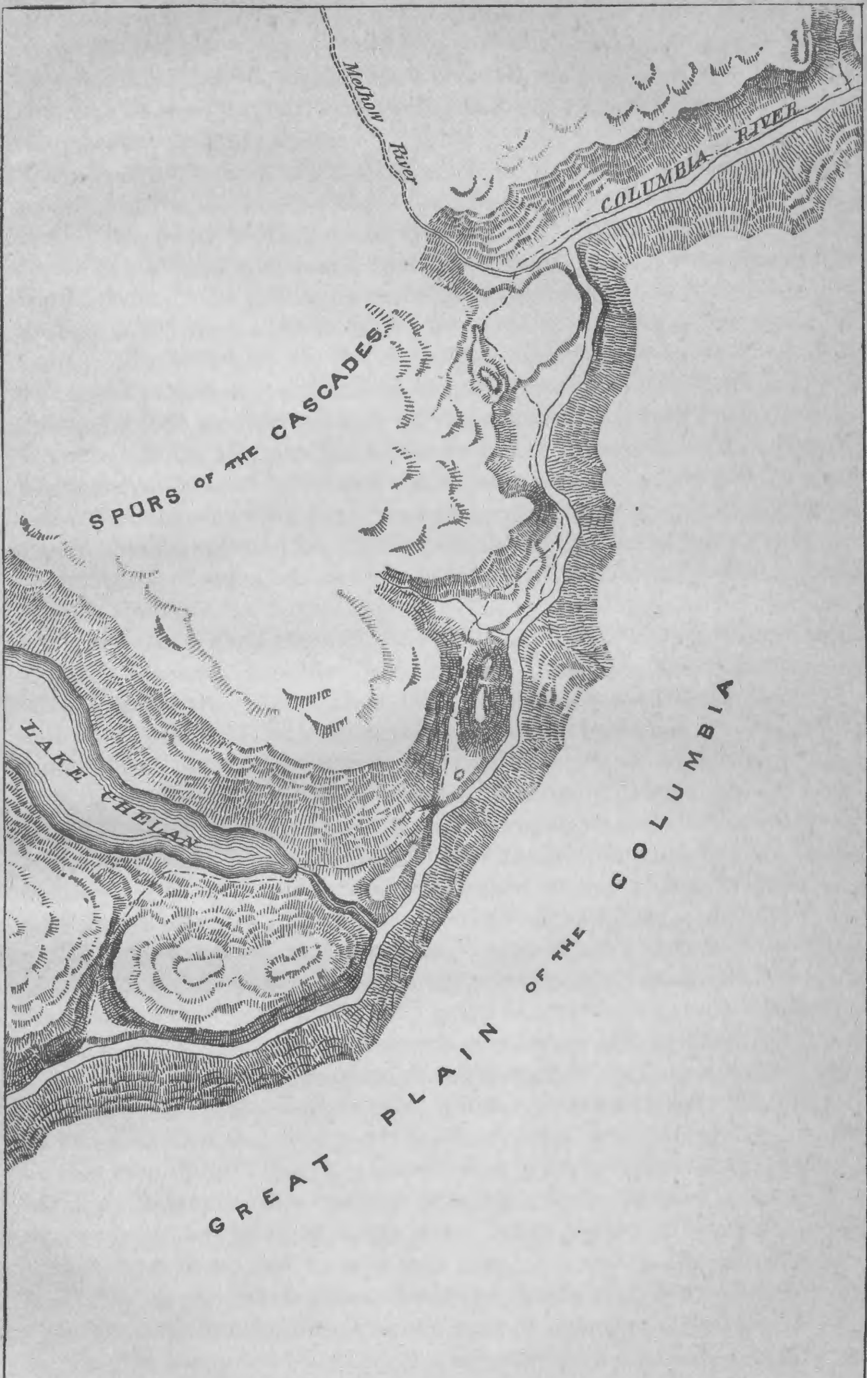
The first instance of this kind is found in the open valley of the Columbia, above Kettle Falls, and its southward continuation in the valley of Colville River and Chamokane Creek, which contrasts with the cañon now followed by the Columbia below Kettle Falls. This wider valley is now occupied by these two small streams, of insufficient volume or fall to remove the gravel over which they flow, and much less able to cut the channel which should carry a great river. They are separated only by a divide of gravel, terraced by erosion, and do not touch bedrock throughout their courses. The Colville River flows through marshes; Chamokane Creek has a swifter current, but is much smaller. It is apparent that a large river once flowed south or north through this channel and that of the Columbia above Kettle Falls, and it may be inferred that the valley was occupied by a glacier, as was that of the Kootenay, and that with the retreat of the ice the postglacial Columbia



PREGLACIAL CHANNEL OF THE SIMILKAMEEN RIVER.



LOWER VALLEY OF THE OKINAKANE RIVER TO THE COLUMBIA RIVER.



COLUMBIA RIVER FROM OKINAKANE RIVER TO LAKE CHELAN.

River was forced by a drift dam across a low divide into its present course. On Plate I are given the elevations bearing on this problem, as determined barometrically by Mr. Louis Nell, then of the Northern Transcontinental Survey, in mapping the area east of the Columbia and north of the Spokane River.

Another north and south depression of preglacial age is now occupied by Curlew Creek, which is said to rise in a rolling gravel plain, and which flows northward to Kettle River. The elevation of the divide at its head was found by United States engineer officers of the Department of the Columbia to be about 2,500 feet; that of its mouth is about 1,700 feet, as determined by aneroid, compared with Spokane Falls. This broad, gently sloping valley is gravel floored, and the older stream had cut a deeper channel than the present one. Curlew Creek flows over but a short section of the older valley, but there is little known evidence to trace the latter in either direction. The course of Kettle River toward it is down a precipitous cañon, which is more open below its northeastward turn. Analogy with other great valleys of the region would suggest that the Upper Kettle River was but a tributary of the former stream, which flowed southward to and under the locus of Curlew Creek.

Still another deep channel, now drift filled and abandoned to small sluggish streams, extends from Miner's Bend, on the Similkameen River, southward (Plates II and III). It presents three sections, two of which terminate with open passes, leading eastward to the Okinakane. The northern division, from Miner's Bend to Wagon Road pass, is a comparatively broad valley, a strip of marsh and lake between steep mountain slopes. The terraces on its sides are continuous with others, which cling to the walls of the Similkameen Cañon below Miner's Bend, and they extend southward to the Three Pools, where they merge into the highest portion of the drift filling.

The second section, that between Wagon Road pass and Fish Lake, is a drift clogged cañon, with abrupt granite walls of considerable height; its northern half presents a very gentle northward slope. From the Three Pools southward the drift surface is dotted with kettle-holes. Terraces again appear on the slope of the mountain northeast of Fish Lake and close the entrance of the pass, which trends eastward. The waters of Fish Lake are held by a gravel dam, from beneath which a small stream escapes into the very narrow and crooked upper channel of the southern portion. The descent from Fish Lake is very rapid and is strewn with bowlders of large size. After passing a very deep and narrow pool three-fourths of a mile long, into which the brook sinks, the valley opens out between limestone bluffs and drift terraces, and ends abruptly in a cul de sac at the head of Johnson Creek (Plate III), the further continuation, whether southwestward or southeastward, being now completely filled.

There can be no question that the cañon described is an old subaërial channel, very probably traversed by the Similkameen. One possible interpretation of the facts is that a glacier descended the valley and discharged through the several low passes eastward. In the several stages of its existence and retreat it spread the drift which now terraces the cul de sac, deposited the coarse material of a temporary terminal moraine below Fish Lake, produced the broad gaps in the hills on the east by glacial and subaërial erosion, and in its later stages left the gorge so dammed that the Similkameen found its present direct and rapid descent to the Okinakane River.

The valley of the latter belonged no doubt to the great system of which all these now abandoned channels were part. Like them, it was drift buried, but, unlike them, not dammed, because of its great width. The present river is a quiet stream, having a fall of about 3 feet per mile from Lake Osoyoos to the Columbia River, and usually flowing between terraces 400 feet high. The lake is but a shallow expansion of the river, retained by a drift deposit.

Other evidences of glaciation are found on that part of the Columbia sketched on Plate IV. A broad gravel plateau, the analogue of the terraces along the Okinakane, lies between the right banks of the Columbia and the Methow River, and is continued down the former wherever the cañon walls are not too abrupt.

An older channel of the Columbia is traversed by the trail just above Lake Chelan, and the bed of the latter was probably deepened by the glacier, which rounded the outcrops about its shores and left the coarse morainal material of a small lateral discharge in the cañon by which the trail leaves the lake basin on the south.

The preceding observations show the former existence of glaciers in the river valleys of the extreme northern part of the Territory, either as portions of a general ice sheet or as tongues pushed forward from disconnected ice rivers descending from the north. It is in keeping with either hypothesis that roches moutonnées should occur, as they do on the mountains south of the forty-ninth parallel, produced on the one hand by the great ice mass or on the other by streams radiating from local centers.

The extent and the direction of flow of the glacier or glaciers therefore remain open questions, to be studied with that detail which the interesting phenomena of the region invite.

The reconnaissance work upon which these notes are based included observations of distribution of rock groups, the results of which are given on Plate I.

No determinations of age were possible, as no fossils were found, and the classification adopted is consequently of a broad lithologic character.

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[Bulletin No. 41.]

The publications of the United States Geological Survey are issued in accordance with the statute approved March 3, 1879, which declares that—

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

On July 7, 1882, the following joint resolution, referring to all Government publications, was passed by Congress:

"That whenever any document or report shall be ordered printed by Congress, there shall be printed, in addition to the number in each case stated, the 'usual number' (1,900) of copies for binding and distribution among those entitled to receive them."

Except in those cases in which an extra number of any publication has been supplied to the Survey by special resolution of Congress or has been ordered by the Secretary of the Interior, this Office has no copies for gratuitous distribution.

ANNUAL REPORTS.

Of the Annual Reports there have been already published:

I. First Annual Report to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Second Annual Report of the United States Geological Survey, 1880–'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 61 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881–'82, by J. W. Powell. 1883. 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882–'83, by J. W. Powell. 1884. 8°. xxxii, 473 pp. 85 pl. and maps.

V. Fifth Annual Report of the United States Geological Survey, 1883–'84, by J. W. Powell. 1885. 8°. xxxvi, 469 pp. 58 pl. and maps.

VI. Sixth Annual Report of the United States Geological Survey, 1884–'85, by J. W. Powell. 1886. 8°. xxix, 570 pp. 65 pl. and maps.

The Seventh and Eighth Annual Reports are in press.

MONOGRAPHS.

Of the Monographs, Nos. II, III, IV, V, VI, VII, VIII, IX, X, XI, and XII are now published, viz:

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt. U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

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— The Fossil Fishes and Fossil Plants of the Triassic Rocks of New Jersey and the Connecticut Valley, by J. S. Newberry.

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J. W. POWELL, DIRECTOR

ON

THE FOSSIL FAUNAS

OF THE

UPPER DEVONIAN

THE GENESEE SECTION, NEW YORK

BY

HENRY S. WILLIAMS

WASHINGTON
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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
ITHACA, N. Y., *August* 2, 1886.

SIR: I have the honor to transmit herewith for publication as a bulletin a second contribution to the study of Devonian paleontology, Bulletin No. 3, "On the Fossil Faunas of the Upper Devonian," having been designed as the first of a series of papers on the comparative paleontology of the Devonian and Carboniferous.

In that paper I gave the results of a study of the section along the meridian of Ithaca and Cayuga Lake, running southward, which may be called the Cayuga section.

In 1883 examination was made south along the meridian running through Genesee County, New York, into McKean County, Pennsylvania, where the Alton coal beds were reached. The general results of this survey were communicated to the Director of the United States Geological Survey and an abstract of my communication was published in Science, Vol. II, pp. 836, 837, December 28, 1883. The present paper is a detailed report of the study of the materials of this Genesee section.

Since the field work was done several additional sections have been examined: in 1884, sections through Western New York (and adjoining Pennsylvania) from Chautauqua County westward and into Ohio as far as the meridian of Cleveland; and in 1885 the region between the Cayuga section and those of Delaware and Otsego Counties, as far as Oneonta, were examined. The materials are under investigation and will be reported upon as soon as their study is completed.

The sections are made along meridians, in order to make them more readily and simply comparable. Each long meridional section runs through the same stratigraphical series of deposits and is made up of a series of small local sections, such as the individual outcrop of the rocks renders possible.

It is not supposed that in any case these sections are exhaustive, but it is intended that so far as they go the relative position of the faunas in the sections shall be precise and the association of species in each horizon shall be given as it is, so that the faunas can be identified, and thus, while they will leave much to be added, these studies, it is hoped, will give an outline of the geographical distribution and geological range of faunas and their species which will make a comparative study of the faunas possible.

In the arrangement of the material of this report I have followed simply the order in which the various sections were originally made, which is in general from north to south and from below upward. The numbering of the stations is that which the specimens will receive when finally deposited in the National Museum. The system used in marking the sections and the specimens representing them is as follows: A number is assigned to each principal locality, as 468 Attica, 477 Cuba, 487 Olean, &c. A letter is assigned to each section, as 477 A, Armstrong quarry, Cuba; 477 C, Smith quarry; 477 E, a ravine south of Cuba. For each section the individual strata or fossiliferous zones receive numbers, running from below upward wherever this order was practicable; thus 477 E^2 is the principal brachiopod zone of this particular ravine, 477 E^5 the red band of the same section.

In the present report special discussion of the faunas of the Hamilton group and of those below the black shales of the Genesee group is omitted, since the sections along this meridian do not present the series with sufficient fullness to throw any new light upon their history. The facts gathered will be presented in their connection when a more typical series of this part of the Devonian is prepared for comparison.

Respectfully yours,

HENRY S. WILLIAMS.

Maj. J. W. POWELL,

Director U. S. Geological Survey.

UPPER DEVONIAN FOSSIL FAUNAS—GENESEE SECTION.

By Henry S. Williams.

INTRODUCTION.

The description of fossils is a most important work for the paleontologist, but it is believed that a still more interesting and a wider field is awaiting his investigation in the comparative and historical study of organisms. This field is open for all who will undertake it, and, while the professional paleontologist may be able to map out the grander features and problems, very much must be left for the local student to fill in by careful and thorough search in his own region. This same line of investigation should be followed out in all the geological stages, and each student will find his best field in that region in which he can make most diligent search. In the present case the selection of the Devonian was determined by the simple fact that the Devonian rocks were for the writer the most accessible. These outcrops are near at hand and therefore can be thoroughly studied. The Silurian offers like opportunities for those residing in the midst of Silurian rocks, the Mesozoic for others.

Scarcely ever do good species range through more than a single geological system, and hence a scrutiny of the laws of the modification of species may be best effected by confining our comparisons to the species of a single system. Till we gather some definite knowledge as to the laws of modification which species undergo when traced through varying geographical conditions and in their geological range, our ideas in regard to modification of genera and families must necessarily be hypothetical. It is hoped, too, that these investigations may throw some light upon the nature of what we call species—as to what may be the conditions determining the constancy of certain characters and the plasticity of others. In order to do this, data must be collected showing what the constant and what the plastic characters actually are, and this in regard to particular species, at particular stages, and in particular regions.

In a paper read at the Ann Arbor meeting of the American Association for the Advancement of Science, 1885, I communicated some of the general results of comparison of the several faunas of the Upper Devonian, as seen in the various sections from Oneonta, Otsego County, N. Y., westward to Cleveland, Ohio. I then named the several long sections whose faunas were made the subjects of comparison. The section described in the present paper is there called the Genesee section. In reference to the identification of species in this paper, I wish particularly to state that I regard them in many cases as imperfect and provisional.

The careful comparison of large series of specimens from the same and from different localities and from different zones has brought out so conspicuously the variability in many of the characters used in the definition of species that the limitation and the validity of species are often called in question. But in order to speak of them and to discuss the problems involved it is necessary to use some names. The rule I have adopted, therefore, is to apply to specimens which have come from the same localities and horizons the names which are in common use in the reports and in the museums where the typical specimens may be found named and described. The literature, too, is often confused, and forms which ought to go under a single name are often called by different names by different authors. This is particularly noticeable when comparisons of our material are made with collections from Europe or from distant portions of our own land. Further, there are in common use in our American literature generic names of very doubtful value, which may be dispensed with to the advantage of science. But to adjust these errors would involve technical and detailed discussion, not appropriate to this paper, and I have therefore somewhat sacrificed precision in the use of nomenclature in order to bring out more clearly, for those familiar with the State reports and the museums in which the typical collections are contained, the general characters of the faunas.

As preparation for these investigations I owe much to the abundant and instructive labors of geologists and paleontologists who before me have studied deeply into the problems and done much toward their solution. In this country, Messrs. James Hall, J. S. Newberry, A. Winchell, C. A. White, and later Messrs. John F. Carll, I. C. White, C. A. Ashburner, and H. M. Chance, in connection with Prof. J. P. Lesley, of the Pennsylvania survey, and Mr. Edward Orton, the present State geologist of Ohio, Messrs. F. B. Meek and A. H. Worthen, of the Illinois survey, and Mr. Carl Röminger, of the Michigan survey, and others, in a more general way, have taken more or less active part in elaborating the facts and in determining the relations which the complicated series of deposits sustain toward one another. In Great Britain the discussion which centered about the Devonian problem, the relation of the Devonian marine deposits and the Old Red Sandstone, is full of instruction, beginning with the classic paper of Murchison and Sedgwick, and expressed most forcibly in the papers of Murchison, Salter, Jukes, Hall, and Champernowne, and practically settled for Great Britain in the exhaustive paleontological paper of Sir Robert Etheridge in 1867. Most of these articles may be consulted in the Transactions and Journal of the Geological Society of London. Recent investigations on the Devonian series of Northern France and Belgium have thrown light on the general problem. The papers of MM. Gosselet, Barrois, and Mourlon may be specially mentioned. Valuable suggestions are also found in the papers of M. Emanuel Kayser on the Rhenish Devonian.

All these investigations tend to show, first: that the series of deposits which immediately preceded the Carboniferous formation, or those deposits which are of a semiterrestrial origin, at the close of the Paleozoic exhibit great variation in the nature and order of the deposits when traced over any considerable geographical area. The termination of the Devonian age and deposits underlying the true Carboniferous age have been a constant source of bewilderment to all geologists in this country who have looked outside their own immediate neighborhood. Secondly, when studied minutely, there appear to be evidences to show that the differences in the faunas in these deposits are not always chronological differences, but must be regarded often as geographical in faunas living at the same time under different conditions.

From the fact of these differences and irregularities in the deposits and in their contained faunas, they seemed to offer a particularly attractive field for studying the effects of changing conditions upon the organisms and a promising field from which to learn the laws of change which, under like conditions, might be traceable to chronological sequence, and at a common horizon could be more properly referred to geographical change of the environing conditions of life.

CHAPTER I.

REVIEW OF OPINIONS; THE BEARINGS OF THESE INVESTIGATIONS UPON THE CLASSIFICATION OF THE UPPER DEVONIAN ROCKS AND FAUNAS.

In planning these investigations into the history of organisms, the Devonian age was chosen as a particularly important field because of the numerous disputed questions there awaiting solution and because it offers, in the various exposures in this country, abundant data for investigation. Between the limits of the Corniferous limestone below and the coal deposits above is found a great thickness of strata in New York, Pennsylvania, and adjacent territory broken up into several well marked *geological formations*. In other parts of the United States the same series is represented by deposits containing like fossils but not always identical, nor are successive strata always composed of the same materials or arranged in the same groups as we pass out of this eastern area.

When these investigations were begun the chief question in mind was the solution of the complex problem of the equivalency of the various sections covering Upper Devonian and Lower Carboniferous horizons in various parts of the country. The first general section therefore did not extend below the Black Genesee shale terminating the Hamilton formation. The faunas from this point to the first coal, as seen along the meridian from Cayuga Lake southward, were reported upon in the United States Geological Survey Bulletin No. 3. But the problems involved are too far reaching to be limited by so indefinite a mass as the black shales lying in the Middle Devonian of New York. Although this section through the middle tier of counties in Western New York is an admirable one for the study of the Upper Devonian, it will be necessary to go farther east to find the lower faunas (i. e., above the Corniferous limestone) so exhibited as to determine the details of their history.

On entering upon fields of which the geological structure is well known and whose fossil species are generally familiar and described, I neither undervalue the excellent work of my predecessors nor expect to do anything to take the place of the geological reports already published. On the other hand, the work here attempted could not be undertaken without this preliminary mapping out of the field and working up of the species concerned.

I am here interested not in adding to the long list of described species, nor in determining to what geological period the species belong, but in ascertaining the laws of association, of sequence, of modification, and of distribution of species in the past. The better known and the more frequent the occurrence of the species the more satisfactory will be the results to be reached by their study. In the course of the investigations already a few new species have appeared, but much more frequently forms have been met with which lie intermediate between the typical forms of already described species.

Facts are thus accumulated for a revision of the characters essential to the distinction of species. Not only am I indebted to the work of other geologists for facts accumulated, but suggestions and partial explanations of the facts, so far as the evidence existed, have been used as guides in extending the research. I have availed myself, too, of the differences of opinion among accepted authorities as a guide to the questions needing most careful study.

On examining the series of deposits found in each State, it was of first importance to consult the published reports of geological surveys already made. I have, therefore, consulted the numerous series of reports of the State surveys of New York, Ohio, Pennsylvania, Michigan, Iowa, Missouri, Illinois, and of other States in which representative deposits were exposed.

PROF. JAMES HALL'S VIEWS.

In the volume on the Devonian Brachiopoda, 1867 (Geol. Surv. of N. Y., Pal., Vol. IV, Pt. I), Prof. James Hall recognized the increase of Carboniferous types among the species of the Upper Devonian on passing from the eastern to the western deposits of New York State; this he regarded as a mark not of a higher geological stage, but of a change in geographical conditions. He wrote (p. 257): "And finally, we have every reason to believe that in those sedimentary formations between the Hamilton group and the Coal Measures in the east, and between the same groups and the Burlington (Carboniferous) limestone in the west, the Devonian aspect of the fauna on the one hand and its Carboniferous aspect on the other are due to geographical and physical conditions, and not to difference in age or chronological sequence of the beds containing the fossils."

The mingling of Devonian and Carboniferous types in rocks of the Lake Superior region occurred to Professor Hall still earlier (see Rep. Geol. Lake Superior Land District, Foster & Whitney, 1851, p. 313), leading to the belief that the transitions are gradual and not clearly defined.

This idea, whether originating with Professor Hall or not, was never elaborated by him in public, so far as I can ascertain. In Great Britain, however, the discussion of the relations existing between the Devonian and the Old Red Sandstone, which practically terminated in Sir Robert Etheridge's masterly paper on "The physical structure of West Somerset and North Devon" in 1867 (Quar. Jour. Geol. Soc., London, Vol. XXIII), has brought out clearly the fact that the Old Red Sandstones, wanting in marine invertebrate faunas and filling the gap between the marine deposits of the Silurian and those of the Carboniferous, are the equivalents of the marine deposits called Devonian—not above nor below them, but contemporaneous, though in separate geographical areas.

The change in the character of the American deposits in passing westward and the differences observed in the faunas were explained by Professor Hall as due to mingling of the Devonian and Carboniferous faunas toward the west.

PROF. A. WINCHELL'S VIEWS.

In 1870 Prof. A. Winchell, in a paper (in Proc. Am. Phil. Soc., Vol. XI, pp. 57–82, 385–418) "On the geological age and equivalents of the Marshall group," objected to this interpretation of the facts, which implied, if it did not assert, that the Waverly and Marshall groups were only geographical modifications of formations of the same general age as the Chemung. Professor Winchell brought elaborate evidence to show that the Marshall, Waverly, and allied faunas in Illinois, Indiana, Iowa, and Missouri were equivalents, that they were not equivalent to the Chemung group of New York, and, finally, that they were separated from the latter by the Catskill group of Eastern New York, which was regarded as following the Chemung and intermediate between the Devonian and the Carboniferous age.

The problem of chief interest to the general geologist awaiting solution in these regions is that of the equivalency, or even the interpretation of the true relations, of these several series of rocks between the Hamilton and the Coal Measures, especially in the contiguous States of New York, Pennsylvania, and Ohio.

In the earlier surveys the Upper Devonian was traced far into the interior, and the Waverly of Ohio, the Burlington sandstone, and the Chouteau beds of Missouri were alike regarded as equivalent to the New York Chemung.

In 1867 Professor Hall receded from this position and recognized the force of Professor Newberry's discovery of *Spirifera Verneuili* (= *S. disjuncta*) below the Cleveland shale (see Geol. Surv. N. Y., Pal., Vol. IV, Pt. I, note at beginning). In 1870 the superior and independent position of the Waverly and equivalents was defended by Professor Winchell in the paper above mentioned.

VIEWS ON THE RELATION OF THE WAVERLY TO THE NEW YORK SERIES.

In 1875, Professor Hall, finding the fossils of the Chemung group in the higher beds of Western Pennsylvania mingling with other species regarded as Carboniferous, concluded that "the Chemung fauna continued its existence till after the appearance of Carboniferous forms, and that the two faunas, if they can be properly so regarded, lived in the same sea and at the same epoch; and the question of the limits between Devonian and Carboniferous formations is likely, at least for some time, to remain undetermined in some parts of the country." (Am. Jour. Sc., 3d ser., Vol. XII, pp. 303, 304.)

In 1878 Professor Newberry defended his early opinion regarding the Ohio equivalent of the Chemung as terminating at the base of the Cleveland shale (see Geol. Surv. Ohio, Vol. III, Geol., p. 14); but this opinion is complicated by the further one that the upper part of the Portage group is the proper base of the Carboniferous series, making these disputed beds merely a base of the Carboniferous.

The confusion in regard to the fossils of these Upper Devonian beds leaves the matter of exact equivalency still in doubt. That is, the mingling of faunas which led Prof. James Hall to regard the Chemung fauna as continuing into the Carboniferous and Prof. J. S. Newberry to draw down the limits of the Carboniferous so as to include the Chemung and the Upper Portage has not yet been satisfactorily interpreted. We see then that this confusion and occasional blending of faunas were variously interpreted by those who gave the subject most careful study. The New York State geologist (Hall), without distinguishing the faunas, regarded them as blending, and he left the relations of the New York and western beds undecided. The Ohio geologist (Newberry), from his standpoint of a Carboniferous Waverly group, brought down the Devono-Carboniferous point of transition to the Portage sandstones of New York, thus including the Chemung group within the Carboniferous; while the Michigan geologist (A. Winchell), recognizing the integrity of his Marshall group formation, but finding still no equivalent fauna for it in the New York series, regarded it as the equivalent of the brackish or fresh water Catskill group, thus putting it above the Chemung group of New York as then defined.[1]

VIEWS OF PENNSYLVANIA GEOLOGISTS.

Since 1875 the Pennsylvania geologists, under Prof. J. P. Lesley, finding the fossils entirely unsatisfactory as means of determining the

[1] Since the writing of this paper, at the Philadelphia meeting of the American Association for the Advancement of Science, in 1884, Prof. James Hall communicated a paper entitled, "Note on the intimate relations of the Chemung group and Waverly sandstone in Northwestern Pennsylvania and Southwestern New York." (Proc. Am. Assoc. Adv. Sc., 1884, Part II, p. 416.) The paper is based upon a section in Warren County, Pennsylvania, made by Mr. C. E. Beecher and Mr. F. A. Randall. In this section the Chemung is regarded as running up to the base of the Waverly, and at the junction is said to be "the place of the Catskill," where "there is a hiatus which, in Eastern New York and Pennsylvania, is marked by the presence of measures having a thickness of from 3,000 to 5,000 feet" (p. 418), and Professor Hall concludes that "the deposition of the estuary Catskill sediments has been going on simultaneously with the open sea deposits of the Waverly formation."

transition beds, adopted stratigraphical conditions as their chief criteria, and Mr. John F. Carll, Prof. I. C. White, Mr. C. A. Ashburner, and Mr. H. M. Chance have given in their several valuable reports various interpretations of the series.

The one point in which they all appear to agree is the equivalency of the Olean-Garland-Ohio Conglomerate, although in 1876 Mr. E. B. Andrews, formerly of the Ohio survey, objected with strong argument to regarding the Conglomerate underlying the Coal as marking a common horizon for even the Ohio-Pennsylvania-Virginia area, and suggested that it would be more appropriate to call this a rock than a common horizon. (See Proc. Am. Assoc. Adv. Sc., Vol. XXIV, Pt. II, p. 84.) The Pennsylvania geologists, taking this Olean Conglomerate as a definite common horizon, recognize a sub-Olean Conglomerate, which in their northwestern counties takes its place below the Olean Conglomerate and above the horizon to which the red beds of the east and their equivalents are assigned. This lower Conglomerate, often merely a sandstone, is distinguished by its flat pebbles, although frequent sandstones and conglomerates are recognized below, having flat and worn pebbles.

When we go below this horizon confusion is greater the greater the number of counties whose sections are compared, but in the northwestern counties, where the red beds offer least trouble by their presence, frequent heavy sandstone beds separated by shales and thinner shaly sandstones are found occupying at least several hundred feet. These have gained the more general name of the Venango oil sands.

Mr. J. F. Carll (Report III, Second Geol. Surv. Pa.) gives several systems of sandstones and shales below this before reaching what he regards the equivalents of the New York Chemung. Prof. I. C. White (QQQQ, 2d Geol. Surv. Pa., 1881) regards the Venango group as resting immediately upon Chemung flags in Erie and Crawford Counties, Pennsylvania, and is obliged, also, to recognize the fact that the fossils of this group are decidedly of Chemung type. This Venango group is included by Mr. C. A. Ashburner in the Catskill (Ponent, No. IX), but he includes the Bradford oil sands, which were placed higher in the series by Mr. Carll, in the Vespertine No. VIII.

THE PENNSYLVANIA SECTION.

Without entering into the minutiæ of the extremely interesting series of sections which the Second Geological Survey of Pennsylvania has brought to light, we find a general agreement in the following arrangement of deposits for the Upper Devonian, leaving out the red beds, which must receive special consideration. After passing the Hamilton formation and the black Genesee shale, where they are recognized, there is—

First. A series of thin bedded deposits, generally more argillaceous than sandy, constituting the blue or green shales of the Portage group, containing little or no iron, except in the condition of pyrites.

Second. A series of similar shales, but of generally lighter color and weathering brown to yellow from iron oxides, and with occasional thick massive beds of light gray sandstones, often coarse grained and in places conglomeratic, and holding petroleum in some areas. When seen on the surface they are often strongly calcareous, and generally give off a strong bituminous odor upon first fracture.

Third. A series of sandstone conglomerates, with soft shales, not strongly separated from the second group, but the two kinds of rock, the shales and the sands, when interstratified, are each purer in composition, and the iron appears in beds or nodules in the sands, where iron oxides are so frequent as to cause them generally to be of a yellowish tint. Flat pebble conglomerate is seen in some of the beds.

Fourth. The coarse round pebble conglomerate, with thin seams of black shales and true bituminous coal.

THE ALLEGANY COUNTY SECTION.

In New York I find the Allegany County section bears a general resemblance to the Pennsylvania series. However, in the second group the sandstones are less prominent and the shales prevail, in the second and third groups the conglomerates are rare and generally only the sandstones are seen, and black shales are interleaved with the shales of the first group nearly to the base of the second. Going farther east in New York, I find the massive sandstones of the second group are reduced to but one or two beds of 2 or 3 feet thickness; and still farther east, but before reaching the Catskill Mountains, this particular class of sandstones is wanting, while the third series, in place of gray sandstones and conglomerates, becomes dark greenish gray, micaceous flags and red shales and sandstones; and, finally, the red and coarse, greenish gray, flaggy sandstones and shales appear still lower and fill the whole interval from the Hamilton shales upward to the Conglomerate.

ORDER OF DEPOSITS IN OHIO.

Now, turning in the other direction, in Ohio we find a different order of strata. The first group, instead of being followed by the heavier and more frequent sands of the second group, is followed by a return of the condition below, black fine shales and soft greens taking the place of thin bedded shales and sands. And the whole interval of the second and third groups of the areas farther east is represented by only one, at greatest only two, of the sandy conglomerate deposits.

The explanation of this condition of things is to be fully determined only by the fossils. I find that the first group holds a Portage fauna in the soft green shales and a Genesee fauna in the black interleaved shales. I find the second group marked by the departure of the Portage fauna at the first massive sandstones; and with the deposition of those sands of the second group, both in them and in the accompanying shales which are more ferruginous than those below, the Chemung fauna appears.

With the deposition of the lower flat pebble conglomerates, a new fauna comes in, but it does not entirely take the place of the other fauna. These first conglomerates are clearly shown to be comparatively local, grading rapidly off into coarse sands or even lost entirely in sandy shales in a distance of fifty miles. But their general place in the series is definite and regular in this eastern area. Also, so far as the facts are gathered, it is clear that the faunas associated with them are distinct, even when they were deposited alternately with Chemung shales bearing the genuine Chemung faunas.

In New York the flat pebble conglomerate appeared before the cessation of the Chemung fauna, and in fact we find traces of the latter up to the base of the Olean Conglomerate.

The exact equivalency of the Ohio grits and overlying shales and their faunas must be determined by a fuller and more thorough comparative study of their faunas than has yet been published.

GEOGRAPHIC AND CHRONOLOGIC RELATIONS OF THE FAUNAS.

It is necessary to recognize the effect of geographical condition upon faunas, as well as the changes incident to chronological sequence, if we would interpret the confusion existing in the Devono-Carboniferous deposits of the eastern portion of our continent. But the assigning of the Marshall fauna to the period of the Catskill group does not settle it. Neither does the expansion of the Chemung to receive the Waverly fauna or the pulling down of the Carboniferous to cover the Portage relieve us from the main perplexities.

It is only by disentangling these faunas and ascertaining the true geographical and chronological relations which they bear to one another that the difficulty is to be met. This is to be attained, not by clinging to any sharp limits of a stratigraphical or a lithological nature or to any absolute division between one formation and the following, but each fauna must be traced upward and downward and its modifications noted until it is replaced by another, and whatever on the way is interpolated or is added to it must be traced to its origin or to its center of occurrence. Thus, I believe, a scale of the chronological sequence in the life history of the organisms and the faunas may be prepared which may serve as a definite standard for determining the relative age of deposits, quite independent of the characters of the sediments which were being continuously thrown down, these being in main part determined by local conditions of the disintegrating shores and the distance away from them. By themselves the rocks, as rocks, present no features which may serve as indications of the particular stage in geological time at which they were deposited.

While the method proposed will make of geology a more difficult and complex study, the entangling of formations and their groups of organisms—inextricably, as it would seem, when the attempt is made to make minute comparisons over wide areas—is much nearer a true appreciation of the facts as they actually occurred than the simple but concise tabulation of typical series and the co-ordination of those that are not typical by thinning or thickening them with assumed gaps or insertions. The method of critical and careful study of the lithological and stratigraphical condition of the rocks, adopted by the Pennsylvania geologists, is bringing out with great distinctness the untrustworthiness of these characters alone for the co-ordination of horizons over any considerable extent of territory. The study of fossils in their relations to the rock deposits and in their association with one another has already suggested that the sharp lines, often observed separating one group of organisms stratigraphically from another, are in part due to local conditions. As our familiarity with different sections from separated areas increases, the faunas which we shall learn to regard as marking a common geological period or stage will comprise, in some measure at least, groupings of species as various as are now met with in the different regions and at different depths of the sea.

In this report the Upper Devonian, including the Genesee shale, comes under detailed discussion. The lowest member of this section is at Attica, Wyoming County, N. Y. Running northward from there the country is heavily covered with soil and no good exposures of Hamilton rocks are met with, and not till the limestone ridge seen at Batavia is reached have the rocks resisted disintegration sufficiently to present fit outcrops for study. Westward from Attica the Hamilton and the Marcellus are exposed, but all this part of the Devonian is far better represented fifty or a hundred miles farther east.

LIST OF THE FAUNAS.

The more important groupings of species into temporary faunas are: The *Lingula* fauna of the Genesee shales, as seen in section 468 (p. 31); the *Cardiola* fauna of the Portage shales, 472 C (p. 41); the early *Leiorhynchus* fauna of the green shales of the Chemung, 476 G (p. 60); the *Spirifera mesocostalis* fauna, as seen about Rushford, 476 (p. 58); the *Streptorhynchus* and *Spirifera disjuncta* fauna proper, as seen in the Cuba sandstones and similar sandstones to the north, 477 (p. 65); the lamellibranch fauna of a member of these sands, 477 A^3 (p. 64); the *Lingula* fauna in the underlying shales, 477 A^2 (p. 64); the *Athyris Angelica* fauna, particularly represented in the soft shales, 477 H (p. 67); the fauna of the flat pebble conglomerate, 486 (p. 91), and the fauna of the ferruginous sandstone (p. 87).

Besides these there are a few local or special faunas, as a brownish red sandstone above Rushford (p. 56), containing a small terebratuloid shell, which appears identical with *Centronella Julia*, of Winchell, and the special fauna of one of the earliest red bands south of Cuba, with an abundance of a small *Orthis Leonensis* (p. 67).

Each of these several faunas is distinguishable as a separate group of species, associated with some distinct character of sediment or definite horizon. Many of them were probably living at the same time within the same general oceanic area, but one was confined to mud bottom, another to sand, one is peculiar to a black shale, another to a soft green shale, a third to a sandy conglomerate. Several of them may contain a majority of the species alike, but hold some one or more species either peculiar to it or in greater abundance or under some particular varietal form. As we approach the top (it may be in some thin stratum differing from the surrounding deposits) we come across a little colony of a species foreign to the general fauna but characteristic of some formation of a different geographical area, as in the case of *Centronella Julia* in the Rushford sand (p. 56); or we may find in a series of apparently identical deposits two distinct faunas, having scarcely a species in common, though within a few feet of each other, as in the Lamellibranch and the Brachiopod faunas of the Cuba sandstone (p. 65).

RELATION OF THE FAUNAS TO THE CHARACTER OF THE DEPOSITS.

By thus disentangling the species and learning their habits of association and their relations to the sediments in which they were buried, the data are gathered for recognizing the faunas in other localities and in deposits where the prevailing lithological character may be so unlike as to give no suggestion of a common horizon.

In the more eastern section, at Cayuga Lake and southward, the black shales are confined almost entirely to the first horizon of the Genesee shale; slight traces of a dark but no black shale are recognized for a few hundred feet above. A rich fauna, the Ithaca fauna, is found in that section before the termination of the Portage fauna, but in its species it resembles both the eastern Hamilton fauna and the true Chemung fauna. The study of its species, and of those occurring above, proves that it represents an earlier stage than that of the Chemung fauna, and that it lies *below* as well as above deposits containing the genuine Portage fauna.

In the more western section of Wyoming and Allegany Counties the black shales recur frequently above the Genesee shales, and are interleaved with the regular Portage shales upward for a thousand feet from their base, each successive stage less distinct and more blended with the contained sediments. This fauna holds on till after the appearance of the Portage shales and its fauna, but becomes less and less apparent with each recurring stage until nothing is left but the *Sporangites*, which was doubtless an efficient cause of the dark color of the shales. Not a trace is seen of the Ithaca fauna. The Portage shales and fauna and the black shales occur in alternate deposits, the latter prevailing at first and the former being more prominent in the upper part of the series, up to the appearance of the first traces of the Chemung fauna.

The first introduction of the Chemung fauna was associated with the deposition of the gray sandstones generally called Portage sandstones. In their typical display at Portage Falls these sandstones are barren of fossil remains. But in tracing the Portage rocks upward I find a gradual increase in the arenaceous ingredients of the sediments. The Portage fauna belongs to the argillaceous deposits and in the upper part is scarcely ever detected except in some thin streak of soft, green shale interstratified with the more common thin bedded, arenaceous shales. The arenaceous shales, by the dropping out of the argillaceous streaks as we ascend, become thin sandstones, which increase in thickness, until finally at the top we have thick, massive sandstone separated by barren olive shales. These sandstones terminate the deposits containing Portage fossils and begin the series of the Chemung group. In this section, too, the black shales reach up to them but not beyond. It was clearly shown, by the work of this year, that the Chemung fauna coming in with the gray sandstones is the regular successor of the Portage fauna, and that the black shales and their special fauna are independent of both and only locally occupy the position in the series here recorded.

Farther to the east the succession of the Chemung fauna upon the Portage is substantially the same, but the black shales had entirely ceased some eight hundred feet below the point of transition.

RELATION OF THE BLACK SHALES TO THE UPPER FAUNAS.

In the extreme western part of Wyoming County a thin sheet of black shale was found immediately under the first sandstone bearing *Spirifera disjuncta*, an undoubted representative of the Chemung Brachiopod fauna (see p. 49); but only a few miles farther east, at Portage Falls, the first sandstones, although following pretty closely the termination of the black shales, contain no trace of the Chemung fauna. We are led to believe, therefore, that with the progress of the Upper Devonian the black shales were gradually withdrawing westward, and that the conditions producing them were independent of the causes producing the argillaceous and sandy shales associated with the Portage and Chemung faunas.

If the same rate of withdrawal of the black shales which is noted on passing from Cayuga Lake to Wyoming County continues on passing farther westward, the black shale should be expected to recur above the equivalents of the Chemung period, or even above conglomerates, as we go westward. That the black shales of Ohio *may* be such a continuation of the shales occurring in New York was shown by the presence of the characteristic species of the Cleveland shale of Bedford Ohio, in the genuine Genesee black shale of Wyoming County.

As I stated in a preliminary report, an abstract of which has already appeared in Science (Vol. II, p. 836), the identity of the two faunas is not necessarily evidence of equivalency of horizon, but I interpret it rather as a fauna which may have persisted with very little change for a long time, possibly during the greater part of the Devonian age, although as yet there is no conclusive evidence that the fauna of the Marcellus black shale was identical with this.

Future study may show the Cleveland shale, at Bedford, Ohio, to be identical stratigraphically with the higher recurrent black shale beds of the Portage of New York, but it is more probable that the fauna persisted with little change, and that the black shales were being deposited continuously (though not continuously in any one particular spot) in the great interior continental basin from the Middle Devonian to the time of the sub-Carboniferous limestones. Another fact brought out by these studies is that the sandstones, as we pass upward from the time of the reign of the Hamilton faunas, changed gradually from thin argillaceous sandstones or arenaceous shales of a dark color and flaggy structure, first to thicker beds with less clay, then into purer and more massive sandstones with slightly coarser grain and of a lighter gray without fossils; and, higher, become light gray sandstones, calcareous and generally fossiliferous, with the Chemung fauna, and, pretty generally, more or less saturated with petroleum.

The petroleum odor of those outcropping on the surface is proportionate to their porosity and freedom from lime.

PLACE OF THE VENANGO OIL GROUP.

From a study of Mr. I. C. White's sections of Erie and Crawford Counties, as given in Report QQQQ, Second Geol. Surv. Pa., it seems more than probable that his Venango oil group is identical with these Chemung sandstones. Comparison of their fossils alone can give conclusive testimony on this point. Mr. White's opinion is that the Panama conglomerate is equivalent to the third oil sand of Venango group (see QQQQ, Second Geol. Surv. Pa.).

Mr. Carll (in Report IIII, Second Geol. Surv. Pa.) still refuses to accept this interpretation, but he makes no positive identification and even suggests a plane of non-conformity. If the method adopted by the Pennsylvania survey were capable of solving this intricate problem, the careful and most industrious study given their rocks should have brought a more satisfactory solution than we at present have. It would be difficult to improve upon the stratigraphical data already accumulated.

If fossils prove as satisfactory in the more western deposits as they have proved in the New York Chemung they should decide, when carefully studied, whether a portion of the series is missing or whether the geographical change alone is to account for the changed faunas. But I reserve opinion until I can compare the fossils themselves and learn their associations.

STRATA FOLLOWING THE CHEMUNG FAUNAS.

Above the Chemung sandstones appear coarser sands with occasional streaks of worn pebbles, the larger sizes of which are flat and of a still lighter gray color. They show decided traces of iron in the higher beds, each bed beginning or terminating, or both, with ferruginous beds composed of clay ironstone nodules in the midst of the sand. As these ferruginous sandstones are reached the Chemung fauna comes to its close and another series of deposits becomes dominant, which, in their purity, contained no marine faunas. They took the place of the Chemung series, but are not sharply distinct at the outset.

In the Allegany County section this new series of rocks began down among the deposits containing the Chemung faunas, first as thin streaks of red argillaceous shale, a little below the first gravel sandstones and ferruginous sandstones and conglomerates, and, at the stage of the latter, the red beds were of frequent occurrence, but rarely over a foot in thickness. These red beds were apparently the continuation, under changed conditions, of the olive shales of the Chemung, which contained a fauna differing in the characteristic species from the sandstones interstratified with them. At first the red beds held a few of the species of that fauna, but soon lost them and were utterly barren at every later stage of their recurrence.

Interstratified with the red, argillaceous shales and apparently taking the place of the sands occurring below, we find rather coarse, micaceous sandstones, generally very evenly bedded, the mica grains sometimes mingled intimately with the sand, causing a loose mealy structure; at other times the mica grains, almost pure, are laid out in thin sheets, making an imitation of schistose structure or forming very even, thin flagging. These micaceous sandstones have no fossils and are of a gray green to a dark green color, and when weathered are often peppered with dark brown spots, from the decomposition of minute ferruginous grains.

As we pass upward the red shales are more frequent and some layers become arenaceous, so that the mass of the deposits is of alternations of red argillaceous shales, red arenaceous shales and sandstones, and green micaceous sandstones and shaly sandstones.

At this stage some of the beds of olive sandy shale, with fewer and smaller grains of mica, contain large scales of *Holoptychius* and other fish remains, and ferruginous sandstones occur, with a restricted marine fauna which appears to be the successor of the Chemung fauna; and, finally, to close the series, a thick massive conglomerate appears, which, in this region, is called the Olean Conglomerate, composed of coarse silicious sand and coarse, rounded, but little worn, often large sized quartz pebbles.

It will be seen, in this brief review of the series of deposits, that the red and green shales and sands which take the place of the Chemung group and occupy the interval between it and the Olean Conglomerate are the equivalents of those thick deposits which form so prominent a feature in the eastern part of New York State and extend southward across

Pennsylvania, &c., where they are known as the Catskill group. They are feebly represented in the western part of New York, where the Upper Devonian is best represented. The thick deposits containing Devonian plants at St. John, New Brunswick, and in the northeast, are undoubtedly a northern extension of the same series, although beginning at a much earlier stage as measured by the progress of marine faunas.

In regard to the Catskill group, my studies have led me to believe that the Catskill red rocks of the east offer evidence of having been contemporaneous with a great portion of the Upper Devonian rocks, and a comparison of faunas, at least, goes to show that the base of the red beds does not form a definite and uniform horizon. Influenced apparently by the contrary opinion, Professor White makes a provisional upper limit for the Chemung group of Columbia County, Pennsylvania, at the lowest red rock, and calls the interval between this point and where the *Holoptychius* appears the Chemung-Catskill. (See Second Geol. Surv. Pa., G^7, p. 63.)

THE INTERPRETATION OF THE FACTS.

Taking the faunas as our criteria of chronological horizon, it seems more appropriate to speak of the red beds as appearing farther down in the Chemung group than to make a break in the series long before any permanent effect was produced upon the character of the faunas.

The interpretation given by the English geologists of the Devonian and Old Red Sandstone series is relevant here. The Old Red Sandstones, with their brackish water fish fauna and plants, are not successors of the Devonian beds with marine fauna, but are the equivalents of the whole series from the base to the top of the Devonian.

The Russian series clearly illustrates this point. Alternation is there seen of the two classes of deposits, the one containing the Devonian marine fossils, the other the sandy brackish water beds with the *Holoptychius*, even in association with the marine brachiopods of Upper Devonian species.

As we follow our Devonian series eastward, either in New York or in Pennsylvania, the lower position of the first red beds is conspicuous, and so long as the red sediments occupied the ground only temporarily we may suppose the marine conditions were not entirely cut off, and slight oscillations drove away and brought back the marine fauna over any particular area, but when the marine conditions were finally shut off there was a termination of the marine fauna. This shutting off of the sea took place earlier in the eastern than in the western part of this New York-Pennsylvania area, and there is reason to believe that in Sullivan County, New York, it was as early as the reign of the Hamilton faunas. (This was shown to be a fact in Chenango and Otsego Counties by investigations in 1885. Communicated to Am. Asso. Adv. Sc. meeting at Ann Arbor, Sept., 1885.)

The *Holoptychius* evidently found its congenial habitat in the midst of the red rock conditions. Its occasional appearance in strata below the termination of the Chemung fauna is rather confirmatory evidence of the actual presence in other geographical areas of those conditions from which the specimens strayed than evidence of any higher horizon than that indicated by the same faunas elsewhere.

In the Western New York area the gradual appearance of Catskill deposits was due to the encroachment of the land and fresh water conditions upon the marine basin in which the Chemung faunas flourished. The Chemung faunas continued to live there so long as the marine conditions were sufficiently pure to maintain their life, and I take it that there is nothing inconsistent in the view that Catskill rocks were being deposited in the Appalachian region at the same time that Chemung rocks were being formed over Western New York areas and during the reign of the Chemung faunas.

As the fossil faunas were traced upward in their successive stages, it was ascertained that, besides the changes occasioned by the dropping out of some species and the introduction of new species, the decreased abundance of common forms, or the increased abundance of others, there was also a change in the dominant varietal modification of the more common forms. Detailed report of these modifications coincident with range and distribution will be more satisfactory after a wider territory has been examined and a fuller series of species and specimens has been brought into comparison. But already some general remarks can be made as to the kind of changes detected.

In one species, *Spirifera mesocostalis*, ranging from the base of the Ithaca group high up into the Chemung, a great modification of form and size was observed. The prevailing type, at its earliest appearance, was small and with fine mucronate extension of the area; the later type, which was more abundant in the western than in the eastern section, was large and coarsely plicate, with great extension of the front, and, though with short mucronate hinge area, this feature is not prominent and this dimension of the shell is prominently short. Moreover, while the later modification is wanting in the earlier faunas, the earlier type still exists in the later faunas, but is relatively rare. A study of the species from a wider geographical territory will be required in order to determine how much these modifications are the effects of geographical conditions.

One modification of this species was found to be entirely coincident with geological range in the collections at command. This is the gradual appearance and final prominence of a median keel dividing the muscular impressions within the beak of the ventral valve. As this is one of the characters distinguishing the genus *Spiriferina*, it is interesting to note its gradual assumption as a purely varietal character of an undoubted *Spirifera*. This character is represented in Figs. 10 and 11 of Plate 40, Geol. Surv. N. Y., Pal., Vol. IV, Pt. I, and slightly in Fig. 2.

I have examined a large number of specimens, but among the earlier representatives from the Ithaca group rarely is even a trace of this character seen; an occasional specimen, however, shows a slight ridge dividing the muscular impressions. In the higher beds it takes the form of a strong median septum, but is less prominent in the small form associated with the prevailing type, but rare at that particular stage. Other representatives of the genus presented traces of the septum at an earlier stage.

Another change in type associated with the geological range of the species is seen in the case of *Orthis impressa*. In the lower part of the Upper Devonian (base of the Ithaca group) it differs little from the round, narrow form of *O. Tulliensis;* in its later stage it is particularly wide at the front, with a wide, pronounced fold and sinus, and of large size.

The *Lingulas* of the black, and later greenish, argillaceous shales present a regular series from the minute *Lingula spatulata* of the black Geneseė shales, through intermediate forms, to the typical *Lingula Melie* of the Ohio black shales. In this area the larger form is attained at an early stage of the Upper Devonian faunas.

So far as at present observed, these varietal modifications of a specific type are at first represented by a few rare forms in the midst of abundant individuals of the typical form; and as we go upward the characteristic feature becomes conspicuous by being assumed by a greater proportion of the individuals of the species, and finally becomes the prevailing form, the original type then appearing only as an occasional variation.

A few facts brought out in the course of these studies may be noted in closing this chapter.

The *vertical fucoid* markings, as they are called, in the Portage sandstones and similar sandstones above, are evidently the borings of some kind of worm or boring animal; and these markings, whatever they were, characterize the Chemung sandstones of the Allegany County section up to the conglomerates of flat pebbles. Above this point, and often in the sandstones associated with the flat pebble conglomerates, a similar marking is seen in some of the sandstone layers; but the size of the boring is always smaller and shorter, generally about half as large in diameter, and the borings are arranged much more closely together. So that, although the organism forming them may have been of a similar nature, the upper one was undoubtedly of a distinct species. This fact, we think, may help in tracing the horizon of the upper fucoid-bearing sandstones (as a name for which I would suggest *Verticalis* sandstones) toward the west, where the fossils are rare.

Also, on comparing our Allegany section with those of McKean County, Pennsylvania, it appears more than probable that what Mr. Ashburner calls the sub-Olean conglomerate is the equivalent of the ferruginous sandstone, which approaches very near the base of the Olean conglomerate, both at Olean and at Little Genesee, rather than the Allegany County flat pebble conglomerate, which is, more likely, represented at a similar position at Bradford below *Holoptychius* beds, but above the appearance of the Chemung faunas, and, on Mt. Raub, was recognized some three hundred feet below the Conglomerate in the outcroppings on the surface.

At Hornellsville, about half way between the Western New York section and that running through Ithaca, in Tompkins County, was seen a remarkable confirmation of the hypothesis advanced in regard to the position of the Ithaca fauna. Here was found exposed a section at the point of transition from the Portage to the Chemung fauna. The gray shales carrying the Portage fauna are preceded by a streak of black shale like the last representatives at Portage. With the Portage *Cardiola* fauna was found the first Chemung stage of *Spirifera mesocostalis*, with an *Orthis*, not the species common in the more western section, but the *Orthis Tioga* of the "Chemung" of the Cayuga meridian. Immediately following the *Cardiola* fauna, in shales more sandy and ferruginous in character, was seen the fauna of the lowest Chemung at Rushford, the *Leiorhynchus* fauna, with the exception that the eastern *Orthis* took the place of the common form of the Allegany rocks. This was followed above by more sandy deposits, containing the typical Chemung faunas. The altitude and the rocks exposed along the railroad all the way to Elmira leave no doubt of a position stratigraphically between six and eight hundred feet above the horizon of the Ithaca group at Ithaca. The transition from the *Cardiola* fauna directly to the lowest Chemung fauna is also unmistakable, and the *Orthis Tioga* is evidence of the genuine Chemung fauna of the eastern section as distinguished from the lower Ithaca fauna.

It furnishes evidence, therefore, that the transition from the Portage to the genuine Chemung formation is far above the Ithaca group, and that the fauna of the latter is an earlier stage, and intermediate between the Chemung and the Hamilton, and has no representative in the section in Wyoming and Allegany Counties.

CHAPTER II.

FAUNAS OF THE GENESEE SHALE AND THE PORTAGE GROUPS.

The exposures of the Genesee shale are noticed first, on going southward, along the northern line of Wyoming County, and most of the exposures in the middle and southern part of the county are of the Portage group.

These include the following stations: 468 Attica, 471 Warsaw, 472 Varysburg, 473 Bennington, including 473 A, the Daubree quarry, and 473 B, the section at Sierk's station, and 475 Java.

Attica, Wyoming County, N. Y — 468.

Attica is situated 10 miles a little west of south from Batavia. After leaving the limestone ridge there are few if any good exposures of rock directly south until near Attica, where the first traces of the Black Genesee shale appear.

The Tonawanda Creek runs directly through the town of Attica, but below this point it runs through clay and gravel banks until reaching the limestones of the northern towns. The creek is dammed just under the railroad bridge; the altitude of the railroad at this point is about a thousand feet (998) above the sea. The bed of the creek below the bridge is black shale—a fine exposure of the Genesee shale. The dam covers its top, but, taking the railroad bed as a datum, I estimate that the top of the Genesee shale at this point is not far from 975 feet above tide level.

The bottom is not exposed; hence the thickness cannot be given.

Several exposures were examined in and about Attica, giving sections 468 A, B, C, D, E, and F. A combination of these several sections gives us a very fair representation of the general character of the base of the Upper Devonian for this region.

The Genesee shale is a black bituminous shale, when freshly broken giving out a strong odor of petroleum, and with dark brown scratch. It is very evenly bedded, compact, and when fresh from the quarry is massive, with a conchoidal fracture. Upon weathering it becomes more fissile, but is generally a very fine uniform shale, withstanding the weather a long time without showing tendency to fissile cleavage. It is seen best in 468 B. The fauna of this exposure (468 B) of the Genesee black shale is as follows:

Lingula spatulata, varying from the minute, sharp beaked form characteristic of the Genesee shales to the wider, more oval form of the Cleveland shales, Bedford, Ohio, called *L. Melie* and *L. subspatulata* by Ohio paleontologists.

Sporangites, the same forms as those of the Ohio black shales.

Conodont teeth, identical with and including the majority of forms figured by Professor Newberry in Rep. Geol. Surv. Ohio, Vol. II, Pt. II, Pal., Pl. LVII.

Palæoniscus scales.

This fauna, therefore, agrees closely with that of Professor Newberry's Cleveland shale of Bedford, Ohio. The broader variety of the *Lingulas* is not only plainly a mere variation of the typical *Lingula spatulata*, but is quite indistinguishable from specimens of the *Lingula* of the shales at Bedford, Ohio, with which I have carefully compared it. The Bedford specimens are generally of larger size, but those of the same size agree in form, convexity, and surface markings for the two localities.

In the olive shales underlying the Cuba sandstones are seen *Lingulas* which agree also in average size with the ordinary *L. Melie* of Ohio.

The close agreement in the species and in the combination of species in these two zones leads us to the opinion that we are dealing with the same fauna in the black shales of Genesee in New York and at Bedford and Chagrin Falls in Ohio, although the evidence has not appeared to prove that the horizons themselves are synchronous.

The Genesee shale is followed by a soft argillaceous green shale, with Portage fossils. Toward the upper part there are some calcareous layers and an occasional thin layer of arenaceous shale. Then comes a second black shale, which is again followed by greenish shales; this by another black shale, and so on for at least several hundred feet.

It is an oscillation between two principal types of deposit, each of which becomes gradually modified in the same way as we ascend the series:

First, the black shale in its pure condition seen in the Genesee shale.

Second, the green argillaceous shale characteristic at the base of the Portage.

These two alternate with each other, and with each change, as we ascend, the green shale increases and the black shale decreases in amount. The black shale at each stage of its reappearance is more arenaceous, assumes a decided iron stain upon weathering, and also weathers quickly to fine fissile chips, which, in the lower beds, long resist further disintegration, but in the upper beds have not the power of resistance and soon are reduced to soil. In the first reappearance of black shale above the Genesee shales there is still a strong petroleum odor upon fresh fracture, and when fresh from the quarry the appearance of the shale is black, massive, capable of conchoidal cleavage, and scarcely distinguishable from the Genesee shale below. But upon weathering it quickly reveals the presence of inequality in the minute constitution of the deposit, causing it to cleave into thin flakes. These first Portage black shales exhibit their relation to the Genesee shales below by the presence of the same fossils.

Lingula spatulata was taken from the black shale fully 100 feet above the Genesee shale, separated from it by the green argillaceous shales with a characteristic Portage fauna.

Higher up the black shales rarely contain a single fossil. The green shales show the same gradual change from soft, fine, argillaceous material to coarser, more arenaceous, and more irregular strata; in the upper part the sandstone masses are interstratified with the softer argillaceous shales. There is also a change in the color; the lighter green shales are more prominent in the lower part, and the black shales lose their color on going upward, till finally they are scarcely distinguishable from the accompanying arenaceous shales of the Portage group.

468 D is a cut in a gorge southeast of the village of Attica, about two miles distant. The first rock exposure of the cut is, approximately, 1,200 feet above sea level. Stratigraphically it begins somewhat above the top of 468 C^3, perhaps over 100 feet. But 468 E is below its base and represents the intervening part of the section, although it is difficult to determine the precise equivalency of the individual strata in the several ravines. The strata are composed of alternating masses of black and soft green shales. The lower part of the series presents thicker masses of black, and as we go up the black shales are less strongly marked, more arenaceous, and each succeeding mass is thinner than the preceding.

The cut 468 D^1 to D^{11} represents something over 200 feet of strata and at the top the green shales entirely replace the black. D^2 is the lowest seam of black shale in this cut; it is very similar lithologically to the first black seam above the true Genesee shale and is but a few feet thick; its termination is not exposed, but when the next exposure appears in the bed of the stream it is the gray green shale again; it contains *Sporangites* and *Palæonicus* scales, but no *Lingulas* or *Discinæ* were discovered. D^4 is a gray shale, rather massive and hard, followed by a second black shale containing *Sporangites*. A little higher, D^5, gray shales predominate, but with thin layers of dark shale, not so black as those below; but along in this part of the cut, for 100 feet, the light gray green shales carry *Sporangites* and *Styliola*, the former very distinct in the light colored strata. In D^6 are some soft, argillaceous, light gray green shales, still showing traces of *Sporangites*. *Styliola* also appears in the soft, light shales at D^7. At D^8 the thin black layers are conspicuous again and hold *Sporangites*, but the gray soft shales prevail and carry the same fauna. At D^9 the black layers have disappeared, and from this point upward only dark bluish strata alternate with the prevailing gray green shales. In the darker parts *Sporangites* are occasionally seen. With the ceasing of the black streaks the Portage fauna begins to reappear. Small aviculoid shells and *Cardiola speciosa* are the first to be recognized at D^9, with *Styliola*. At D^{10} the shales are light olive in color and soft, argillaceous, and quickly weathering into soil; in this stratum *Cardiola speciosa* is conspicuous; *Pterinopecten*

Atticus, n. s., *Leperditiæ*, the broad variety of *Lingula spatulata*, a small imperfect *Pleurotomaria*, a crinoid stem half a centimeter in diameter, and a minute *Chonetes lepida* constitute the fauna, so far as discovered. A little higher, $D^{10\frac{1}{2}}$, the shales are decidedly arenaceous, and from there to the top of the gorge the shales are harder and coarser and the olive tints are replaced by bluish and darker grays. At D^{11} *Cardiola speciosa* appears with a *Hyolithes* and *Goniatites* and some new forms. All the species of this cut are small, delicate forms, and are nowhere abundant, but require very close, careful search for their discovery. Enough, however, was found to demonstrate the general relation of the faunas to the deposits containing them.

It is evident, from a study of this series in connection with 468 A, B, and C, that the deposits from the base of the Genesee shale, for several hundred feet at least, are the result of oscillating conditions which brought from one direction the black muds, highly bituminous in nature, and from another direction light gray muds, at first very fine and argillaceous and later mixed with coarser, silicious particles.

The *Palæoniscus* scales are peculiar to the black shales. The *Sporangites*, although characteristic of the black shales, are not confined to them so long as they were in the neighborhood, as is shown by their occurrence in the light, argillaceous shales interstratified with them, but when the black shales finally withdrew from this locality the *Sporangites* ceased.

The *Lingula spatulata* is peculiar to the soft, argillaceous deposits, most abundant in the bituminous shales, and there typically represented; in the light colored shales only the broad and larger variety appears.

The other species, the *Cardiola speciosa*, the *Aviculas*, the *Pleurotomaria*, the *Chonetes*, the *Leptodesma*, the *Hyolithes*, and the *Goniatites*, belong to the fauna of the gray shales, rare in the pure, argillaceous sediments, but more abundant as the silicious and coarser muds were depositing.

Leperditia and *Styliola* may have been common to both faunas; the former was rare. Other evidence shows the latter to be more abundant in the black shales.

The Cardiola Fauna—468 A.

The following species have been identified in the soft, argillaceous shales at the base of the Portage:

Cardiola speciosa,[1] abundant.
Styliola fissurella, abundant in some layers.
Goniatites uniangularis Conrad several specimens, small.
Goniatites complanatus.
Lunulicardium fragile.
Lunulicardium levis, n. sp.
Coleolus acicula.

[1] The generic name *Glyptocardia* has been proposed for this well known species by Professor James Hall (1885). (See Pal. N. Y., Vol. V, Pt. I, Lamell. II, p. xxxv.)

Sporangites, rare.
Lingula spatulata, the broad variety, a single specimen.
Pleurotomaria ? capillaria, fragments.
Leperditia, sp., a few impressions.
Aptychus of *Goniatites?* of *G. uniangularis*.
Aptychus ? or *Spathiocaris ?* (Clark), fragments marked like *S. Emersoni*, but broken so that the shape is not shown.

In similar shales, but calcareous (C^2), there are, besides the *Cardiola*, *Calceola*, and *Styliola*, which are the more frequent forms, a small *Orthoceras* and a *Palæoniscus* scale of larger size than those in the black shales; in another exposure, a small *Loxonema ?*, not preserving the exterior, but resembling the terminal portion of *L. delphicola*. The *Styliolas* often occur in elongated masses, which weather a yellowish brown from iron stain, and the shape of the masses suggests a possible coprolitic origin.

DESCRIPTION OF TWO NEW LAMELLIBRANCHS.

Pterinopecten ? Atticus, n. sp. Plate III, Figs. 10, 11.

This is a small species, with subquadrate form, hinge line straight and shorter than the greatest width of shell, ears small and indistinctly defined. The middle portion of the surface marked by irregular, rounded, radiate folds or plications, which bifurcate and are more conspicuous toward the front; the sides are either smooth or faintly marked by fine radiate striæ. Concentric lines of growth are apparent over the whole surface, but not strong. The beaks are prominent, slightly arching over the hinge margin. The wing is not produced into a mucronate point, as in most of the Pterinopectens, nor is it shortened, as in the Lyriopectens. The anterior ear is separated by a rounded sulcus and fold, but is not sharply defined. The posterior wing is much as in Lyriopecten.

Dimensions of medium sized specimen: Length, 6.5^{mm}; width, 5.4^{mm}.

Horizon and locality: The soft, green shales, Middle Portage group, Attica, N. Y.

Specific name from Attica: Lat. *atticus*, dwelling in Attica.

Ptychopteria ? mesocostalis, n. sp. Plate III, Fig. 9.

A small pterinoid shell, oblique, similar in form to some of the smaller shells of Hall's genus *Ptychopteria* (see *P. Proto.*, Geol. Surv. N. Y., Pal., Vol. V, Pt. I, Pl. XXIII, Lamell. I), but marked across the middle by irregular rounded radiate folds, the sides by faint and finer radiate striæ. The anterior wing separated by a sulcus and fold, the posterior wing moderate, without mucronate extension, the ventral margin slightly concave and posteriorly broadly rounded into the posterior margin. With concentric rounded lines of growth.

In its details this shell is marked almost exactly as the erect forms, found in the same rocks, which I have called *Pterinopecten Atticus*. I do not find intermediate forms. The only definable difference could be accounted for by the development of this shell more obliquely and rapidly in the direction of its umbonal ridge.

I am constrained, after much study of the material at hand, to regard the specimens, like Fig. 12, as a smoother and extreme variety of this species, although this would be more appropriately called a Leptodesma, except for the radiate striæ of the surface. These three forms, figured as 9, 10, 11, and 12 of Plate III, could be taken as types of three species, and even three distinct genera if we were to follow some of the modern usages in describing them. While I refer them provisionally to two distinct genera I believe that they are closely allied, and that they should all be included in the same genus, but that genus is neither of those named as they are now defined, but should be bounded by different characters. The present classification of *Pterinea* Goldfuss into the genera *Actinopteria* and *Ptychopteria* on the one side and *Leiopteria* and *Leptodesma* on the other, used in the fifth volume of the Palæontology of New York, leaves practically no characters for the differentiation of the species concerned, except those of contour and general form, and whenever I have seen these species in abundance in the same locality the variations in both of these particulars are so considerable that it is difficult to believe that the division into so many species as are defined is either judicious or will be of any use to science further than giving a thorough illustration of the plasticity of this type of shells. At a future time I hope to discuss this subject more fully.

Warsaw, Wyoming County, N. Y.—471.

This station is ten miles southeast of Attica (468) and nine miles east of Varysburg (472). The town is in a valley with hills, both east and west, rising over three hundred feet. The altitudes are, for the New York, Lake Erie and Western Railroad station, 1,326 feet above tide; for the Buffalo, Rochester and Pittsburgh Railroad, on the west side of valley, 1,117 feet above tide. The post office is reported by surveyors of the place to be 1,017 feet above tide. The hillsides are cut by several ravines, exposing two or three hundred feet of rock outcrops.

Crystal Brook, Warsaw.—471 A.

This ravine cuts down the hillside a little northeast of the village. The first rocky exposures may be 1,050 feet above tide, and they were examined upward about two hundred feet, to the first solid sandstone under the New York, Lake Erie and Western Railroad, at an altitude of approximately 1,250 feet.

The whole exposure is composed of thin bedded deposits of argillaceous and arenaceous shales, with occasionally a stiff, thin seam of flaggy sandstone. The prevailing colors are blue gray near the bottom; the softer, more fissile shales are more greenish or olive. The general characters resemble very closely those of 468 D, with the exception of the absence of black shales. No sandstone strong enough to form any considerable fall is met with till we reach the top, and this seam is gray, but finer, harder, and more flaggy than the typical Portage sandstones. It is, however, calcareous. No traces of the *Verticalis* borings were seen. Underlying it are some soft, greenish shales, some layers of which are nodular. Under these are darker blue shales bearing the same fauna found in the upper part of 468 D.

Omitting the consideration of the black shales and comparing the general character of the deposits and their fauna (that is, the olive shales gradually changing into bluish and more arenaceous deposits, with flaggy and wave marked structure, as we ascend), I should regard the base of this section as occupying a stratigraphic position somewhat higher than the top of section 468 D.

The aviculoid shell *Pterinopecten Atticus*, abundant at 468 D^{10}, at an altitude of 1,340 to 1,350 feet, is identical with the species most abundant in the Warsaw station 471, at an altitude of about 1,200 feet. The following 100 feet of the Attica section (468 D) takes us up to sandy and flaggy deposits; in the same way the upper deposits of 471 are sandy and flaggy, following soft, light colored shales.

The species of 471 A^3 are —

Cardiola speciosa, abundant.
Lunulicardium levis, n. sp.
Styliola fissurella, rare.
Pterinopecten ? Atticus, n. sp., abundant.
Ptychopteria ? mesocostalis, n. sp.
Sporangites, rare.
Euomphalus ?, a fragment.
Goniatites uniangularis.
Fragments of crinoid stems.
Coleolus ?acicula.
Aptychus of *Goniatites*. Plate III, Figs. 3 and 4.

The specimens figured are of a small, thin, scale-like fossil, black when the substance is preserved, and apparently chitinous originally. In outline it has the shape of a transverse section of the outer chamber of *Goniatites*, like *G. bicostatus*, and of the same size as would fit such specimens as have been found in the same horizon.

The shorter specimen (Fig. 4) may belong to a more closely coiled species, like *G. uniangularis*, which also is found in the same rocks.

The more perfect specimen (Fig. 3) is 8.3^{mm} long, 5.2^{mm} wide, and the depth of the rounded sinus is 2^{mm}. This is supposed to represent the groove formed by the inner coil of the shell partly inclosed by the outer lining chamber. The *Aptychus* is not flat, but transversely arched, the arching confined to the central portion, and marginally it is nearly flat. I find no reason to doubt that this was an *Aptychus* of one of the *Goniatites* so frequent in the Portage rocks, and in size and form it agrees very closely with the figures in Keyserling's Wiss. Beob. Reise

Petschora-Land, Pl. 13, Figs. 3-7, and referred by him to *Aptychus* (see pp. 286, 287, and Fig. 5 particularly). The specimens were from the concretions in the Dominick black shales. It is one of the same class of objects referred to *Cardiocaris* by H. Woodward, Geol. Mag., London, vol. 14, p. 386, and to *Spathiocaris* by J. M. Clarke (Am. Jour. Sc., Vol. XXIII, 3d ser., p. 477). The recent discoveries of Kayser, Dames, and Woodward leave no doubt of the *Aptychus* nature of some of the so-called phyllopod crustacea of the Silurian and Devonian.

The specimens here figured are of the type called *Anaptychus* by Offel and belong to the group *Simplices* of Zittel's classification (Palæont., Vol. I, Part 2, p. 403), consisting of a single piece. It is probable that all the forms from the Portage rocks described by J. M. Clarke as *Spathiocaris* and *Cardiocaris*, and possibly some other genera, are of a similar nature. (See Dames, Zeitschrift d. deutsch. geol. Gesellsch., 1882, Vol. XXXIV, p. 819; Neues Jahrbuch, Bd. I, 1884, p. 178; and Woodward, Geol. Mag., Dec. III, Vol. II, 1885, p. 345, and Plate IX.)

Lunulicardium Munster.

Several specimens from the green shales of the Lower Portage group are referred, after considerable study, to the genus *Lunulicardium* as restricted by Zittel (Handb. d. Paleont. Vol. I, Part 2, p. 36) and as applied by Hall (Geol. Surv. N. Y., Pal., Vol. V, Pt. I, Lamell. II) to such forms as *Avicula fragilis* Hall of the Geol. Report, 4th dist. N. Y., p. 222.

The specimen figured on Plate III (Fig. 7), on careful comparison with genuine examples of *L. fragile* from the Marcellus shales and higher, is found to be indistinguishable, except in its more gibbous form, which is ascribed to its better preservation through the possession of a thicker shell. The typical forms of *L. fragile* were evidently very thin and are found in the fossil state crushed very flat, but always with more or less wrinkled surface. These Portage specimens occasionally show fine radiate striæ on the surface, a character recorded as appearing on well preserved specimens of *L. fragile.*

In the more oblong forms (Plate III, Figs. 5, 6, and 8) the fine radiate striæ are pretty generally visible upon magnifying the surface, and the position, length, and direction of the byssal fissure are those of *L. fragile.* In one specimen (Fig. 8) the lip of the byssal gap is reflected, as in well preserved specimens of *L. fragile*, but in another specimen (Fig. 6) of the opposite valve the lip of the opening is inflected, as in some of the *Limas.* The latter appears to be a right valve and the former a left valve.

In each of the oval specimens opposite the byssal opening is a very small angular extension of the cardinal margin, upon which are two or three sharp radiating plications or lateral cardinal teeth. In this feature they recall such forms as *Mytilarca* (*Plethomytilus*) *oviformis* Hall of the Hamilton group (Geol. Surv. N. Y., Pal., Vol. V, Pt. I, Lamell. II, Pl. XXXI, Figs. 7 and 8), but the direction of growth and the curvature of the shell and direction of the beak are distinct. The cardinal angle is also much more prominent in that species. While there appears reason for regarding the shells under consideration as allied to the *Mytilarcas*, as may possibly be also the *L. fragile*, taking all points into consideration they fall more naturally under the genus in which *L. fragile* is found.

I propose for specimens figured on Plate III, Fig. 6 and Fig. 8, the name *Lunulicardium levis*, and refer provisionally to the same species the larger form, Fig. 5.

DESCRIPTION OF LUNULICARDIUM LEVIS.

Lunulicardium levis, n. sp., Pl. III, Figs. 6 and 8.

Shell medium size, obliquely oval, with sharp, short beak nearly central, with byssal gap starting close under the beak on the anterior side and reaching obliquely about one-half the length of the shell, lip reflected in the left valve and inflected in right valve, the front broadly rounded and curving around regularly to near the beak on the posterior side, where is a slight angular extension of the hinge margin, upon which are two or three well defined radiating plications which may be lateral cardinal teeth. Surface nearly smooth, with concentric lines of growth and very fine, radiate striæ.

Dimensions: Length, 20^{mm}; width, 15.2^{mm}; length of byssal fissure, 12.9^{mm}; angle of byssal lip with central axis of shell, 40° to 41°.

Horizon and locality: The green shales of the Lower Portage group at Varysburg and Warsaw, Wyoming County, N. Y.

Varysburg, Wyoming County, N. Y.—472.

At Varysburg three sections were examined, 472 A, B, and C. The position of this station is about seven miles south and a mile or so west of the Attica station 468. The altitude, estimated by railroad grade, is 1,239 feet above tide level. The bridge across the Tonawanda Creek in the valley is approximately 1,121 feet above tide level. Along the banks of the stream some thick layers of black shale appear, with interstratified masses of the olive Portage shales. But we are here near the top of the black shale deposits, the highest traces of which were 472 B^5 at 1,270 feet and a thin streak in section 472 C.

These are not pure black shales, but contain particles of pyrite and mica mingled with the arenaceous particles of the including strata, and they show traces of *Sporangites*. 472 C^0 is a more massive black streak of the same shale, several inches thick; by its physical characters it is evidently one of the last of the recurrent deposits of the black shale. 472 A and B are sections on the west side of the valley, while the section C runs off to the northeast along the gorge of Stony Brook, and traverses 160 feet of strata, the top sandstone C^6 reaching an altitude of 1,345 feet approximately.

472 A is an imperfect section directly west of the village, traversing about the same strata as those seen in B.

The sandstone in the midst of this section is apparently the same that is worked in the quarry at 472 B and met with again in the section C at C^3. Above this sandstone no black shales have been seen. In section A it is several feet thick, massive, calcareous, of a gray color, weathering brownish gray, fine grained, and hard. It contains in the upper layers the perforations called *Fucoides verticalis* in the State reports.

The sandstone is followed by irregular layers of thin sandy shales and thicker olive shales, not fissile, but blocky in fracture and of rough surface, and in places nodular, the nodules about the size of hickory nuts and calcarceous; the shale is also slightly calcareous. A few fossils were found in these olive shales, but in a poor state of preservation.

The fauna determined is as follows:

Cardiola speciosa.
Lunulicardium levis, n. sp.
Goniatites complanatus.
G. bicostatus.
Lucina Wyomingensis, n. sp.
Lucina Varysburgia, n. sp.
Orthoceras (frag.).
Pleurotomaria (frag.), *(? P. capillaria)*.
Crinoid stems.

All rare, but the *Cardiola* and *Goniatites* are more common.

Quarry of the Tonawanda Valley and Cuba Railroad—472 B.

This quarry is west and about fifty feet above the station of the Tonawanda Valley and Cuba Railroad at Varysburg. The top of the ledge from which quarry stone is worked is 1,292 feet above tide.

The upper course is two feet thick, with a tendency to divide into two one foot courses. This is 472 B^1. It is a light olive gray, massive sandstone, calcareous, and perforated in the upper part by numerous tubes of the so-called *Fucoides verticalis;* these are filled with the darker material similar to the overlying shales. It weathers to a cream olive or brownish gray, but has very little iron impurity and is a fine grained, firm sandstone.

B^2 lies upon a six inch mass of fine, blue, fissile, argillaceous shale, which separates it from the second two foot course of sandstone, which is a solid, compact, and even textured calcareous sandstone of light green gray color, like that above, except that the worm tubes, *Fucoides verticalis*, are wanting. Below this, separated by thin layers of soft shale, are two thin courses, respectively twenty and ten inches thick, forming the bottom of the quarry. There are no worm borings in these lower courses, but the petroleum odor is more apparent than in the upper sands.

The total thickness of this sandstone ledge is thus about seven feet, and it has furnished some very fine stone for railroad bridges and heavy masonry. In the shales forming the partings there are seen a few chips of fossil wood, but no other fossils were detected.

B^4.—Under the sandstone is about ten feet of a greenish, nodular, calcareous shale, irregular and with rough fracture, mainly argillaceous; the upper half is more nodular, the lower strata becoming more even and smoothly stratified. This is nearly barren of fossils, but in it were seen traces of a small *Cardium*, with prominent beak, and a small *? Goniatites.* Below this is a fifteen inch course of sandstone like the quarry stone above, underlined by green gray, nodular shales, which run down into bluish gray, rough surfaced shales, and at about three feet from the base of the sandstone there is a few inches of fissile, finely laminated, black shale (B^5), with petroleum odor and *Sporangites.* Under this, as far as was examined, were alternations of argillaceous, bluish green shales, with the thin, arenaceous shales so common in the Upper Portage deposits. The former shales are distinctly calcareous, and a single small *Palæoneilo* was found about fifteen feet below the base of the quarry. This *Palæoneilo* is of the type of *P. brevis* and *P. Bedfordensis*, but of much smaller size. It agrees in shape and marking more closely with the Hamilton form *P. plana*, though but one-third the size. I have provisionally called it a variety of the latter species, with the varietal name *Varysburgia;* it is seen again in 472 C^1.

Stony Brook, Varysburg — 472 C.

The first rocky exposure is approximately 1,185 feet above tide. Beginning from the base and running up it presents the following characters:

C^{00} is a tough, calcareous sandstone, seen just at the water's edge. It is greenish gray in color, but is not a pure sandstone, showing some admixture of the greenish shale. It is immediately followed by C^0, 6 inches to a foot of compact, black, bituminous shale, containing an occasional *Sporangites* and fragment of carbonized wood. Minute pyrite accretions are also seen, and an occasional worm boring perforating its lower layers from the green sandstone, C^{00}, below. The line of superposition is irregular, as if the surface of the sandstone material were broken up and disturbed during the deposition of the first part of the black shale. The green, sandy shale occurs in irregular lumps and layers, and the black shale itself, after it began to be deposited in thin, perfectly smooth layers, is seen, on a cross section, to be interlaminated with very thin sheets of the lighter shale.

C^1.—Above the black shale is, first, a foot of smooth surfaced, gray shale without fossils, followed by two inches of fine, soft, argillaceous shale, greenish gray in color, not very fissile, but breaking up in blocky flakes, with rough, uneven surface, and containing numerous fossils, and slightly calcareous — a frequent character of the fossil bearing shales of the Portage group. It appears like a soft mud deposit, stirred up by worms or mollusca moving about on the bottom, though the material is identical with the fine, smooth, fissile, olive shales met with in the same series. Where this shale cleaves with a smooth, even surface it is extremely rare to find the least trace of a fossil.

The fauna of this shale (C^1) is as follows:

Cardiola speciosa (= *Glyptocardia speciosa* Hall, 1885).
Coleolus acicula.
Goniatites bicostatus ?
Lunulicardium fragile.
Pleurotomaria, a fragment, *? P. capillaria.*
Palæoneilo plana, variety *Varysburgia* H. S. W. (n. var.).
Orthoceras, a fragment of a small, slender form.
Leda diversa.

The first two species of this list are common; the *Goniatite* is represented by several fragments; the other forms are rare.

These fossiliferous shales are followed by a few feet of blue gray shales like those below, capped by two layers of hard, sandy shales occupying a foot and a half, the lower part wavy and perforated by the *Verticalis* worm borings, the upper part concretionary and greenish in color. Above this for some fifty feet, are alternations of the greenish, soft, argillaceous shales, and thin, darker bluish, more arenaceous layers, with an occasional thin, black streak, quite black near the bottom, but only recognized by a darkening of the ordinary bluish shale toward the top. An occasional *Cardiola speciosa*, but no other fossil, was detected in the mass.

This is terminated by a solid, compact, gray sandstone, C^2, two feet thick, darker than those above, but like them in having the upper part penetrated by the worm borings called *Fucoides verticalis.* The fillings are darker than the matrix and are apparently composed of the material of the overlying shale. This is C^2; it is calcareous and in general character is like the majority of the gray sandstones of all this region. They may well be denominated *Verticalis* sandstones and are generally light gray in color, rarely less than two feet in thickness, calcareous, and very generally give out a strong petroleum odor when freshly quarried, which they lose upon exposure to the atmosphere. The *Verticalis* borings are sometimes wanting, but the top layer of the mass will generally be found to contain these markings. The Portage sandstones of Portageville and the falls are a well known example of them when deposited in thick masses.

In the sandstone, 472 C^2, a single fossil of considerable importance was found. It consists of a fragment of a fish plate, an inch wide by an inch and a half long, thin on one edge, but tapering at one corner to a third of an inch in thickness. The surface markings consist of tubercles partly confluent and resemble the markings of the *Holoptychius giganteus* scale figured in Murchison's Silurian System. It may be a fragment of the dorsal shield of some such fish as the *Aspidichthys* of the Huron shale, but the tubercles are not isolated, are closer together and more confluent than in Dr. Newberry's species of *Aspidichthys clavatus*. From the thickness of the fragment I infer that it belongs to a dermal plate, and refer it provisionally to *Aspidichthys clavatus* Newberry.

Above C^2 the sandy shales, in their alternation, predominate over the olive shales; they are more frequent, and stand out on the cliffs as stiff seams two to eight inches in thickness.

Nineteen feet above the top of C^2 is the base of a second *Verticalis* sandstone, C^3, eight feet thick, but not in a compact mass, being broken up by thin, shaly partings, though one solid layer two feet thick lies at the top. This is calcareous, as usual, and is impure by admixture of a little material of the green shales; also traces of iron are seen in the slight brownish tint of weathered surfaces. The ordinary nodular, olive shale underlies it, and this rests on the blue shales, which are becoming more common among the tougher, arenaceous deposits of these upper beds. In the bed of the creek a broken block of C^3, or something very similar, contains a large *Cladochonus*, with cups nearly two centimeters long, and on the same slab are the impressions of a *Cardiola speciosa* and a *Chonetes lepida*. This fragment shows no trace of lime, but this is not strange, as some of the sands by weathering seem to lose what little calcareous matter they may have contained. The light olive shale associated with C^3 is slightly calcareous, not fissile, but with blocky fracture and rough surface, approaching the character of the nodular shales. In it I found a specimen of what I first supposed to be *Cardiomorpha suborbicularis*, originally referred to *Ungulina*. Several specimens of this shell have been taken from various exposures of these olive shales of the Portage, presenting some features not referred to in the descriptions of the species. These are figured in Plate III, Figs. 13 and 14, and described below under the genus *Lucina* of Bruguière and referred to new species, *L. Wyomingensis* and *L. Varysburgia*. (See p. 44.)

The sandstone, C^3, is immediately followed by tough, wavy, arenaceous layers, running up, in a few feet, into blue shales, then green shales, and the peculiar nodular, olive shales of rarer occurrence at this position.

These characters continue in irregular order for about twenty feet more, when a third *Verticalis* sandstone appears, C^4. This is very similar to C^3 in general characters and thickness. The upper part, particularly, shows the *Verticalis* markings. The nodular shales underlie this sandstone as they do the sandstones of lower position.

In the green nodular shales the following fauna appear:

Goniatites Patersoni.

Nucula corbuliformis, var., a small variety, in form and markings like *corbuliformis*, but about half the normal size.

Orthoceras pacator.

Lucina Varysburgia, n. sp. (?= *Ungulina suborbicularis* Hall).

Cladochonus, sp. Same as seen in the Eastern Portage.

DESCRIPTION OF TWO NEW LUCINAS.

Lucina Wyomingensis, n. sp. Plate III, Fig. 13.

Outline nearly circular, about 12^{mm} wide; hinge margin nearly straight, 10^{mm} long; umbone subcentral, small, extending slightly beyond the hinge margin. Shell evenly arched, the umbonal ridge subangular anteriorly near the beak, but rounded beyond. Surface with strong concentric ridges, no radiate striæ, except on the cardinal angles, where are several sharply defined, radiating striæ, stronger toward the margin and reaching under the beak; eight or nine of these ridges can be seen each side the beak, occupying the space of 4^{mm} from the cardinal angle, beyond which no traces of striæ can be seen. The concentric folds are about the size of the larger folds of *Lucina* (*Paracyclas*) *lirata*, which the shell resembles. From that species it differs in the more erect beak, in the radiating striæ at the cardinal angles, and in the absence of finer intermediate concentric striæ; the concentric folds are rounded, and not sharp as in *L. lirata.*

From the Portage shales at Varysburg (472 A).

Lucina Varysburgia, n. sp. Plate III, Fig. 14.

Outline of shell nearly circular, 17^{mm} long, 18^{mm} wide. It resembles in form the *Paracyclas Chemungensis* of Hall, Geol. Surv. N. Y., Pal., Vol. V, Pt. I, Lamell. II, Plate XCV, Fig. 23, but still more the figure of *Ungulina=Cardiomorpha suborbicularis*, 1883=*Edmondia ? tenuistriata*, 1885, Geol. Surv. N. Y., Pal., Vol. V, Pt. I, Lamell. II, Plate LXIII, Fig. 9. The surface is nearly smooth, slightly and evenly convex, except in the presence of a slight sulcus, separating a triangular portion of the anterior ? cardinal angle. The cardinal angles near the margin are marked by radiate striæ fainter and fewer than in *L. Wyomingensis*, but of the same character; four or five are visible on each side. There are faint concentric striæ visible near the margin of the shell; also very faint radiate lines.

In a second specimen, which is crushed, but appears to belong to the same species, there are stronger concentric folds near the front margin. The beaks are erect and nearly central, low, and scarcely extending beyond the hinge margin. Upon first examination I was inclined to refer this form to the species originally described as *Ungulina suborbicularis* by Hall in Geol. of N. Y., 4th dist., p. 243, Fig. 2, 1843. This was figured in plates and explanations of Lamellibranchiates, Geol. Surv. N. Y., Pal., Vol. V, Pt. I, Lamell. II, Plate LXIII, Figs. 9, 10 (issued in 1883), under the name *Cardiomorpha suborbicularis;* but in the final volume (Vol. V, Pt. I, Lamell. II), published in 1885, the species is altogether discarded and the Figures 9 and 10 are referred to another genus, *Edmondia ?*, and described as a new species, *E. tenuistriata*, on page 393. (See also Am. Jour. Sci., 3d ser., Vol. XXXII, p. 192.) The original is said to come from the shales of the Chemung group near Elmira, instead of Eighteen Mile Creek, Portage group, from which the original of *Ungulina suborbicularis* is recorded. So far as literature goes, we are left no means of distinguishing *Ungulina suborbicularis*, except the original brief description in the Geology of New York, first dist., 1843. The condition of the specimens is too imperfect to enable us to recognize such surface markings as are given on Fig. 10, Plate LXIII, Geol. Surv. N. Y., Pal., Vol. V, Pt. I, Lamell. II. The specimens before us also differ from the *Ungulina* and from any described *Lucinas* of the Devonian in the radiating striæ on the cardinal angles.

This mass, 472 C^4, tends to be flaggy and break up into layers an inch or a few inches thick, and it is less easily separated at the top from the coarse shales that follow. A few feet above the solid part of this sandstone mass the shales are bluish and break up into irregular slabs, rough surfaced, and a few of the layers contain abundant specimens of the *Spirophyton cauda-galli.*

C^5.—The shales containing the *Spirophyton* are rather darker than the general color in this part of the section, of bluish green tint, and calcareous. Worm tracks are abundant, producing markings very similar to what are usually called *Fucoides graphica*, if not identical with them. These conditions continue upwards, varying somewhat, but with the general character of coarse, blue gray shales and thin, arenaceous layers occasionally containing numerous specimens of *Spirophyton*, till we reach the highest sandstone of the section, C^6.

C^6.—This is a thick ledge of solid sandstone about 8 feet in thickness at the thickest part exposed. It appears to be a lenticular mass, thinning out in two directions; the grain is a little coarser, mica specks are more numerous, and the weathering gives it a decidedly yellowish tint, from the presence of iron. It is not calcareous, so far as observed, nor were any traces of the *Verticalis* worm-borings seen, though they may appear in the top layers covered by soil.

This terminates the rock exposure of this ravine; the top of C^6 is approximately 1,345 feet above tide level, or 160 feet above the base, 472 C^{00}. This section shows us the general law of the appearance of the *Verticalis* sandstones in relation to the black shales. The sandstones first begin to appear soon after the last black shale; after a genuine *Verticalis* sandstone of two feet or more in thickness has appeared, no black shale is seen again. The sandstones appear in this section about twenty-five feet apart, becoming thicker above and farther separated from one other.

They certainly begin in the midst of the green shales of the Portage, with its characteristic fauna, and, as will be shown further on, continue after this fauna ceases; their order of appearance in thin shales is similar in each case: the nodular, green, calcareous shales precede the sands and the bluish and more arenaceous deposits follow. The greenish shales are evidently the mark of the older conditions and the bluish shale of the later, as the former are more frequent and characteristic below, while the bluish shales and thin, flaggy, and often wave marked sands are characteristic in the higher part of the series.

In relation to other sections, the base of 472 C probably laps over the top of 468 D, the latter not reaching quite to C^2, but passes to the top of the recurrent black shales.

DESCRIPTION OF WORM TRACKS.

Arenicolites duplex, n. sp. Plate IV, Fig. 9.

In the green shales in the lower part of the Stony Creek section was found the single specimen which is figured in Plate IV, Figures 9*a* and 9*b*. This was lying horizontally in the rock and combines several interesting features. At the free end (upper in the figures) the specimen presents in each of the arms the characters so frequently met with in the New York Devonian, and when regular often spoken of as *Fucoides graphica*. When closely examined these are found to be not stems leaving their impression in the mud, but the fillings of grooves made in the surface of the mud and filled by repeated depositions of thin layers of mud in the groove. In the lower part of the figure will be seen the mode of joining of the two tube fillings, curving around in a regular arch, the arch being repeated a number of times at different places, but nowhere as strong as the side tubes. This character is repeated in the forms called *Spirophyton* (see particularly *Spirophyton velum* of the 16th Ann. Rep. Reg. Univ. N. Y., Plates LXXX, LXXXI, originally figured by Vanuxem in the Geol. N. Y., 3d dist., p. 177). I liken them to the vertical borings called by Salter *Arenicolites* and by various authors *Scolithus* and *Fucoides*, and consisting of tubular fillings more or less vertical in the rock.

I select the generic name *Arenicolites*, following Salter, who proposed to restrict this name (an adaptation of Binney's name *Arenicola*) to those worm borings connected by a loop or appearing in pairs and showing double openings (see Salter, Quart. Jour. Geol. Soc., London, Vol. XII, p. 248, 1856; Vol. XIII, p. 204, 1857).

The explanation of the formation of such dissimilar markings by the same organism is easily understood by watching the common earth worm penetrating deep into the soil, out of sight, and after a rain storm coming to the surface, stretching out its length, and by sudden retraction drawing sticks and leaves and loose fragments into the mouth of its tube.

I can imagine how a worm with slightly modified habit might bore its tube in the mud and with its posterior part anchored in the hole throw its body out, curving it to one side, and thus form a loop, which, by sudden retraction, would leave the kind of mark seen in the *Spirophyton*. And it is easy to conceive how the same kind of worm which left its mark on the surface might perforate vertically in the mud, as we find worms doing today.

I call this specimen *Arenicolites duplex*, but imagine the maker of the track was nearly related to the maker of the markings called *Spirophyton*, and that the vertical borings so common in the sandstones of the Upper Devonian were made by the same kind of animal, though many species or even genera may have been engaged in forming these various worm tracks.

Daubree quarry, Bennington, Wyoming County, N. Y.—473 A.

This quarry is situated on the hillside above the railroad, westward, between Sierk's and Earl stations on the Tonawanda Valley and Cuba Railroad, 3½ miles south of Attica. According to estimates based upon the grade of the railroad, the top of the quarry is approximately 1,465 feet above tide. The rock outcrop was first struck about 40 feet below the top of the quarry and measured up; a few outcrops below this point furnished specimens, but their altitude was not measured—only their order.

A^1, altitude 1,426 feet, a calcareous sandstone averaging a foot in thickness, gray olive, with *Verticalis*, followed above by seven and one-half feet bluish and nodular shale.

A^2, altitude 1,433½ feet, two feet of massive, gray, calcareous sandstone, weathering brownish, with *Verticalis*, followed by six feet of bluish and nodular, olive shales, then an 11 inch sandstone seam, then five feet and a half of shales and a six inch seam of sand, then nine feet shales, in which *Spirophyton* and the so-called *Fucoides graphica* appear, bringing us to the base of the main quarry stone. The shales immediately under it, bearing *Spirophyton*, are greenish gray, calcareous, and rather soft, breaking with rough surface.

The quarry stone, A^3, is light gray, calcareous, and very uniform and massive; in the quarry it is composed of a ten inch course at the bottom, then what appears to be a solid course of seventy-one inches (but in quarrying there are a few lines of cleavage), on top of all a fourteen inch course, in the upper part of which *Verticalis* tubes are abundant. Above the quarry about twenty feet are exposed of blue gray shales, and towards the top a few thin sandstone layers. The fifty feet below A^1 is composed of bluish and gray shales, with hard, flaggy, arenaceous layers, and below, at about 1,375 feet to 1,380 feet, is a layer of nearly pure limestone, outcropping in a ledge of several inches thickness, but mostly covered, a few feet above which is a stratum of black, fissile shale with *Sporangites*.

The next exposure examined below this is at Sierk's station, where black shales appear both above and below the railroad, and they continue upward, appearing in considerable thickness, certainly fifty feet above the railroad. There is a thickness of 275 feet above the lowest black shales at Sierk's before they entirely cease. Taking the upper beds of the black shales as criteria, there would be evidence of very little, if any, dip from Attica (468 D) to Sierk's (473 B), and even at Varysburg

(472) they reach above 1,200 feet in their recurrences. At Java, eight miles farther south and three miles west of Varysburg, the black shales appear in thick masses considerably above 1,200 feet altitude, and underlying the fine, thick sandstone, above 1,300 feet altitude, is a layer of black shale with *Sporangites* and a strong smell of petroleum. This quarry sand of 473 A^3, if we regard it as equivalent to C^6 of 472, which is also underlaid by a shale bearing *Spirophyton*, dips to the south at about fifty feet to the mile.

If now we compare this with the Java section (475) we find that the first strong sandstone stratum (475 A^6) actually underlaid by a black shale lies over seventy feet higher than the first sandstone of Varysburg (472 C^2). And across the county, eastward, the highest streaks of black shale do not reach much above 1,050 feet altitude, at Portage Falls, but the sands beginning at the upper falls occur in masses scores of feet thick before an altitude of 1,300 feet is reached.

These facts tend to show that in this region the rocks show as great differences on passing from west to east in line of the supposed strike as they do from north to south in line of the dip. The relation stratigraphically between the black shales and the *Verticalis* sandstones is not uniform, even within the limits of a single county. There is nothing to show that there is any considerable folding of the general rock masses to account for these differences.

The only feasible explanation seems to be that the *Verticalis* sandstone is stratigraphically connected with the cessation of the black shales, and that the black shales run up higher in the midst of the Portage green shales, as we trace them upward, in a western and southwestern direction.

This points to a possible explanation of the apparently much higher position of black shales in Ohio, in relation both to the lower deposits and to the subcoal conglomerates, upon which point further light must be thrown by the study of the sections farther west as we approach and enter Ohio.

Sierk's Station (T., V. & C. R. R.), Wyoming County, N. Y.—478 B.

The railroad grade at this station is approximately 1,100 feet above tide level. The profile of the road, which I was permitted to consult through the kindness of Mr. J. V. D. Loomis, general freight and passenger agent at Attica, gives the original survey of the road, but I was not able from the maps at hand to locate precisely the present station at Sierk's. Taking the altitude of the grade at Attica as 998 feet and at Earl's as 1,178 feet, I estimated that Sierk's crossing is not far either way from 1,100 feet. About fifteen feet below the railroad, the lowest exposure is a massive, black shale. The black shale is the principal rock, though for twenty-five or thirty feet upward blue shales alternate with it.

The black shales, 473 B^1, resemble very closely the second recurrence of black shale at Attica, as seen in 468 C^3 or 468 E. It is fissile, with some arenaceous particles, weathers with brown iron stain, has petroleum odor in the freshly opened strata, and contains *Sporangites* and *Styliola*. This station is three miles a little west of south from station 468 C and E, and the black shales at the bottom are nearly on a level with the lower black shales of 468 C^3 and E. The section 468 D contains no such massive black shale and begins about a hundred feet higher. It is evident, therefore, in these three miles going southward, either that the black shales increase in thickness upward or that there is very slight dip of the rocks, not over fifty feet in the three miles. This is further corroboration of the view expressed in the discussion of 473 A. (See p. 47.)

Ravine east of Java Village, Wyoming County, N. Y.—475 A.

This station is nine miles north of Arcade (474), about eight miles southwest of Varysburg (472), and two or three miles west of the direct line from Attica (468) to Arcade (474). In direct line it is about twenty miles west and a little north of Portageville, lying about six miles north of the latitude of the falls. The altitude is estimated from a series of levelings run from the railroad at Java Center, 475 A^6, showing the top of this sandstone to be approximately 1,315 feet above tide level.

This sandstone (A^6) is a ledge of about two feet workable sandstone, as seen in the old Macoon quarry. It is a solid gray sandstone, the thickest course averaging a foot in thickness and calcareous. Two brachiopods were detected in it, one a minute shell, like a *Cyrtina*, but too indistinct to be clearly defined, the other a large *Spirifera*, over an inch wide, the best specimen crushed, but showing the ventral sinus with plications about the same size as those on the main part of the shell. This is plainly of the *S. disjuncta* type, but it would be difficult to determine it certainly. What is preserved of it looks like a *Spirifera disjuncta* with extended hinge and moderate area. With these were found fragments of crinoid stems. This is the lowest point at which traces of the Chemung fauna have been seen along this meridian, and it is of particular interest on account of the prominent stratum of black shales underlying it by only a few inches bearing a few *Sporangites* and, when freshly broken, giving out a strong petroleum odor. The sandstone has the same odor when freshly broken. It is followed above by soft, argillaceous shales, much as in the McGee quarry at Arcade (474 A), and lies upon a few inches of similar shales (475 A 5^a). The black shale (A^5) is massive, six to eight inches thick, a decided black, but not the brown black of the lower representatives. Below the black shale, for some fifty feet, the rock is the ordinary alternation of bluish shales and thin sandstones, the latter often wavy and flaggy, as seen in the Upper Portage series. At this point is a heavy sandstone ledge which could not be reached, forming a fall of some twenty or thirty feet. Under this ledge the cliff is composed of soft green shales, with frequent bands of black, increasing in thickness toward the bottom, with an occasional seam of the green, nodular shales such as those seen at Varysburg and other places. At about thirty-five feet below the brink of the fall the green shales were examined and furnished numerous small fossils (A^3).

A^3.—This is an olive gray shale, soft, argillaceous, calcareous, and nodular in places. The fossils determined are—

Cardiola speciosa, numerous.
Coleolus acicula, rare.
Palæoneilo (small).
Goniatites (minute).

Below this are a few feet of shale, then another strong black streak, another mass of olive shale, and a thick mass, six feet or more in thickness, of brown black shale (A^2), with *Sporangites* and strong petroleum odor; under this is seen, in the bed of the stream in the village, a gray sandstone, A^1, very similar to the bed at the base of 472 C, calcareous, with petroleum smell and traces of crinoid stems, but no other fossils were detected. This base is not far from 100 feet below A^6 and at an altitude a little over 1,200 feet above tide.

It will be seen from this description that the black shales continue to recur frequently up to, say, 1,250 feet altitude, and are represented by a stratum of six inches average at 1,300 feet. If we compare this section with that at Portage Falls, we appear to be perfectly justified in regarding it as equivalent to the rocks underlying the upper falls, that is, entirely below the genuine Portage sandstones. This conclusion appears to be supported by the general nature of the strata as well as by their stratigraphic order. Though lying at a considerably higher altitude than the Portage Falls sandstones, the facts of the apparent running out of the black shales and of the absence of any thick, massive sandstone up to the top forbid co-ordinating it with lower strata of the Portage section, where the black shales are frequent, or with strata above the Portage sandstones, where the black shales cease to appear. But the occurrence of the *Spirifera*, of decidedly Chemung type, shows plainly that when the sandstone 475 A^6 was deposited the Chemung fauna could not have been geographically far distant and was in full force somewhere.

CHAPTER III.

THE PORTAGE SANDSTONES AND THE FAUNAS OF THE CHEMUNG GROUP.

As we approach the southern boundary of Wyoming County the Portage sandstones form the principal rock outcrops and slight traces of the Chemung fauna begin to appear. Crossing into Allegany County, the Chemung rocks are the only rocks on the hills, though in the northeast corner of the county the lower rocks are still Portage, and in the southern part of the county the higher hills are capped by conglomerates — the flat pebble conglomerate in several places, but the Olean conglomerate at Little Genesee.

The group of rocks included in this chapter are represented at the following stations:

Wyoming County: Arcade, 474; Allegany County: Rushford, 476; Cuba, 477; Black Creek, 478; Rockville, 479; Belfast, 480; Caneadea, 481. Here is also included the section at Portage Falls, 482.

Portageville, Livingston County, N. Y.—482.

The Portage sandstones, as seen in section 482, were early recognized as an important member of the Upper Devonian series in Western New York.

Prof. James Hall, in the first reports of the State survey, described them as exposed at Portage Falls and regarded them as characterizing the close of the Portage formation and separating it from the Chemung group above.

"The upper part of the Portage group," he says (Geol. of N. Y., 4th dist., 1843, p. 484), "consists of a mass of slightly argillaceous sandstone, compact and fine grained, from 150 to 200 feet thick, in some places containing pyrites which stain the rock an iron rust color. This rock is quarried in blocks from 1 to 3 feet thick, and of any required thickness and any required size; it breaks easily when first quarried and will scarcely stand the vicissitudes of climate."

These Upper Portage sandstones are regarded in the early reports as characteristic of the termination of the true Portage series in this part of the State. The presence of the "vertical fucoids" in this heavy sandstone is another character marking the terminal mass. (See op. cit., p. 248.) But it did not escape the acute observation of the New York State geologist that these distinctions between groups of continuous sedimentary deposits must be, from the nature of things, provisional and in great measure local.

The re examination which I have made of these deposits brings to light another fact, viz, that the conditions associated with and marked by the deposition of these gray sandstones — which were generally slightly calcareous, and when fresh distinctly bituminous to the smell and showing almost universally the presence of the "vertical fucoids" at their upper junction with the shales—were the conditions regularly following the termination of the black shales. Although in some cases there may have been thin deposits of the sandstones between black shales, it is not until after the cessation of the Devonian black shales that these massive gray sandstones appear in full force. When they appear in the midst of the Portage shales containing the Portage fauna they are, so far as observed, barren. The lower down in these Portage shales we find them, the darker, the more finely grained, and the more impure are they by admixture of argillaceous matter; and after reaching the Chemung faunas the sandstones are of lighter color in the western areas of the State and of purer sand and coarser grain in proportion to the lateness of the beds in the general Chemung series.

The altitude of these sandstone deposits at Portage Falls is between 1,100 and 1,200 feet above the sea. The New York, Lake Erie and Western Railroad bridge passes over the gorge at an elevation of 1,314 feet above tide level. The top of the quarry sandstone is about 100 feet below the bridge, or say 1,200 feet altitude. Good quarry stones are found at the level of the old canal road, which is at an altitude of 1,125 feet to 1,130 feet along these cliffs, and, even considerably lower, thick courses of the sandstone are seen, but there the shales prevail.

The prevailing color is a pure light gray of slightly olive tint, abou the same shade as the Rockville stone, somewhat lighter than the upper stone of Wyoming County, north, and darker than the upper Rushford stone. The Cuba stone has a decidedly lighter shade and a more open and coarser texture. No fossils have been seen in these typical Portage sandstones. The black shales are recognized nearly up to the upper fall, which may be regarded as the first genuine stratum of the sandstone, but no black shales have been detected by me in this section above the strong stratum of 3 or 4 feet thickness of this sandstone. Interstratified with the black shales below are seen the regular gray and olive shales of the Portage group, containing the Portage fauna, *Cardiola speciosa*, *Goniatites complanatus*, *Palæoneilo plana*, var.

The lighter colored bands have the peculiar nodular structure frequently found in the Portage formation. The highest band of black shale I saw in the ravine contained a few well defined specimens of *Sporangites*. The petroleum odor associated with all these gray sandstones following the black shales of the Portage group gives strong reason for the opinion that they are the sandstones which occur farther south, and there, covered by thick masses of overlying strata, contain the oils reached by drilling.

McGee Quarry, Arcade, Wyoming County, N. Y.—474 A.

This quarry is on the hillside south of Arcade, about three-fourths of a mile from the center of the town and east of the cemetery. The top of the main quarry stone ledge, A^2, is approximately 1,600 feet above tide. This altitude is based upon railroad grade at Arcade and measurement from that by aneroid barometer. Both Locke level and barometer have been used in obtaining levels in this survey, and while I regard them as approximately correct for purposes of geological comparisons of levels of the respective rock exposures, they may often vary several feet from the absolute altitude above sea level.[1]

The region north of Arcade for several miles is high rolling land, with heavy soil, and directly north no rock exposures are met with till passing beyond the summit in Java township.

The quarry 474 A is composed of the following courses from below upward:

A^0.—Three foot sandstone, fine working and soft when first quarried, running below the base of the quarry as now worked. This is followed by

A^1.—Six inches of soft, blue, argillaceous shale, weathering quickly into a tough clay;

A^2 is a 16 inch sandstone, compact; and

A^3 is six or seven inches of thin parting of soft blue shale; then six inches irregular sand; then slate with sandstone veins and masses, or what may be called a clay breccia, appearing as if it were a clay bottom which had assumed some solidity when it was violently disturbed by the rapid insertion of the sand, often with mica, so that the clay nodules, like broken lumps, are in the lower layer of the sand and all mingled with it. This peculiar condition of rocks has been observed in several localities, associated with the incoming of the conditions in which the Chemung fauna appears. A similar rock appears farther east, at the base of the Catskill rocks.

A^4.—Then follows a 13 inch sandstone, compact and calcareous; at the top of this sandstone, separating it from the course lying above, is another layer of the peculiar claystone conglomerate; then a 20 inch course of sandstone; then a 6 inch course.

A^5.—The whole is terminated by an uneven mass of the clay pebbles, embedded here in a calcareous mass of purple color, with some sand,

[1] Though I have employed an aneroid considerably in the past few years—using a Troughton & Simms registered, compensated for temperature—so far as the machinery is concerned, I am convinced, after trying several instruments, that the more delicate the instrument the more certain it is to be affected by the atmospheric fluctuations and to record only approximately altitudes which require more than ten minutes in passing between them, even under like conditions of temperature; and in the field, without a stationary barometer for comparison, altitudes determined by a single reading cannot be considered as more than approximately correct when pressure of atmosphere is the basis of the determination.

All the altitudes given in this report, unless particularly stated as railroad grade, must be regarded as subject to such correction. The error in any case, however, I do not believe is enough to seriously affect the geological considerations for which the measurements are made, as in each case the diurnal fluctuations and the changes in temperature have been taken into account, as well as the general atmospheric conditions, in making up the estimated altitude.

but principally calcareous matter composed of fragments of shells and bryozoa and crinoid stems, very much pulverized, but showing their source in the occasional fragments, large enough to examine, and terminating above in soft, argillaceous shales.

In this quarry the sandstones are of a gray color, weathering brownish or chocolate, then bleaching upon long exposure to a purer gray, and some fresh specimens gave a strong petroleum odor. No *Verticalis* borings were detected. Even weathered samples are calcareous, but fresh, light gray samples are highly calcareous, and the purple layers, such as terminate A^4, are more calcite than sand.

The layers of soft, green, argillaceous shale, whether in layers or in pebble-like nodules embedded in the sandstone or limestone, are not calcareous. There appear, also, at these intervals, between compact sandstone and thick strata of green shale, thin, vein-like streaks, very uneven but in the main horizontal, stratified with the shales, of nearly pure quartz sandstone, varying from a sixteenth of an inch to an inch or so in thickness. They are often pure white or very light gray, with not a trace of calcite. There are also frequent partings of grains of mica, forming very evenly laminated, flaggy layers, from a quarter of an inch to several inches thick.

In the arenaceous limestone layers there are traces of several fossils which are decidedly distinct from the Portage fauna. The limestone has a purplish tint and is distinctly crystalline in some parts. It appears to weather quickly by solution of the calcite, leaving a greenish brown, loose, crumbling sandstone. Among the pulverized fossils several generic characters were identified (but they are too fragmentary for the determination of specific relations): little bryozoan stems like *Ceriopora*, numerous small sections of crinoid stems, pieces of a brachiopod with the structure of *Orthis*, a small *Spirifera* with plications in the ventral fold, another portion of the beak of a *Spirifera*, which may be the same species, the surface characters not visible. From the fragments obtained the *Spirifera* appears to be of the *S. Archiaci* type of *S. disjuncta*, near *S. Whitneyi* Hall or *S. Orestes* Hall & Whitfield, from the Rockford beds of Iowa. Although it is not possible to strictly identify the species, it is important to note that it is a representative of the group of spirifers so common in the Chemung group. In some parts of this strange deposit are found numerous bivalve crustacea, *Estheria* and *Leperditia*, and *Entomis ?*, the latter of a green color or filled with green phosphatic ? mud. In section 475 the sandstone, 475 A^6, has a *Spirifera* similar to those just mentioned.

Although in both cases we see only slight traces of the fauna, I feel confident that what we do have is not the disintegrated material of an earlier age, but signifies the presence, at no great distance geographically, of the fauna which we know immediately followed the close of the Portage while these deposits were being made. The nature of the deposit and its associations are very similar to the calcareous stratum at High Point, Naples, Ontario County, in which a peculiar fauna for New York rocks was discovered, an account of which is given in Am. Jour.

of Sc., 3 d ser., p. Vol. XXV, pp. 97-104, 1883. There is nothing in the fragments found in stations 474 A and 475 A to prevent them from belonging to the same fauna and the probability is strong that they are from a common source. Further search should be made for this interesting forerunner of the Chemung fauna of New York.

Although the precise equivalency may not be determinable between this particular limestone deposit and any other series of deposits in which this fauna does not appear, it is a very suggestive fact that here for the third and fourth times traces of the Iowa Devonian fauna occur in New York deposits just at the point of transition from the Portage fauna, which seems to be peculiar to the east, to the Chemung fauna, which occupied the interval between it and the lowest coal formations.

Rushford, Allegany County, N. Y.—476.

The altitude of Rushford at the railroad station I estimated by aneroid readings running from Attica and to Cuba to be nearly 1,500 feet. These were long runs, but as they were severe tests upon the accuracy of this kind of estimate of altitude it was gratifying to learn later, through Mr. W. E. Wormelsdorf, the engineer of the railroad, that the measured altitude of Rushford station was 1,504 feet above tide. By aneroid estimates the deposits 476 G^0 are 1,350 feet or less, 481 A is about 1,600 feet in altitude, 481 B near 1,700, and 476 A is not far from 1,770 feet above tide.

The dip along Caneadea Creek is slight; near A it is perceptibly northward, but nearly level elsewhere, and it is probable that here is the southern rise of the gentle undulations in the rocks which produce but slight variation in the general southerly dip of the rocks in this part of the State. The dip is rarely more than fifty feet per mile and except in very limited areas rarely less than fifteen feet per mile southwestward.

The section 476 A is a ledge exposed alongside the railroad near the bridge, No. 57, between two and one-half and three miles north of Rushford.

A^1.— At the top are exposed six feet or so of soft, argillaceous shales which weather to an olive green; no fossils discovered; mica partings are seen, and by continuous deposition of the mica occasionally sheets an eighth of an inch thick separate the soft shales.

A^2.— Under the shales are about six feet of sandstone and mixed sand and clay. The sandstone at top is rather coarse, of loose texture, with occasional mica grains, with some iron stain and occasionally ironstone nodules, not calcareous, weathering brown, dark brown, to almost chocolate black. The sandstone rests on a kind of mixture of sandstone and clay nodules, with large roundish masses of micaceous limestone or concretions of dark greenish gray, with much mica and fragments of wood fossilized. These calcareous masses have the petroleum odor common to many other similar masses. Where they are in contact with the shales fossils appear.

A^3 is a second shale underlying the mass A^2; it is a bluish, fine, mud shale, not so evenly bedded as A^1, but breaking with conchoidal fracture when not weathered; this is veined with horizontal streaks of almost pure silicious sand, very light gray, with rough surface, often showing worm tracks. In the midst of the shale is an uneven mass of sandstone similar to that above, varying from eight to ten inches in thickness, and below are shales similar to those at the top. In a part of the exposure the color of the sandstone of A^1 at the juncture with the clay nodules (whether from weathering or not is not apparent) is a decidedly brownish red, the red of the Catskill rocks farther east, and the sandstone is slightly calcareous. It contains a unique fauna, though mingled with some Chemung types.

Fauna of the Centronella Red Band.—476 A·.

Of the fossils the most abundant form is a small terebratuloid shell, in size and general form most closely resembling *Centronella Julia* Winchell, of the Marshall sandstones. Next to this in abundance is a large, winged form of *Spirifera disjuncta.*

There are also—

Rhynchonella ? camerifera Winchell.
Productella Shumardiana, var.
Pleurotomaria, sp.
Rhynchonella contracta, var. (See Pl. 54 A, Figs. 50, 51, and pp. 417, 418, Geol. Surv. of N. Y., Pal., Vol. IV, Pt. I. The specimens of this station resemble the finer plicatėd forms of Rockford, Iowa, which were referred to *R. contracta*, var., and in a note were said to resemble young of *R. eximia* Hall.)
Nucula, n. sp., marked like a *N. lamellata*, but in outline approaching a *Grammysia Hannibalensis* (such as Meek gave in Pl. XVI, Fig. 5c, Geol. Surv. of Ohio, Vol. II, Pal.).
Nucula, n. sp., gibbous, quadrate, beak nearly central.
Cytherodon (*Schizodus*) *pauper ?*
Crania, sp.
Ambocœlia umbonata, var. *recta.*
Naticopsis ? sp., an allied form, new.
An incrusting *Bryozoan*—fragments.
Crinoid stem fragment.

476 B is a little outcrop of six feet, about thirty feet below 476 A. It is mainly thin layers of a very tough sandstone interstratified with softer shales. The sandstone is light colored, not calcareous; in one stratum the sandstone is very calcareous and appears to be a concretionary layer, not in balls, but nearly continuous.

B^1.—The sandstone contains several fossils; the first two species in the list are abundant.

Leiorhynchus mesocostalis, varying to *L. sinuatus.*
Ambocœlia umbonata.
Rhynchonella contracta, var.
Productella speciosa to *P. hirsuta.*
Spirifera mesocostalis, second and first varieties with median septum.

Streptorhynchus ? (small).

Orthis impressa ? large (faint).

B². — In a softer piece of shale from this horizon a *Spirifera disjuncta* was seen.

B³. — The calcareous streak contains *Ambocœlia* and traces of the *Streptorhynchus*.

The form and variation of the species of the sandstone B¹ are very similar to the species met with several hundred feet lower in a similar stratum in the shales at 476 G.

The outcrop 476 C is near bridge No. 59 and may be fifty feet lower than A. The principal stratum, C¹, is a strong, massive sandstone of six feet thickness at the bottom of the exposure, with soft argillaceous shales above for fifteen or twenty feet, interrupted by an irregular stratum (C²) of sandstone, averaging about a foot in thickness, in the midst of arenaceous shales, and in places becoming coarse sand of loose texture, weathering yellow upon exposure. At one part of the exposure the sandstone is very coarse, more like a fine conglomerate, with pebbles as large as an eighth of an inch in diameter and of flattened form, resembling in general character of the mass the lowest conglomerate or flat pebble conglomerate, as seen at 484 D and other places. This contains fossils, as will be seen beyond. C³, a shaly mass underlying this seam, contains also fossils of a decidedly Chemung type. This is strongly calcareous in places.

A calcareous slab from the bed of the creek appears to be from the same stratum, and its fauna will be given under 476 Bˣ, as it contains in fine state of preservation several species not found in the exposure in place.

On going down to the village thicker masses of conglomerate were found in the fences. This conglomerate, in the character of the gravel composing it and the fossils contained, appears to be identical with 476 C² in its coarser parts, and it is reasonable to infer that the conglomerate in the fences, with Chemung fossils and appearing there in slabs of several inches thickness, is from the same horizon as 476 C² or was deposited at a recurrence of the same conditions higher up; 476 A approaches very closely to the same conditions. In the latter, coarse, loose sand is seen, with a few pebbles, but no mass of gravelly sand or fine conglomerate.

476 C¹ is a fine, massive sandstone, in thick courses, without shales, of 6 feet thickness. The bottom courses are stained brown upon weathering and show mica grains conspicuously through the mass. A single fossil was found in this part of the sandstone, a dorsal valve of a large *Productella*, which may be defined as a large quadrate *P. lachrymosa*, moderately gibbous for a dorsal valve and showing clear indications of the radiating wrinkles which are more prominent in carboniferous species. The upper part of the sandstone is in a course of some 2 feet thickness as it appears in the ledge, massive, a pure gray, of uniform texture. with strong petroleum odor upon fracture, which the specimens

have not lost after six months in a dry room. There is only a faint trace of calcareous matter in these sands and the upper courses show only a slight yellowish tint of gray upon weathering.

Above the sandstone C[1] are soft shales (C[2]), tending toward a green color at first and strongly iron stained on weathering; on passing upward a few feet the shales become sandy (C[3]) and in places calcareous. The fauna appears to be the same for both and the lithological characters seem to vary locally in the relative prominence of the shales, sandy shales, or calcareous layers.

C[3] contains the following fauna:

Spirifera mesocostalis (common), var. 2 and 3, with high area and strong median septum.
Athyris Angelica, several specimens, but not common.
Spirifera disjuncta, var. like *S. Whitneyi.*
Rhynchonella contracta, var. (small) common.
Productella hirsuta ?, rare.
Streptorhynchus Chemungensis, several.
Centronella Julia, rare.
Mytilarca Chemungensis, one specimen.

A fine slab filled with fossils was found in the bed of the creek between C and B, and marked B[x]. The fauna of 476 B[x], as well as the character of the rock, leads me to regard it as belonging to the same horizon as 476 C[3]. It is more fossiliferous and is a calcareous mass which has in all probability fallen down from the cliff at some point the continuation of 476 C[3].

The species identified are:

Streptorhynchus Chemungensis, large, gibbous, of the quadrate form, with mucronate ears.
Spirifera disjuncta, the variety with high area and quadrate form.
Spirifera ? Whitneyi, a single specimen presenting some of the characteristics of this Iowa form, but comparison of many forms leads me to think this but an extreme form of the *S. disjuncta* type.
Rhynchonella contracta, a small variety, resembling var. *saxatilis* Hall, Geol. N. Y., Pal., Vol. IV, Pt. I, p. 417, Pl. 54 A; also another variety very similar to Fig. 23, Pl. 55, but not belonging to the species *R. duplicata*, to which that figure is referred.
Productella costatula, with concentric wrinkles.
Athyris Angelica.
Orthis Michelini.
Chonetes scitula.
Centronella Julia.
Chætetes, sp.
Productella onusta.

476 C[2] is an outcrop of sandstone south of the exposure of C[1] and somewhat higher. I was not able to trace its exact equivalent in the

cliff above C^1 and conclude that the character of the seam rapidly changes. At C^2 it is not over a foot thick, not massive, but is a coarse, sandy layer, tending to pebbly conglomerate in places, weathering yellow, and is in the midst of the same soft, rough shales which lie above C^2.

The fossils are *Streptorhynchus Chemungensis* (large), *Rhynchonella contracta*, *Spirifera mesocostalis*, and some crinoid fragments. Markings, like those called *Fucoides graphica*, are conspicuous on the surface next the shales. The sandstone is hard and very compact in some parts; in other places it suddenly becomes coarse and loosely agglutinated, and contains pebbles an eighth of an inch in size, forming a fine gravel conglomerate.

476 C is a coarse sandstone forming a stratum above C^3 and is probably the continuation of C^2. It is a loose grained, coarse sandstone, weathering yellow, not massive, but apparently a local bed. It contains —

Spirifera mesocostalis, second and third vars., with strong median septum and moderately high area.
Productella lachrymosa.
Rhynchonella contracta, varying to the form called *R. suborbicularis.*
Orthis impressa, large, broad form (frag.).
Orthis (*Michelini* or *Vanuxemi*), small.
Centronella Julia.
Rhynchonella contracta (small var.).
Bellerophon mæra ? (internal casts).
Orthoceras Demus ?

C^4.—Other slabs of sandstone were found loose in the creek below with a similar fauna. In one hard silicious layer the following association of species was met:

Leiorhynchus of the *L. sinuatus* and *L. multicosta* types.
Productella, resembling *P. hirsuta*, but with strongly wrinkled margins.
Ambocœlia umbonata.
Spirifera mesocostalis, second var. with median septum.

These sandstones (C^2, C, and C^4) are not calcareous, but are more purely silicious than the ordinary sandy layers of this neighborhood. The loose conglomerate masses met with in the fences between 476 A and Rushford are composed of fine, silicious pebbles, often dark in color, but after weathering coated with a dark brown covering of iron stain. The pebbles are of the flat form met with in the lower conglomerates farther south, and the masses appear to be at best only a few inches thick, grading at their upper or lower surfaces into coarse sandstone.

The following species were found in these fragments:

Spirifera disjuncta.
Spirifera mesocostalis, with median septum, the small and the coarse type both represented.

Euomphalus, sp.? This is represented by only a fragment, but it has the character of this genus so far as it goes.

In these more northern exhibitions of the flat pebble and fine, polished gravel conglomerate the fossils associated leave no doubt as to their general position in the series. The presence of *Spirifera mesocostalis* with *Spirifera disjuncta* shows us that this conglomerate was not restricted to the closing stage of the life history of the Chemung faunas. In middle and southern Allegany County *S. mesocostalis* had been absent from the faunas a long time before the laying down of the typical deposits of the flat pebble conglomerate occurred, as at Wolf Creek and Portville. The period of the deposit of the Olean (the Portville) conglomerate was doubtless of long continuance, a period of violent oscillation, of rapid erosion, and of rapid spreading out of the coarse sediments. It put an end to the marine conditions for all this eastern area and closed the Devonian age. But my study of the section herein discussed reveals the general law that the faunas of the Upper Devonian in this area maintained their integrity longer the farther distant they were from the center of origin of the sediments, which must have been somewhere in the region of the Appalachian axis, and also that the coarser shore deposits, worn pebbles and gravel, were occasionally carried out and spread over the bottom during a comparatively early stage of the Upper Devonian faunas.

Interpreting this for Western and Central Pennsylvania I should expect there to find greater thickness and more numerous deposits of coarse sand and worn pebbles below the Olean conglomerate, extending far down into the Chemung period, as marked by the life; but I should expect the fossils to be rare after the appearance of the red and micaceous green shales, and the few that did appear should represent earlier stages of the faunas than those appearing in like lithological conditions in Western New York.

Caneadea Creek, below East Rushford.—476 G.

This section continues from 481 C upward. The shales at the base G^0 are more bluish than lower down, but are fissile and weather much in the same way. They contain more fossils and a few more species, but they are evidently of the same fauna. The streaks of hard, nearly white, silicious material are more frequent, and calcite appears in thin, greenish white, argillaceous layers. Mica appears occasionally, peppering the surfaces of some of the thin shales.

476 G^0 contains the following species:

Leiorhynchus mesocostalis, abundant in layers.
Leiorhynchus multicosta (or *L. sinuata*), var.
Orthis impressa, large, wide form, frequent.
Spirifera mesocostalis, second var., mucronated, rare.
Ambocœlia umbonata Hall, var.

Rhynchonella Stephani, var. approaching *R. Saffordi* var.
Athyris Angelica.
Worm tracks.
Productella lachrymosa, var. *stigmata.*

The *Leiorhynchus* is more common where the shales and sandy layers meet.

In the higher layers of the shale, where the sandy character becomes predominant (G^1), there is a *Rhynchonella* difficult to distinguish from the more regular forms of the *Leiorhynchus* occurring below. One of them is distinctly the *Rhynchonella contracta* of Hall (Pl. 55 A, Fig. 30, Pal. N. Y., Vol. IV, Part I). Others are irregular in the plications, more like *Leiorhynchus multicosta* Hall, and are possibly what Professor Hall has called *L. sinuata.*

For the first thirty feet above, the thin shales (G^2) and sandstones prevail, the sands in the upper part appearing as thick as six inches. At thirty-five feet a strong seam of sandstone (G^3) of three or four feet thickness appears, with some thin shale partings, so that the mass cleaves upon weathering into layers six to ten inches thick. In some of the exposures the sandstone is broken into thin, flag-like slates by thin layers of pinkish mica. Higher the fissile shales appear, but the fossils are not seen, and the arenaceous layers are more frequent and thicker than below. About ninety feet above G^3 appears a second massive sandstone (476 G^4). This forms the top of the cliff. Although I could reach its base I could not get at the top of it, which was covered by loose talus from the shales still higher. It appears to be from six to eight feet thick. For eighteen inches or two feet at the base it is solid, massive, of a gray color, weathering to a slight brown or chocolate tint, and of loose texture; above the rock is more firm and gritty, but no specimens were found to be calcareous. This is probably the rock referred to in the Report on Geology of the Fourth District of New York, p. 485, as extensively used for grindstones and quarried. It is the only exposure seen between Caneadea and Rushford likely to furnish material fit for such a purpose.

Just under G^4 *Rhynchonella contracta*, *Spirifera mesocostalis*, a small *Palæoneilo*, and stems of plants (or worm tracks?) were found in arenaceous strata; in more shaly strata the *Leiorhynchus*, varying as below from *L. multicosta* to *L. mesocostalis*, was seen. The clay nodules, so often found associated with these sandstones, were seen at the base of G^4, some of them being clay ironstone. The *Spirifera mesocostalis* of these sands is the variety with extended ears, moderate area, median septum developed in the ventral valve, and reduplicated fold in the sinus.

476 G (loose). In the bed of the creek near G were found slabs of conglomerate, resembling very closely those met with in the stone fences above Rushford and of which distinct traces were found in place at 476 C^2. Although we cannot identify the horizon of these loose slabs with precision, the evidence is strong that they were deposited before the Chemung fauna ceased. The sources of the Caneadea Creek are high up in

the hills to the north and west in the towns of Lyndon, Farmersville, and Centreville, and nothing has been discovered to show that any of these hills run above the rocks bearing Chemung fauna.

The pebbles are flattened and range from coarse sand to fine gravel. Ironstone concretions are contained in the mass; when not weathered, the matrix is decidedly calcareous, and, while the pebbles themselves are often dark colored, green, and smoky quartz, the iron stain, upon weathering, coats them brown, giving the weathered slabs a chocolate brown color. Several fossils are found in the mass, though not in condition to identify always with certainty.

Spirifera mesocostalis, the second type, with finer plication and extended wings, and well develoved median septum.

Streptorhynchus Chemungensis, of good size.

Orthis, sp., several fragments too imperfect for specific identification.

Rhynchonella ? Sappho, var.

Numerous worn fragments of fish bones, and a fish jaw, *Dipterus Nelsoni* Newberry.

This resembles Newberry's *Ctenodus serratus* in general form, but the teeth are not serrate, although slightly wrinkled along the edge, which might possibly be the result of attrition of a serrate tooth.

While revising the manuscript in March, 1886, I submitted this specimen to Prof. J. S. Newberry, who identified it with *Dipterus Nelsoni*, a species which he has described from the fish beds at Warren, Pa. It is somewhat smaller than the original of that species. The matrix in which it is embedded is also very similar to that of the Warren fish bed.

DESCRIPTION OF FISH REMAINS.

Dipterus Nelsoni Newberry, ms. Plate III, Fig. 1.

This is a small jaw, referred to this species after comparison with Professor Newberry's original specimens from Warren County, Pennsylvania. The grinding surface is of hard enamel, triangular in shape, grooved by seven grooves radiating from near one angle, which is smooth and rounded and divided into finger-like ridges. The tops of the ridges and bottoms of the grooves are subangular. The ridges are arranged in pairs, every other groove running back a little farther than its neighbor toward the angle from which they radiate, and each ridge is slightly notched by four or five constrictions on the side; these notches are only superficial, and upon the crest of the ridges produce only faint undulation, no definite serration. The dimensions of the specimen (No. 16055 U. S. Nat. Mus.) are: length, 20^{mm}; width, 11^{mm}; length of the process of the jaw vertical to the grinding surface, 11^{mm}.

The original is from a gravel-like conglomerate found at Rushford, Allegany County, N. Y. (loose), but traced to the midst of Upper Chemung rocks and associated with Chemung fossils.

Dipterus (?) lævis Newberry, ms. Plate III, Fig. 2.

This is a small and worn specimen, evidently distinct from *D. Nelsoni* and possibly a worn representative of Dr. Newberry's species *D. lævis.* It is nearly as large, but proportionately shorter; the grinding surface has but four finger-like ridges, which are smoothly rounded and hard; the bottoms of the grooves are also rounded. It is smaller and has fewer ridges than the typical specimens of *D. lævis*, and, while this may partly be the result of attrition, it is with some doubt that I refer it to the species, and in case future discoveries prove it to be distinct I would propose *D. Alleganensis* for this form. It occurs in a fine pebble conglomerate at Little Genesee, Allegany County, N. Y., in the Upper Devonian.

Cuba, Allegany County, N. Y.—477.

Cuba, the third township north from the State line and in the western tier of townships in the county, is situated about fifteen miles north of Pennsylvania and thirteen miles south from Rushford, 476. The Erie Railroad grade is given as 1,542 feet above sea; the altitude of the grade of the canal railroad (Rochester division, Buffalo, New York and Philadelphia Railroad) is called 1,488 feet. Several exposures were examined on the hillsides, all at about the same level.

477 A.—The Armstrong quarry is extensively worked just above the Erie Railroad near the depot. Some ten or twelve feet of good building stone can be quarried here; the base of the quarry is about thirty feet from the railroad, or nearly 1,570 feet in altitude. Several courses of solid, even grained sandstone lie above the base, with some intervening layers of shale or shaly sandstone. Below the sandstone are some twenty feet of soft, fissile shales, bluish at the bottom, tending to olive toward the top, and weathering iron stained.

477 B is three-quarters of a mile north, on the same level, and is now abandoned—the old Guilford quarry.

477 C is Smith's quarry, on the east side of the valley and a mile and a half northeast of A on the same level. The quarry rock is a light gray, calcareous sandstone, strongly bituminous upon fresh fracture. The grain is generally fine, and though working easily when fresh is more tenacious than the Berea sandstone of Euclid or Amherst, Ohio; but the grain is coarser than the Portage sands and of lighter color. Upon weathering there is enough iron to give the stone a creamy to yellowish brown tint. This ferruginous quality is associated with the thinner, more flaggy structure; the purer, thicker courses are of a lighter and purer gray color. The lowest course, from which thick slabs are blasted or wedged off, running from three to four feet thick, makes the finest quality of building stone. A second thick course in the center of the quarry furnishes three to four feet thickness of stone, in which occasionally are seen *Verticalis* perforations on the upper layers. Above this the courses are thinner, rarely furnishing over a foot of

sandstone. Between the layers of shale in these sandstones are the brachiopods.

There appear to be two quite distinct faunas present in the quarry. Although the upper layers of sandstone are very similar in general character to the lower, more strongly calcareous deposits, generally the lower thick beds carry scarcely anything but a lamellibranch fauna, with occasionally an *Orthoceras*. The lamellibranch fauna is generally found in the midst of the solid sandstone, with *Grammysia communis* as its most abundant species. The brachiopod fauna occurs higher up in the thinner sandstone, where the argillaceous matter is so interstratified as to make poor building stone and the shells (in the principal layer) are so thick as to make the stone unfit for cutting. In the fauna the *Spirifera disjuncta* is the most abundant form and lamellibranchs are rare, though occasionally a single specimen of *Sanguinolites* appears at the base or top of the stratum.

Below the sandstones are exposed some twenty feet of soft, fissile shales, A^1 and A^2, containing another distinct fauna. Only a few specimens were found, but those were well marked *Lingulas* and a few other forms. The *Lingula* is the more conspicuous and frequent form, and it is indistinguishable from the Ohio *Lingulas* of the Cleveland shale at Euclid, Ohio. These lingula shales are, however, light in color at the base, the ordinary blue shale, and toward the top are light olive green upon weathering.

Lingula fauna of 477 A^2:

Lingula Melie.
Chonetes lepida, or small *C. scitula.*
Palæoneilo, sp., a small form.
Discina, sp.
Sanguinolites rigidus (=*Sphenotus contractus* Hall, 1885).

Grammysia fauna of 477 A^3:

Grammysia communis.
Grammysia communis, var. approaching *G. cuneata.*
Grammysia communis, var. very short.
Schizodus rhombeus, var.
Aviculopecten, a variety near *A. cancellatus.*
Edmondia ? Philipi.
Pterinopecten suborbicularis.
Orthoceras pacator ?
Crinoid stem fragments.

Brachiopod fauna of 477 A^6:

Spirifera disjuncta, abundant.
Rhynchonella contracta, small var., frequent.
Streptorhynchus Chemungensis, frequent.
Athyris Angelica, frequent.
Chonetes scitula.

Productella costatula.
Productella, sp.
Ceriopora, sp.
(*Crenipecten ? impolitus.*)
Sanguinolites rigidus (= *Sphenotus contractus* Hall, 1885).

The first four species constitute the main bulk of the fossils; the remaining species are represented by several specimens in the lot collected, but are not common. *Spirifera disjuncta* is very abundant in quarry A, and with few *Streptorhynchus Chemungensis*, while the latter species is almost as abundant as the spirifer in some layers of 477 B.

Guilford Quarry, Cuba, N. Y.—477 B.

Sandstone, massive gray, weathering brown; some layers highly ferruginous, the fossiliferous layers decomposing by solution of calcareous matter and producing brown rottenstone. Some pebbles are seen, but no regular conglomerate layers. In the lower sandstone is the lamellibranch fauna, as in 477 A. Above is a thinner layer, more calcareous, filled with brachiopods.

Brachiopod fauna of 477 B:

Spirifera disjuncta, abundant.
Streptorhynchus Chemungensis, common.
Chonetes scitula.
Rhynchonella contracta, var. small.
Productella onusta.

The *Streptorhynchus* is gibbous, often extremely so, and the *Spirifera disjuncta* has the median fold duplicated.

Smith Quarry, Cuba, N. Y.—477 C.

The lithological and stratigraphical characters are essentially the same as in the Armstrong quarry, 477 A.

The brachiopod fauna is the same, though *Productella* and *Streptorhynchus* are more frequent than in the more southern exposure at A.

The fossils obtained are:

Spirifera disjuncta.
Streptorhynchus Chemungensis.
Productella onusta.
Rhynchonella contracta, var.
Rhynchonella duplicata ?
Athyris Angelica.
Pleurotomaria, sp., a finely striated form.
Sanguinolites rigidus (=*Sphenotus contractus* Hall, 1885).
Productella, near *P. arctirostrata.*
Ceriopora, sp.

The brachiopod fauna of these three Cuba quarries is in all essential points identical with the fauna of 476 B^x.

Ravine in South Cuba.— 477 E.

Near the base of this ravine there are some thin sandstone layers, but, comparing it with the Cuba quarries a mile or two north, I judge that the first exposures at the base of the ravine are stratigraphically equivalent to the upper part of the Armstrong quarry and that the fine quarrystone layer is below the surface. The shales predominate throughout, though in the lower part some solid sandstone strata, a foot or more thick, are seen. The ravine begins (the first rock exposure) at about 1,600 feet altitude and rocks are visible to nearly 1,725 feet.

Near 1,625 feet altitude or a little higher is an abundant brachiopod fauna, in a calcareous sandstone seam (E^2), with the same species in general as in 477 C, the *Spirifera disjuncta* and *Streptorhynchus Chemungensis* both abundant, and the more common species. Above this stratum no strong seam of sandstone occurs; there is an alternation of thin arenaceous layers, with prevailing argillaceous shales.

Near the middle of the ravine is a layer of rather coarse micaceous sandstone (E^4), 18 inches thick; soon above this traces of red coloring begin to appear in the generally olive argillaceous shales. These argillaceous shales become prominent at about 1,700 feet altitude and continue to the top of the ravine. At several places they run into brown or red shale, and one layer of several inches is strong brownish red and contains fossils (E^5).

Brachiopod fauna of 477 E^2:

Spirifera disjuncta.
Streptorhynchus Chemungensis.
Chonetes scitula.
Rhynchonella contracta.
Productella hirsuta.
Productella costatula, and varieties.
Ceriopora, sp.
Crinoid stem fragments.
Grammysia communis, var.

In thick greenish shale (E^3):

Spirifera disjuncta.
Streptorhynchus Chemungensis.
Leptodesma, near *L. sociale.*

In brownish sandstone, near bottom, 477 E^4:

Athyris Angelica, abundant.
Rhynchonella contracta, var.
Productella, sp.

Above E^4 the rocks are generally argillaceous, and, while generally olive green in color, contain streaks of red and brown and some thin streaks or nodules of oölitic red iron ore. The fauna of these beds is probably uniform and the reddening of the shales does not prevent the presence of numerous fossils.

Fauna of 477 E⁵:

Orthis Leonensis, abundant.
Lyriopecten, sp. = ? *L. orbiculatus.*
Rhynchonella contracta, small.
Spirifera disjuncta.
Ceriopora sp., abundant.
Aviculopecten cancellatus?.
Leptodesma, sp.
Athyris Angelica?

Station 477 H is a low bluff alongside the stream which runs into the Cuba valley from the southeast, and is situated about two miles nearly south of Cuba. Stratigraphically the rocks are apparently the soft argillaceous shales following the quarry sandstones of Cuba and are nearly equivalent to 477 E¹, at the base of section E, which lies only half a mile north of H. The shales are normally bluish in tint, being slightly ferruginous, weather to an olive color, tending to a brownish shade; they break up into fissile flakes after weathering, but the bedding is not so fine as to give the true fissile character to the rock in mass.

The fossils are numerous in some layers, in others rare. In the beds examined, the *Chonetes* is most abundant; the *Athyris*, *Streptorhynchus*, *Productella*, and *Spirifera* frequent, the other species rarer. With the exception of *Spirifera* and *Streptorhynchus* the species are generally small.

The following species were identified in the fauna of 477 H:

Chonetes scitula.
Streptorhynchus Chemungensis.
Productella costatula.
Athyris Angelica.
Spirifera disjuncta.
Orthis Leonensis, small size.
Ceriopora, sp.
Crania, sp.
Palæoneilo brevis, var.
Palæoneilo, sp., near *P. filosa.*
Palæoneilo, sp., a minute form, possibly young.
Rhynchonella contracta, small var.
Pleurotomaria filitexta.
Leptodesma, a minute specimen.
Leptodesma sociale?
Goniophora Chemungensis, small.
Mytilarca Chemungensis.
Centronella Julia?

Crinoid stem fragments.
Aviculopecten cancellatus.
Modiomorpha ?

Following up the valley from 477 H southeastward, two exposures were met with near the southern boundary of Cuba township. They are about 2½ miles south of 477 A and respectively 2 and 2½ miles east of the same point. Stratigraphically they lie above the section 477 E, station 477 G being not far above the top of E, and 477 F is some 60 feet higher.

Fauna of 477 G, in the sandy layers, weathering brownish to dark bluish brown:

Spirifera disjuncta.
Athyris Angelica.
Plant remains.
Rhynchonella, sp.
Bellerophon, sp.
Chætetes, sp.

In the soft, coarse, argillaceous shale, weathering brownish olive, were:

Rhynchonella, sp.
Palæoneilo, imperfect specimen.
Leptodesma Mortoni ?

Fauna of 477 F, in greenish, arenaceous shale:

Spirifera disjuncta.
Streptorhynchus Chemungensis.
Chonetes scitula.
Sanguinolites rigidus (=*Sphenotus contractus* Hall).
S. clavulus and a variety resembling *Nyassa arguta* in general form.
Palæoneilo Bedfordensis.
Mytilarca Chemungensis.
Leptodesma Mortoni.
Plant stems.
Leptodesma potens.

A comparison of the several faunas from Cuba and the immediate neighborhood gives the following as the general character of the two hundred feet or so which we are able to examine.

(1) Olive green to blue, argillaceous shales with a *Lingula* fauna, when most pure and fine, as seen in 477 A¹ and 477 A².

(2) This is followed by sandstone, locally, of solid, massive character, calcareous and often strongly impregnated with petroleum. Where this sandstone is purest and most massive, the fauna is mainly lamellibranchs. In the more argillaceous layer, where the alternating arenaceous and argillaceous deposits are more frequent and mingled, one of the typical Upper Chemung brachiopod faunas appears, with abundance

of *Spirifera disjuncta*, and in some exposures and layers *Streptorhynchus Chemungensis* is common (477 A, B, and C).

(3) Above the sandstones appear shales again, of the olive, argillaceous character, varying from pure, fine, soft shale to arenaceous shale with more or less iron stain. In this zone *Athyris Angelica* may be found, lamellibranchs of several genera, and several of the common species of the sandstones below.

(4) Next appear traces of those iron gray, micaceous sandstones, so common in the lower Catskill rocks further east, and streaks of red iron ore and red shales. The red shales still contain Chemung brachiopods, *Spirifera disjuncta*, and other species. The most characteristic brachiopod is a small *Orthis* (*O. Leonensis*); this occurs quite abundantly in a thin, arenaceous, reddish brown shale. Here, too, in the midst of the soft, olive shales is seen red oölitic ore, but only in thin veins or nodules. It is interesting to notice that in the lowest clay iron nodules of Chemung and Tioga Counties, New York, in the midst of the same Upper Chemung brachiopod fauna, are seen the representative of the *Orthis* of that section as well as the more typical form of *O. Michelini*, showing conclusively that this type of *Orthis* is associated with nearness to shore conditions of habitat.

(5) Above this the Chemung brachiopods come in again; also a new lamellibranchiate fauna. This time *Leptodesma*, *Sanguinolites*, and *Avicula* are more common, and this rock is a fine, arenaceous shale, from bluish to olive gray in color. This is 477 F and G. Traces of pebbles are seen in the lower sandstones; some of them are an inch in diameter, but no collection of pebbles forming conglomerate was seen. In this section are seen, for the first time going up, distinct masses of red iron ore.

The brachiopod fauna (477 A and 477 C) is remarkable for the absence of any trace of *Spirifera mesocostalis* or *Orthis impressa;* and *Strophodonta Cayuta*, *Productella lachrymosa*, *Orthis Tioga*, and *Cryptonella Eudora* are entirely absent, unless we may regard *Orthis Leonensis* as a small variety of *O. Tioga* and some of the gibbous forms of *Productella* as extreme varieties of the common form of the eastern section. Yet all these species are common in the typical Chemung fauna of the Chemung and Tioga County sections. Several of these species do not appear at all in this Wyoming-Allegany County section, while such species as *Athyris Angelica*, the gibbous varieties of *Productella*, and the smaller varieties of *Rhynchonella contracta* and *Rhynchonella duplicata* appear to be wanting in the eastern section, though often abundant in the Allegany County section. This difference in fauna cannot be geological, for it characterizes the whole Chemung group fauna. We can only look, therefore, to geographical conditions to explain the faunas.

Some of the species of the eastern Chemung do appear at the base of the Chemung fauna in Allegany County, such as *Spirifera mesocostalis*, *Orthis impressa*, and the common Chemung *Leiorhynchus;* but it becomes evident upon comparison of the two sections that upon passing upward the characteristic Chemung species mentioned above become more and more strictly confined to the east. Again, the species which appear associated with Chemung species in the Allegany County section and that are wanting farther east are of the same types and, in some cases, the same species which are characteristic of Lower Carboniferous rocks of the States farther west. The conclusion appears plain that with the passage of Upper Devonian time over Western New York territory there was a shifting of the faunas in an easterly direction, and that with such shifting species which are regarded as belonging to a later period, when they occur more isolated in the western interior, appear in the western part of New York before the close of the Chemung fauna, but farther east, in Tioga County, do not appear at all up to the close of the Devonian. This study of the faunas gives us a hint toward solving the relation of the eastern and western beds.

If the Waverly or Lower Carboniferous fauna may be regarded as a separate and complete fauna, it was doubtless a local one, and it may be regarded as probably contemporaneous with a part of the Upper Devonian of New York. The indisputable evidence we have that during this Upper Devonian epoch the faunas were moving eastward over Western New York gives reason for the belief that species which belong to a later horizon must have come in from the west, and that the normal contemporaneous faunas farther west were of a later type than in the east. Examination of the species confirms such views. The *Productellas* of 477 C are frequently of the very gibbous form, agreeing in this respect with specimens from the section 476 B[4] of Rushford. Although the specimens are generally smaller, the larger specimens are very like the larger Waverly forms (Geol. Surv. Ohio, Vol. II, Pal., Pl. 10) mentioned by Meek, and the *Streptorhynchus Chemungensis* from these beds reaches a very gibbous form not readily distinguishable from Meek's *Hemipronites crenistria* of Ohio. The *Palæoneilo* of these Cuba beds is different from *P. brevis* in the features distinguishing Meek's *P. Bedfordensis* from that species; it is, therefore, a variety approaching the Ohio Waverly type. The crinoid is of the Waverly variety of *Forbesiocrinus communis* type, as here recognized by stems, but in the fauna of 479 A[4] represented by some specimens of the calyx.

We observe just under these rich fossil bearing calcareous sandstones, 477 A, a series of fissile shales bearing a fauna of *Lingula* and other small delicate shells. Although the fauna is not strictly identical with that of the lingula shales of Van Ettenville, described in U. S. Geological Survey Bulletin No. 3, the stratigraphical sequence is the same and the general character of the fauna is similar. In that section the rich Chemung brachiopod fauna immediately follows the soft lingula bearing shales, and no similar shale was discovered below until within two or three hundred feet above the Genesee shale. In the western section he lingula bearing black shales are constantly recurring for a thousand feet above the typical Genesee shale, but this soft, olive mud shale, with *Lingula*, does not appear below this horizon (477 A).

In these lingula shales, in both the eastern and the western sections of New York, we find the first traces of the ironstone nodules, and the brown color from iron stain becomes more conspicuous above this horizon, and this marks the lower part, if not quite the beginning, of the common marine fauna of the Chemung group. In the Ithaca section we observe a fauna resembling the Chemung fauna some eight hundred feet below the genuine Chemung fauna. It is preceded by a similar dark lingula shale, but the absence of *Spirifera disjuncta* and the rarity and small size of *Productella* alone suggest the fact that the Chemung horizon, as it is known in Western New York, has not been reached.

From these comparisons we conclude that the Van Ettenville shales and the following fossiliferous sandstones are the stratigraphical equivalents of the Cuba shales and its sandstones as seen in the Armstrong quarry. The interval below, down to the Genesee black shale, is mainly filled by rocks carrying Portage faunas in the Allegany County section, while the section of Tompkins and Tioga Counties holds a fauna only a few hundred feet above the Genesee shale, which is paleontologically intermediate between the Hamilton and genuine Chemung faunas.

Black Creek, New Hudson Township, Allegany County, N. Y.—478.

This station is northeast of Cuba, about five miles from the Armstrong quarry (477 A), and estimating from the canal railroad (Rochester div., Buff., N. Y. and P. R. R.) grade by aneroid barometer, the quarry is approximately at the same altitude as the Cuba quarries, not far from 1,575 feet. The quarry has been extensively worked, but is now abandoned. At the base is a heavy course of light colored sandstone, running from two to three feet thick; next above, five feet of thin layers of sandstone and shale; then two feet of solid sandstone, followed by a fossiliferous zone of a foot or so containing the brachiopod fauna, 478 A^4; above this is another solid sandstone three feet thick, above which the thinner alternating shaly and arenaceous layers predominate. The lithological characters correspond very closely with those of the Cuba quarries, but the fauna differs slightly in its prevailing characters.

The tracing of actual equivalency of horizon is a matter of considerable difficulty on account of the absence of exposures at intermediate points. According to Prof. James Hall's original section, generalized for this part of the State (see Ann. Rep. of N. Y. Geol. Survey, 1838), a general dip of something like fifty feet to the mile is represented, and each of these quarries at Caneadea, at Rockville, &c., is in a separate zone in the series, separated from others by considerable thickness of deposits. My examinations lead me to the opinion that the general dip of these upper strata is by no means so great, and that there are also long folds in the strata, giving at some exposures even a decided dip to the north, thus complicating the task of following strata from exposure to exposure in traversing the country.

Knowing, as we do, that the faunas are considerably modified as we pass from east to west, even in a hundred miles, it should not surprise us to find a like difference between the more northern and more southern faunas of the same horizon. The differences in the faunas may be due to differences in geographical conditions on the same horizon or they may be modifications of the fauna, marking geological range or difference of horizon. The present fauna, to all appearances, is at the same altitude now as the Cuba brachiopod fauna, 477 A. At the Cuba quarry the dip is slightly southward. At this station the strata are as nearly level as we can read; at Rockville, three miles farther north, there is a decided dipping to the north. From these facts the conclusion is strong that there is a gentle anticlinal fold near Cuba, sloping northward as we reach Rockville and already showing its southward slope at 477 A.

The fauna of 478 A^4 shows differences pointing to the characters of more eastern faunas or those that are met in the exposures farther north than 477. The presence of *Orthis impressa*, the broad winged, high beaked *Spirifera disjuncta*, and the presence of *Spirifera mesocostalis* may be noted in this connection. In making comparison of faunas, too, we find the same peculiarities in station 481 A, which is actually less than fifty feet higher than 478 A, and nine miles north and a little east, with the rocks again dipping northward, though at intermediate points the dip is decidedly southward.

If we consider each of the sandstone beds as relatively local, when a particular horizon is concerned it is more probable that the sandstone deposits for continuous geological epochs (at least for such length of time as the Upper Chemung may require) were nearly continuous, but shifted their geographical position, than that there was any total cessation and renewal of their deposition.

When we compare the faunas in similar or like lithological conditions, as a tentative rule (which further investigation may modify), we make the supposition that likeness in the composition of two faunas, i. e., the association of the same species, is more apt to persist through the gradual changes brought about by time and that constancy in the lesser varietal characters is more likely to signify likeness or equivalency in geological horizon; hence, if we have two faunas in apparently like conditions of matrix and in the same general geographical area, if the species are the same and those abundant and those rare maintain the same comparative relationship to the fauna, we infer that the fauna is the same. If the species show the same varietal peculiarities, we say the horizon is synchronous; if the varietal characters differ, we say it is probably a different horizon, although the species are identical. Hence in an imperfect fauna, the lack of the full complement of species might signify geographical shifting of the fauna, but if the species that did appear presented the identical varietal characters, we would infer that the horizon was identical.

Fauna of 478 A^4:

Spirifera disjuncta, large, broad, mucronate form.
Athyris Angelica.
Rhynchonella contracta.
Crinoid stems.
Productella acutirostra, var.
Spirifera mesocostalis.
Orthis impressa.
Chætetes, sp.

The *S. disjuncta* is abundant; the other species are only occasional. The *Productella*, sp., is a large form, with the outline (dorsal valve) of a large *P. arctirostrata*, with strong concentric wrinkles at the cardinal end of the shell, the front geniculate, the interior pitted like *P. hirsuta.* It does not agree with any of the ordinary New York forms, and in general resembles the carboniferous types, but is doubtless a variety of the gibbous Upper Devonian type of *Productella*, and near the form called *P. acutirostra* in the reports. The same form is seen in 479 A^4.

Rockville, Allegany County, N. Y.—479.

Situated in Belfast township, about nine miles northeast from Cuba (477); altitude, approximately, as determined from railroad grade and by aneroid barometer: A^1, 1,410 feet; A^7, 1,460 feet. The section near the old canal lock at Rockville is visible for about fifty feet. At the base is a thick sandstone seam (A^1), six feet of it being visible. A^2 is shale of two feet thickness, then a second seam of sandstone two feet thick (A^3). This is followed by shales and thin arenaceous layers for thirty-five feet, and at the top are two seams of sandstone less than a foot thick, separated by shales. The principal sandstones of the series are massive and of the deeper gray color of the true Portage sandstones, considerably darker than the Cuba stones and of finer grain, and have a strongly bituminous odor on fresh fracture. The shales are green to olive, soft, argillaceous, and do not differ materially from the soft shales which frequently appear in the Chemung series. The rocks dip evidently to the north, not extensively, but enough to show plainly that we are on the northern slope of a gentle anticlinal.

The brachiopod fauna is in the first and second sandstones; the most numerous fauna is just at the close of the second sandstones, in the soft shales, 479 A^4. The upper sandstones are tough but thin, of a pinkish tinge, and contain minute streaks of brown iron ore. There is occasionally seen a passage of the sandstones into a local bed of gravels, with fine pebbles, flat and of a dark and even black color. These are cemented in a calcareous matrix.

Fauna of the calcareous sandstone, 479:

Spirifera mesocostalis (common).

Sp. disjuncta (rare).
Orthis impressa.
Rhynchonella contracta.
Streptorhynchus Chemungensis.
Productella hirsuta.
Ambocœlia umbonata (rare).
Sanguinolites rigidus (=*Sphenotus contractus* Hall, 1885).
Crinoid stems (large).
Bellerophon mœra? (frag.).
Nucula, sp.?
Platystoma, sp.?

Fauna of the olive shales, 479 A[4]:

Spirifera mesocostalis (of smaller and finer structure than that of the sandstones).
Productella hirsuta.
Productella lachrymosa, var. *stigmata.*
Productella (with several varietal forms running off toward *P. onusta* and *P. speciosa*).
Chætetes, sp. (a branching form, quite abundant).
Mytilarca Chemungensis.
Rhynchonella contracta (running into the form called *R. sappho*, var., by Prof. James Hall, Geol. Surv. N. Y., Pal., Vol. IV, Pt. I, Pl. LV, Figs. 49, 50).

The above species are found in abundance; the following are less common:

Spirifera disjuncta, a small variety, with very high beak, in general form and size closely agreeing with the Iowa *S. Whitneyi* Hall.
Orthis impressa.
Productella rarispina.
Athyris Angelica.
Orthis Tioga (or var. *O. Leonensis*), rare.
Crania, sp.?
Bellerophon, near *B. Euclid.*
Palæoneilo brevis.
Macrodon Chemungensis.
Modiomorpha subalata?
Modiomorpha quadrula.
Loxonema styliola.
Ptychopteria, a form near *P. Eugenia* (=*P. Salamanca* Hall, 1885).
Crenipecten obsoletus.
Crenipecten crenulatus.
Pterinopecten suborbicularis.
Aviculopecten, sp.?, a very finely striate fragment.
Forbesiocrinus communis.
Crinoid stems, another species, with nodose joints.
Chonetes scitula.

Belfast Quarry, Belfast, Allegany County, N. Y.—480

This is an exposure about three miles east of the Rockville section, approximately 50 feet lower, or from 1,340 to 1,360 feet in altitude.

The sandstone (480 A[1]) is fine grained, of a darker shade and finer texture than the Cuba stone, and very similar to the Arcade stone (474 A). It also closely resembles the Rushford stone (476 G[4]). The color is gray, with a slight brownish or chocolate tint, which changes upon weathering to a purer gray. It is calcareous and upon fresh fracture has the petroleum smell so common to these sandstones. Some layers are flaggy and separated by thin partings of mica. At the top of the quarry are very uneven layers, as if violent action of the sea had disturbed the bottom, making it uneven with pitholes. There are small masses of shale mingled with the sandstone and large irregular masses, calcareous agglomerations of pebbles or fine gravel (480 A[2]). These have something of the nature of concretions, but are mainly coarse sand and fine gravel cemented by calcareous mud.

In these were found the only fossils of the station. Above and below the sandstones the rocks are thinner layers of arenaceous and argillaceous shales, with no thick layers and no traces of fossils visible.

Fauna of the concretionary masses, Belfast, 480 A[2]:

Orthis impressa, large, broad variety.
Productella hirsuta, with spines from cardinal margin.
Spirifera mesocostalis, third var., with median septum.
Rhynchonella contracta, approaching the *R. eximia* type.
Ambocœlia umbonata.
Athyris Angelica.
Crinoid stems, same as in 479.
Leiorhynchus sp.
Productella onusta.
Chætetes, sp.
Streptorhynchus Chemungensis, var.

Caneadea, Allegany County, N. Y.—481.

The examinations at this station were confined to the exposures along Caneadea Creek, up to E. Rushford (481 C), and two exposures (481 A and 481 B) made in the hill a few miles northwest of Caneadea by persons who supposed they had found a gold mine.

The altitude of Caneadea railroad station, based upon the profile of the old Genesee Valley canal — in the bed and along the towpath of which the Rochester division of the Buffalo, New York and Philadelphia Railroad is built — is 1,224 feet above tide. This benchmark I have not been able to identify precisely. By aneroid barometer, the cliff above 476 G is estimated to be 1,490 feet in altitude. The cliff to the base, G[0], is 140 to 150 feet, or say 1,350 feet in altitude. The other stations, according to aneroid reckoning, are, 481 A, 1,600 feet, and, 481 B, 1,700 feet in altitude.

The dip of the rocks in the creek is very slight, but what there is is northward. At 476 A two or three miles north of Rushford the dip is strongly northward, and at the base of the creek the rocks incline to the southwest.

Shean excavation, above Caneadea.—481 A.

This section is an opening made on the farm of Mr. Shean, near the division line between Caneadea and Rushford Townships, about two miles in direct line northwest of Caneadea village. It was opened on the supposition that gold and silver ores were there in rich quantities. The report of this "silver mine" I heard of at several places in the county. By aneroid estimate the altitude is about 1,600 feet.

The rock exposed is mainly a gray calcareous sandstone, highly fossiliferous. The stone varies in the amount of calcareous matter. In the more compact portions the sandstone is of a dark bluish gray color and the matrix appears to be almost pure carbonate of lime; but where the sandstone is loose textured it is a pure light gray, with little or no carbonate of lime.

The facts suggest that the difference is due to a solution and removal of the lime from the more compact variety to form the loose textured, light gray variety. The presence of petroleum in the porous sandstones probably had no relation to the original deposition of the sandstones, but wherever these beds of calcareous sandstone were made porous by removal of the carbonate of lime the conditions were present for the absorption and retention of petroleum distilled from underlying black carbonaceous shales. The sandstone weathers a little brownish, but the iron stain is very slight. The sandstone becomes coarse in places, forming a fine gravelly conglomerate, with flat and dark colored, silicious pebbles, the matrix calcareous, and containing fragments of fish bones, shells, and chips of wood very similar to 476 C^2.

The fossils in 481 A are:

Ambocœlia umbonata, abundant.
Productella (*lachrymosa*, var.? see beyond).
Productella hirsuta, var., small.
Rhynchonella contracta.
Spirifera mesocostalis, second var. with strong median septum, and third var. coarse and with reduplicated fold.
Orthis Tioga.
Orthis impressa, larger.
Streptorhynchus Chemungensis.
Rhynchonella, sp.? (like *R. Horsfordi*, broad).
Crinoid stems.
Chætetes, sp., slender branching form.

? *Lingula*, with punctate inner layer.
Spirifera disjuncta.
Aulopora, sp.
? ? *Cryptonella*, sp., a fragment.

Caneadea Creek, lower part.—481 C.

This is the section referred to in Geology of Fourth Dist., N. Y., p. 485, as "a good exhibition of the characteristics of the base of the Chemung group of this part of the State, better than is elsewhere seen." The distinction between this section and those of Steuben County consists mainly in the prevalence here of the "pure aluminous shale of a deep green or bluish green color," with intervals only of thin sandstones. The green shales referred to prevail in all the lower part of this ravine. I would describe them as a fissile, greenish gray shale, argillaceous, weathering brownish with iron stain, and containing at intervals streaks, from an eighth of an inch to several inches in thickness, of hard, silicious sandstone, the surface of which is often rough and uneven and sprinkled with mica grains. In the upper parts, from 476 G upward, the sandy layers are more conspicuous and thicker and of looser texture and coarser grain, forming strata of a foot or more in thickness. These are referred to in another place.

The shales contain a few fossils as low down as Caneadea, but there they are rare and are mainly *Leiorhynchus mesocostalis* and *L. multicosta.* A single *Rhynchonella sappho*, var., was found, and a *Productella*, which, though differing from any particular figure and description, is probably a variety of *P. hirsuta.* This general character of deposits continues up to the base of the cliffs at 476 G. an account of which is given in another place.

Friendship, Allegany County, N. Y.—491.

The exposures at Friendship were examined at Mr. P. Miller's quarry and in the ravines south of the village. They lie at about the same altitude as the Cuba quarries and above them and are directly east of Cuba. Substantially the same series of rock deposits and the same faunas were met with as in the ravine south of Cuba (477 E). In the higher exposures the micaceous flags were reached; a red band was seen before the close of the Chemung fauna.

Mr. Miller showed me several fine specimens of *Dictyophyton*, two of which were presented by him to Cornell University. They came from a fine compact sandstone lying above the Chemung fauna. The sandstones exhibit traces of the same polished quartz gravel seen in the same layers of the Cuba sandstones.

Wellsville, Allegany County, N. Y.—492.

There is a quarry on the hillside at Wellsville a hundred feet above the railroad, the top reaching over 1,600 feet elevation above tide. In this quarry the prevailing rocks are a brownish gray sandstone, in not very thick courses, thin bedded micaceous shales, and soft, fragile olive shales, with an irregular seam of fossiliferous, red, arenaceous shale.

In the sandstone are—

Spirifera disjuncta, abundant.

Productella hirsuta.

Ambocœlia umbonata.

A large, flat, fish scale, the surface broken off so that it cannot be determined; but the nature of the bone still preserved is like that of *Holoptychius.*

Ceriopora, sp., casts showing the form of branching, but no structure.

In the soft olive shales—

Rhynchonella contracta.

Productella costatula, var.

Ceriopora, same as above.

The red shales are oölitic in spots and also contain streaks of fine polished pebbles. The fossils are generally in imperfect condition; the fish remains are in broken fragments. The following species were recognized:

Spirifera disjuncta, rare.

Goniophora Chemungensis, small, and with rather coarse concentric striæ.

Mytilarca, sp., small, and presenting characters between *M. occidentalis* and *M. simplex.*

Macrodon Chemungensis, small.

Grammysia communis.

A small *Orthoceras*, an *Aviculopecten*, a *Crenipecten*, and a small *Palæoneilo*, none of them perfect enough for specific identification.

The branches of *Ceriopora*, sp., seen in the other shales, and among the grains a few minute spiral shells.

In the same quarry are seen layers, or rather large lumps, of a sort of pudding of white sand, mingled with small nodules of green clay and streaks of mica flakes.

This condition of rock appears to indicate a transition of conditions, in which considerable disturbance took place, but the break indicated was so slight that the mud at the bottom was still mud and not consolidated into rock when the sand was thrown down upon it.

Very similar characters were seen in the sandstone quarry at Arcade. The horizon of this quarry is considerably above that of the Cuba sandstones, but between it and the Wolf Creek conglomerate.

Belmont, Allegany County, N. Y.—493.

This is the locality called Phillipsburg in the New York State geological reports, from which many species are quoted.

The sandstone, which is quarried in several places in the neighborhood, is light gray, calcareous, and with petroleum smell. It is underlaid by a soft, olive shale, as is the case with the Cuba sandstone. It lies at about 1,450 feet elevation and represents very closely the horizon of the Rockville sandstone, 479.

Some of the more common species are—

Spirifera mesacostalis, second and third varieties.
Orthis impressa, large.
Streptorhynchus Chemungensis
Rhynchonella contracta.
Grammysia elliptica.
Productella hirsuta.

Hornellsville, Steuben County, N. Y.—494.

On my return eastward I stopped at Hornellsville, where I made an examination of some cliffs along the railroad west of the town, at which point is exposed a section of about a hundred feet, beginning at the base at 1,200 feet elevation, the railroad grade at the station being 1,161 feet above tide.

Running eastward along the Erie Railroad from Allegany County, the summit at Alfred, elevation 1,793 feet, presents some cliffs of heavy sandstones and shales which are well up in the Chemung; but as we go down the grade no strong sandstone layers are met with as far as Hornellsville, elevation 1,161 feet, and from there to Elmira, elevation 863 feet, the whole series is made up of alternate layers of arenaceous shales and stiff seams of thin bedded sandstone of a prevailing dark brownish gray, no light or pure grays appearing, nor are there any of the gray sandstones marking the Upper Portage and Lower Chemung of the Wyoming-Allegany section.

For topographical and stratigraphical reasons I thought that at about this point, which is intermediate between the two long sections of Tompkins-Tioga Counties and Wyoming-Allegany Counties, would be found the horizon at which the Portage and Chemung faunas meet. Stratigraphically it should lie not far from the horizon of the Portage sandstones of Portage Falls, and for similar reasons, looking eastward, it should lie several hundred feet above the horizon of the Ithaca shales. Upon examining the rocks I found it even more important than I had expected. The general appearance of the cliff is very similar to those in Caneadea Creek below Rushford, but here there are none of the light colored sandstones of Allegany County.

The section (494 A) presents the following lithological characters and faunas from below upward:

(1) A stratum of very dark, almost black, shale appears at the base; this is lithologically identical with the upper black streaks underlying the Portage sandstones at Portage Falls.

(2) These black shales are followed by soft fragile shales, olive gray in color, and bearing a very interesting fauna, marking very decidedly the transition between the Portage and Chemung faunas.

The species identified were the following:

Cardiola speciosa, common (=*Glyptocardia speciosa* Hall, 1885).

Palæoneilo plana, var. A small form frequently seen in the Portage shales; it appears indistinguishable from *P. plana*, except that in size it is much smaller

Coleolus acicula.

Coleolus (*Coleoprion*) *tenuicinctum.*

Fragments of a small *Orthoceras* and of *Goniatites* of the *G. bicostatus* type.

Productella speciosa, a single valve of small size.

Fragments of *Cladochonus* and of crinoid stems.

Orthis Tioga, several specimens, small, but with the characteristics of that species.

The *Cardiola* and the *Palæoneilo* of this shale (which are the principal fossils, the others being of rare occurrence) are identical with those of the last olive Portage shale of the section at Portage Falls, (see p. 51), and the whole fauna, except the *Productella* and the *Orthis*, is purely Portage in character.

(3) Above this are coarser shales and thin layers of argillaceous sandstone, staining brown in places, with occasional thin streaks of light or nearly white sand in the midst of the olive shales, just as they occur at station 476 G, in Caneadea Creek below Rushford, in which was found the earliest appearance of Chemung fauna for the eastern part of that section.

The fauna of this zone, 494 A^3, was as follows:

Leiorhynchus multicosta, running into the form *L. mesocostalis.*

Ambocœlia umbonata.

Productella speciosa, a few specimens.

Spirifera mesostrialis, a single specimen, but with the characteristic markings.

Spirifera mesocostalis, a single poor specimen

Orthis Tioga, larger than those below.

Rhynchonella Stephani ?, a coarse variety approaching *R. contracta.*

This fauna is in its main features like a forerunner of the Chemung fauna occurring a few miles south of Ithaca, lying far above the Ithaca fauna. The *Leiorhynchus* and *Ambocœlia* are the common species; the others are rare or seen in a few specimens. The list of species taken as a whole is similar to that of 476 G^0, at the base of the Chemung series in Allegany County, although the *Orthis* of that fauna is *O. impressa*, while this one is *O. Tioga.* This, however, is evidently a geographical feature, as the common species of *Orthis* in the Chemung faunas of Allegany County is *Orthis impressa*, while *O. Tioga* is the more common form in Tioga and Chemung Counties.

(4) Immediately following are more sandy layers, with Chemung fauna wherever fossils occur in them.

In one slab several good *Spirifera mesocostalis* were seen, all marked with the strong median septum not developed in the specimens living at the Ithaca stage. This single section throws considerable light upon the history of the faunas we are studying. Geographically it lies between the two main sections already fully developed. One of the most striking differences between those two sections is seen in the interval between the Genesee shale and the zone containing the first *Spirifera disjuncta.*

In Wyoming County this interval is filled by a long series, of a thousand feet or so, of black and olive shales, containing respectively the Lingula fauna of the Genesee and the *Cardiola speciosa* fauna of the Portage, and is terminated by thick deposits of gray sandstone.

In Tompkins and Tioga Counties the black shales terminate a short distance above the Genesee; a special Portage fauna, the *Spirifera lævis* fauna, occurs near the base of the Portage; a few hundred feet higher a rich brachiopod fauna, that of the Ithaca group, occupied the field. While two or three hundred feet of sediments were depositing, this fauna withdrew and the *Cardiola speciosa* returned, and is occasionally seen in the almost totally barren, flaggy, arenaceous shales and sandstones, until at about the same distance above the Genesee shale, as in the more western section, the Chemung fauna begins to appear with the first *Spirifera disjuncta.*

The stratigraphical conditions help us very little in interpreting these differences, except that the coincidence of the occurrence in each section of the first good representation of the *Spirifera disjuncta* fauna in a bed of heavy calcareous sandstone is suggestive of a common horizon.

The fossils of the Hornellsville shales show us definitely where we are in the history of the faunas. Stratigraphically these shales are at the general horizon of the passage beds of Portage Falls, and, compared with the eastern section, near the point at which the genuine Chemung fauna first appears.

The fossils show that the Portage fauna is still intact, even in the presence of a characteristic species of the true Chemung fauna, *Orthis Tioga.* The presence of this species, instead of *O. impressa,* shows that we are dealing with an eastern extension of the fauna. The *Spirifera mesocostalis,* with strong median septum in the ventral valve, as well as the *Orthis,* is evidence that we are far above the stage of the Ithaca fauna.

Taking all the facts together, we could scarcely hope to find stronger confirmation of the hypothesis advanced in my report in U. S. Geological Survey Bulletin No. 3 that from a paleontological point of view the Ithaca group and its fauna are really intercalated in the midst of the deposits which in western counties are regarded as one continuous series on account of their fauna holding its integrity from the beginning to the close. I regard, therefore, the Ithaca fauna as a separate, earlier stage of the Chemung fauna, intermediate between it and that of the Hamilton group and occupying an intermediate position; while the special fauna of the Portage shales is a more general one, probably of partially pelagic character, less restricted in both geographical distribution and geological range, but during the Middle and Upper Devonian making its appearance where the conditions were unfavorable for the more vigorous brachiopod faunas, and rarely, except at points of transition to another zone, mingling with any brachiopod fauna.

CHAPTER IV.

THE UPPER CHEMUNG—THE SANDS AND THE CONGLOMERATES.

As we pass above the principal Chemung faunas we find coarse, flaggy sands, red beds, and conglomerates. The conglomerates are of two kinds: The first is composed of smooth, gravel-like pebbles, with layers of flat pebbles, and is called the *flat pebble conglomerate.* The higher is composed of large, coarse pebbles, not much worn, and sand; this is the *Olean conglomerate* and its equivalents.

The exposures of these deposits were examined at Clarksville, 483; Little Genesee, 484; and Bolivar, 485, all in Allegany County, New York; at Portville, 486; Olean, 487; Great Valley, 490, of Cattaraugus County, New York; and at Bradford, 488, and Alton, 489, in McKean County, Pennsylvania.

Clarksville, Allegany County.—483.

This station is six miles south of Cuba and upon higher ground, the hills running up to two thousand feet above tide level. The rocks exposed are of a geological horizon higher than the highest of the Cuba section, but the base of the Clarksville section is the same paleontological zone as that seen in the ravine south of Cuba (477 E).

In the township of Clarksville, including the upper part of Wolf Creek, where the flat pebble conglomerate is seen in full development, we find the passage from the olive shales and the thin bedded sandstones of the Upper Chemung, with their typical fauna, through the coarse, yellow sandstone and flat pebble conglomerate with an occasional jasper pebble, which, all through this region, is recognized as the first of the Devono-Carboniferous conglomerates, and thence up into the green and red, arenaceous shales and those green, micaceous shales, of a loose and mealy texture, so characteristic of the Catskill deposits farther east.

The lowest exposure (483 A^2) examined in this locality was a ledge cropping out in a small run about half a mile northwest of the railroad station at an altitude of approximately 1,745 feet above the sea. Near this, in the same side hill, is the second exposure (483 A^1), from nine to ten feet higher. The rocks at these exposures are green, argillaceous shales, with thin, flaggy sandstones and arenaceous shales with fossils.

The green shales (483 A^2) contain the following species:

Rhynchonella contracta, numerous, large, and variable.
Leptodesma Mortoni, var., of the form of *L. potens* and *L. Mortoni* Hall.
Plant remains, chips, and fragments of stems.

In 483 A[1], a few feet above A[2], the shales are more arenaceous and darker, are iron stained upon weathering, and, though they contain the same *Leptodesmas*, the principal fossils are brachiopods. The sandy layers are micaceous, and though dark have a trace of the mealy texture peculiar to the green Catskill rocks as they appear farther east. One slab contains —

Athyris Angelica.
Leptodesma Mortoni, var.
Productella hirsuta, var. near *P. hirsuta*, but not the typical form.
Traces of *Rhynchonella*, sp., *Spirifera*, sp., and crinoid stems.

In other sla bs *Spirifera disjuncta*, *Athyris Angelica*, and the *Leptodesmas* are associated.

Taking the species occurring within two or three feet of one another as of a single zone, we have the following fauna for 483 A[1]:

Spirifera disjuncta, the most frequent species.
Athyris Angelica, common.
Rhynchonella contracta, small variety.
Leptodesma, sp., of the *L. Mortoni* type, some specimens approaching *L. robustum* and others *L. potens*.

And of the following species single specimens are rare:

Spathella typica, Hall, distorted, resembling *Nyassa arguta.*
Mytilarca Chemungensis.
Productella costatula, var., a small form of the type of *P. costatula.*
A trace of a *Pterinopecten*, sp.
Sanguinolites rigidus (=*Sphenotus contractus* Hall, 1885).
? Macrodon Chemungensis.

On the eastern side of the valley is a very steep, high hill, rising rapidly from the valley, and on its side the rocks occasionally crop out, not in solid strata, but in broken pieces, disintegrating rapidly, and partly covered by soil. The order of the rocks composing this hill is easily traced by these loose pieces on the surface, but it would not be safe to place any dependence upon the actual altitude of occurrence of any particular stratum. This is 483 B. The place for the lower conglomerate is between the base, about 1,880 feet, and the top, approximately 2,110 feet, in altitude, but I found no trace of the genuine conglomerate on it. The lowest rocks appearing contain the same fauna found on the other side of the valley, at 483 A. The rock is a dark, arenaceous shale, micaceous in some layers and weathering brownish. At the base of the hill, and within the first 120 feet, the above are the prevailing characters and the following species were detected as constituting the fauna of 483 B[4]:

Spirifera disjuncta, frequent.
Productella costatula.
Rhynchonella contracta, small var., and approaching the type *R. duplicata.*
Chonetes scitula, rare.

A small *Chætetes*, sp.

Orthis Leonensis, same as seen in the red beds of 477 E and green shales of 477 H.

Mytilarca Chemungensis, small var.

Athyris ? Angelica, probably *A. angelica*, but near the form of *A. polita*.

Sanguinolites clavulus (=*Sphenotus clavulus* Hall, 1885).

In the upper portion of this part of the section, 483 B^4, traces of the conglomerate are seen in the form of fine pebbles, with oblique bedding on the ordinary dark brownish gray sandstone.

A slab, one side of which is thus turned into conglomerate, contains a fine specimen of *Grammysia subarcuata*. Another slab, with the same *Grammysia*, contains also some imperfect *Rhynchonellas* of the *R. contracta* type. Large oblique *Leptodesmas*, of the *L. Mortoni* type, appear in the same association.

Above these fossiliferous shales (B^4) occur light colored green shales, not calcareous, but breaking up into lumpy pieces. They are arenaceous and with streaks of the fine green mud shales (B^3). Above these are thin, fragile, red shales, first in thin streaks with the green, but the top of the hill is a rich red earth of several feet in thickness, composed of the disintegrated red shales.

As well as can be determined from surface indications the uppermost hundred feet is composed of alternation of the green and red shales, some layers micaceous and mealy, others fine red mud shale, constituting the specimens designated 483 B^1, B^2, and B^3 in the collections, and at an altitude from two thousand to twenty-one hundred feet above sea level.

It is perfectly evident on ascending this hill that we pass from the Upper Chemung zone through the zone which in other places is represented by a conglomerate, the first or flat pebble conglomerate, and pass upward a hundred feet at least into the estuary or brackish water deposits represented in the green and red shales, devoid of fossils and often micaceous and presenting the peculiar mealy appearance so characteristic of the barren measures which separate the typical Chemung deposits from the conglomerates, forerunners of the Coal Measures.

Ascending the hill on the west side of Centerville Valley, or Dodge's Creek, and passing over into the valley of Wolf Creek, on the eastern slope, we find the same conditions. At the base traces of the Chemung fauna are seen for one or two hundred feet, then we run into the green and red shales, with traces of the flat pebble conglomerate intervening at an altitude of about 1,950 feet, above which the green and red shales hold on uninterruptedly to the top of the hill, over 2,100 feet high, and the micaceous structure is more frequent, with a tendency to form evenly laminated layers, separated by deposits of nearly pure grains of mica. As the mica grains are more abundant so also are they larger than in the rocks of the same horizon on the hill a couple of miles farther east. As we descend the western slope, into Wolf Creek Valley, we find traces of the conglomerate at the point of junction of the Chemung fauna bearing rocks below and the green and red barren shales above, and across on the west side of Wolf Creek Valley, near its head, is a fine representation of the flat pebble conglomerate.

The altitude of outcrop of this conglomerate on both sides of the hill is not far from 1,950 feet, and above 2,000 feet no conglomerate or fragments of it are seen. But in the small runs below this altitude large blocks of the coarse sandstone, merging into fine conglomerate, with streaks of larger flat pebbles, are frequent. On the extreme top of the hill, which by aneroid was estimated to be 2,250 feet above sea level, a loose block of nearly white sandstone with a few pebbles was found, but no outcrop. This may be a drift from the second conglomerate, but the several hundred feet of green and red shales below it preclude the idea of the occurrence of the first flat pebble conglomerate at this altitude.

Wolf Creek conglomerate.—483 C.

This conglomerate is best seen near the head of Wolf Creek, over the hill directly west of Clarksville, or "Centerville Station." The main mass of it lies between 1,950 and 2,000 feet in altitude (aneroid estimate), and it may be fifteen or twenty feet in thickness; at no place were both top and bottom seen exposed. In the bed of the stream are large blocks of it from six to ten feet thick. Its general character is a coarse, loosely agglutinated, silicious sandstone, of a yellowish color, in some places stained strongly brown, at other places bleached nearly white, obliquely laminated, with the direction of the obliquity reversed several times during its deposition, containing streaks of coarser gravel, and occasionally becoming a thick mass of gravel and flat, white, silicious pebbles, with an occasional pebble of red jasper.

The fossils occur at or near the top, where the rock abruptly changes into the ordinary brown gray, arenaceous shales, with distinct traces of the Chemung brachiopod fauna again. The animal remains of the conglomerate, 483 C, constitute a characteristic fauna recognized in several other places under like conditions. At this locality numerous chips of carbonized wood were found, as well as the following species:

Palæanatina typa, abundant.
Modiola præcedens, common.
Cyrtoceros ? Hector, several specimens.
Orthoceras ? sp. = ? *O. Demus.*
Goniophora Chemungensis, single specimen.
Leptodesma lichas ? resembling *L. lichas* Hall.
Spiraxis ? Randalli, var. Newberry.[1]
Spiraxis ? major Newberry.

[1] The name *Spiraxis* is preoccupied for a genus of Gasteropoda, by C. B. Adams, 1850. I propose, therefore, for this genus the name of *Prospiraxis*.
JUNE 1, 1887. H. S. W.

These last two peculiar spiral fossils are identified with *Spiraxis* described by Prof. J. S. Newberry in the Annals of the New York Academy of Sciences, Vol. III, No. 7, p. 220 (read December 10, 1883). Neither of them agrees precisely with the figures or specimens described by Professor Newberry; but, as the specimens themselves are imperfect and from study of these and other known specimens it is found that the detailed characters presented by their peculiar forms are not uniform, it is believed that the truth is more nearly reached in referring them provisionally to these species than it would be if an attempt were made to make them the types of new species.

Little Genesee, Allegany County, N. Y.—484.

Genesee is the next township south of Clarksville and lies next to the State line. The "rock city"[1] north of Little Genesee, 484 A, is about five miles south and a little east of the Wolf Creek conglomerate exposure west of Clarksville, 483 C. On the southern slope of the hill on the top of which "rock city" is situated traces of the Wolf Creek conglomerate were seen in slabs and blocks between the elevations of 1,925 and 1,975 feet. The rock was not seen in place, but fragments of it were met several times along this zone and none above. The small flat pebbles were very distinct from the round and larger pebbles of the second conglomerate of the "rock city." Along the railroad, from Clarksville to Little Genesee, as well as in the sections on the hillsides, the series of strata were in the same general order as at Clarksville. No extended exposure was discovered where the precise thickness of the individual masses could be measured.

The Chemung fossils were rarely seen above the horizon of the first (Wolf Creek) conglomerate and but for a short distance. After the green, micaceous, and flaggy shales and the soft, red iron shales had fairly set in, the Chemung fauna ceased.

With the incoming of the second conglomerate of Little Genesee "rock city," there was deposited a coarse mixture of clay, iron ore, and yellow sand with fossils.

DESCRIPTION OF RHYNCHONELLA ALLEGANIA.

This ferruginous sandstone is characterized by a *Rhynchonella* of large size, differing from any species lower in the series, but it also contains frequent specimens of *Spirifera disjuncta*, linking its fauna with the Chemung fauna below. I propose to call it

Rhynchonella Allegania, n. sp. Plate IV, Figs. 1–8.

This is a large rhynchonella, peculiar in this section to the coarse, ferruginous sandstones following the Chemung and found, generally, not far below the Olean conglomerate. It occurs in the form of empty

[1] The term "rock city" is applied to the massive conglomerates as they appear capping the hilltops in several places in the southern counties of New York. In Cattaraugus County, six miles south of Olean, a station of the Olean, Bradford and Warren Railroad, built upon one of these "rock cities," has received the name of Rock City

impressions in the coarse sand, but presents features separating it from the usual form of any of our Devonian rhynchonellas. Of the New York forms it approaches more nearly *R. orbicularis* or some varieties of *R. Sappho.* It appears identical in specific details with specimens I have seen in collections from Ohio marked *R. Sageriana,* but from the description of that species I believe it to be quite distinct. The costæ are more numerous than in the typical form of any of these species, from 10 to 13 being on each side of the center. It bears a close resemblance to some Eifelian varieties of *R. laticosta,* and the gutta percha cast of the exterior of a dorsal valve, represented in Plate IV, Fig. 3, is very close to *R. princeps* Barrande (Fig. 12, Plate CXX, Syst. Sil. Bohême). But after considerable study of the specimens and comparison with Devonian rhynchonellas I am led to the conclusion that it is scarcely more than a varietal modification of the rhynchonellas from the ferruginous sandstones of Licking County, Ohio, called *R. Sappho,* var., by Prof. James Hall and figured in Geol. Surv. N. Y., Pal., Vol. IV, Part I, Figs. 47-52, Plate 55, p. 354.

In the form in which it is here represented it appears quite distinct, and I therefore propose the name *Rhynchonella Allegania.* The characteristics of this form are its large size, the broad, flat sinus and fold including five to seven well defined, rounded plications; the broad, flat, tongue-like platform representing a depression in the shell itself, under the beak of the ventral valve (Plate IV, Fig. 8); the well defined serrations of the cardinal teeth seen in Fig. 1; the presence of a strong but short median septum in the dorsal valve (Figs. 1 and 4), with an elongated rounded beak of the ventral valve, perforated near the extremity (Fig. 7).

The specimens have been found in the ferruginous sandstones underlying the conglomerate at Olean and Little Genesee, in New York, and at Bradford, McKean County, Pa. In the larger forms the tongue shaped platform for muscular attachments in the beak of the ventral valve is very broad and flat, giving a peculiar appearance to the casts, unlike the ordinary rhynchonellas of the Devonian.

The same rhynchonella occurs just below the Olean conglomerate at Rock City[1] (487 A^3) in the same associations and in a ferruginous sandstone of the same character. On the way up the hillside to Rock City loose slabs were met with, though not found in place, presenting the same order of occurrence as at Clarksville.

Along the zone of the first conglomerate were found several slabs of the same character of rock and bearing the fossils of 483 B^4, i. e., *Grammysia subarcuata,* and some specimens running into the *G. communis* type, as figured by Prof. James Hall, and *Sphenotus clavulus,* with one specimen closely approaching the form called *Allorisma Winchelli* of Meek. In these gray, shaly sandstones *Spirifera disjuncta* appears; also *Rhynchonella contracta.*

[1]See note, p. 87.

Flat pebble conglomerate also occurs here with *Spirifera disjuncta*, *Rhynchonella contracta*, with traces of a *Bellerophon*, sp., and a bryozoan. In this fine pebble conglomerate, fish teeth appear, one very similar to that met with in a similar conglomerate, found loose in the bed of the creek at Rushford = a *Dipterus* tooth (*Dipterus ? lævis* Newberry); also conical teeth resembling those of *Holoptychius;* but only the casts are preserved, so that it is impossible to identify them with certainty.

This section confirms the order of these upper rocks as interpreted at Clarksville. After the regular gray green shale of the Chemung, with its brachiopod fauna (rich in *Spirifera disjuncta* and often containing *Rhynchonella contracta*), has passed its meridian and is nearly terminated, a flat pebble conglomerate is deposited locally. Sometimes the conglomerate contains seams of large flat pebbles, at other places it is a thin stratum of fine, very hard pebbles, often containing black and greenish quartz, all highly worn and bearing fish teeth, together with *Spirifera disjuncta*, or, where the conglomerate is several feet in thickness, it is terminated by a coarse sandy deposit, with the unique fauna of *Palæanatina typa* and *Mytilarca Chemungensis* and *Modiola præcedens*, with *Orthoceras* and the peculiar coiled stems which Professor Newberry has referred to the genus *Spiraxis*. (See note, p. 86.)

Above this conglomerate it is rare to find any Chemung fossils, but they do not entirely cease till the second conglomerate of 484, Genesee "rock city," the Olean conglomerate. Between the two conglomerates are red and green, argillaceous shales (the former sometimes bearing Chemung fossils), with flaggy, micaceous, green shales and sandstones. The intervals between these two conglomerates may average about three hundred feet, but the first conglomerate varies considerably in thickness and probably varies in the precise position it occupies in the series, since it probably represents a shore line which must have occupied consecutively a higher and higher position as the slow elevation brought it farther seaward from its earliest position.

Bolivar, Allegany County, N. Y.—485.

The rocks about Bolivar were examined, and, although no extended exposures were met with, all the evidence obtained confirmed the order of the series as already given. Bolivar is about four miles east and perhaps two miles north of station 484, at the "rock city," Little Genesee. The region for a radius of a mile or more is perforated by oil wells, and although, as above said, no good rock exposures were seen, there are along the steep hillsides slabs and broken pieces of rock which, from their very order alone, show that they are not far from their source. I collected the surface rock at various elevations on the hillside in the northern part of the town, on the "oil farm" of Varney & Co., and, upon examining the material, I afterwards found it arranged in the same order as in other sections in the county. The elevations must be regarded as only approximate, but for general purposes they are valuable.

Supposing the railroad station to be 1,600 feet in elevation, we find the greenish gray shales of the Chemung with some gray sandstone, containing *Spirifera disjuncta*, *Rhynchonella contracta*, and *Sphenotus clavulus*, up to 1,800 feet elevation. The flat pebble conglomerate occurs on the surface from this level upward for fifty feet, and in this conglomerate we still find *Spirifera disjuncta*.

Above an elevation of 1,850 feet the coarser gray sandstones are more conspicuous, with red shales and mottled arenaceous shales; toward the top, or above an elevation of 2,000 feet, coarse, micaceous and ferruginous sandstones are the prevailing surface rocks. From such a series of specimens we recognize the general position of the section. It is substantially the same as that seen on the hill separating Clarksville from the valley of Wolf Creek (see section 483 C), but as a whole lies a hundred feet lower down. The position of the flat pebble conglomerate is between 1,800 and 1,875 feet in elevation, and at Clarksville it is near 1,950 feet.

I obtained from Mr. W. T. Reed, the obliging superintendent of the Varney & Co. wells, the measurements from the mouth to the top and bottom of what are called by the oil men the "third sand," in this oil field being known as the "Richburg sands." As usual, the first oil sand is here regarded as lying about three hundred feet above the oil bearing third sand, although in drilling the place of the second was not clearly distinguished. Records of nine wells were given, the thickness of the third sand varying from thirteen to forty-seven feet. Taking the records as they are, measuring from the mouth downward, the top of the third sand does not vary over a hundred feet for the nine wells of which a record was made; but the average altitude of the top of the Richburg sand, for this lot of wells, according to aneroid measurements and estimates, is 800 feet above the sea, or something over a thousand feet below the flat pebble conglomerate of the Upper Chemung.

The nature of the "oil sandstone" from well No. 11, at the level mentioned above, after shooting the well, is like the gray sandstones of the surface twenty or thirty miles farther north. It is calcareous and contains a few black grains as well as grains of mica. No traces of fossils were seen in it. It is probable that this sandstone is represented at the surface farther north by the Portage sandstones at Portageville, 482.

Portville, Cattaraugus County, N. Y.—486.

This station is between Little Genesee and Rock City, Cattaraugus County; and the "rock city" of Portville is directly west of Little Genesee "rock city," and between four and five miles distant. The top of the conglomerate (486 A) is at an altitude of approximately 1,850 feet, as determined by aneroid.

The fossils found at its top and the relations of the rock to those below and above leave no doubt of its indentity with the Wolf Creek conglomerate (483 C) four miles to the north. We are able to trace the same zone in the side hill below the Little Genesee "rock city" and at Bolivar at approximately the same elevation.

The conglomerate is a massive, unevenly bedded, coarse, yellow sandstone, with a few pebbles scattered irregularly through the mass and some beds or layers of pebbles cemented by sand. At the top is a fossiliferous layer containing numerous fossils, the most abundant being *Palæanatina typa*, with several species of mytiloid shells. The pebbles are of the lentiform shape so characteristic of these lower conglomerates, and jasper pebbles are found among them, as in the other flat pebble conglomerates.

Above the conglomerate are dark, thinly and evenly bedded, micaceous shales, and within the next hundred feet are red, argillaceous shales and the greenish gray, micaceous shales characteristic of the deposits between the two conglomerates.

The species identified in this fauna, 486 A, are—

Palæanatina typa.
Modiola præcedens.
Mytilarca? sp.
Rhynchonella contracta, the ordinary type and a small variety.
Leptodesma? sp., a form near the *L. lichas*, Hall.
Orthoceras? sp., apparently identical with the species from the Wolf Creek conglomerate, 483 C.

No Chemung fossils were detected above the conglomerate.

Great Valley, Cattaraugus County, N. Y.—490.

The flat pebble conglomerate forms a "rock city" about six miles south of Ellicottsville, on the ridge separating Little Valley and Great Valley.

The first trace of fossils in loose slabs under the conglomerate is of the same fauna which runs up to the conglomerate at Wolf Creek, Allegany County, and other places in the same region. But in Great Valley I found no fossiliferous ledges in place. The elevation of the top of this conglomerate has already been carefully determined by Messrs. Chance and Hall, and is 2,190 feet above sea level and thirty-five feet thick. (See Report IIII, Second Geological Survey Pennsylvania, J. F. Carll, p. 203.)

The rocks are the ordinary flat pebble conglomerate, with some ferruginous streaks, while the main mass of the rocks is a coarse, yellowish sandstone. The sands are obliquely bedded and the direction of this beach lamination is reversed several times during the formation of the deposit.

The characteristic jasper pebbles are also found; but no fossils were found in any part of the conglomerate.

In all the elements of composition, structure, and color, this corresponds with the conglomerates of Wolf Creek, Portville, and places in Allegany County.

Olean, Cattaraugus County, N. Y.—487.

From Olean upward to the Rock City[1] conglomerate, six miles south of the city, the Upper Chemung rocks are exposed in numerous places, clearly exhibiting the general sequence of faunas and stratigraphical characters.

Olean, at the Buffalo, New York and Philadelphia Railroad depot, is reported as 1,435 feet in elevation; 1,430 feet is C. A. Ashburner's corrected altitude.

The first exposures in the hillsides are of Chemung rocks, containing the *Athyris Angelica* fauna, and for fully two hundred feet, extending to 1,700 feet in altitude, the characteristics of the Upper Chemung are conspicuous. Although thin sheets of red, argillaceous shale are met with in the midst of the ordinary greenish gray, fossil bearing Chemung shales, they become more conspicuous, in thicker masses and associated with coarser, micaceous, flaggy, and barren shales, as we ascend above the fossiliferous parts. The highest exposure of a characteristic Chemung fauna was found in gray, arenaceous shales two hundred and thirty feet below the first sandstone and about four hundred and thirty feet below the base of the Olean conglomerate. A considerable bed of red shales occurs half way between the first sand and this top of the Chemung fauna.

The first sandstone, as determined by examination in several places, is not uniform, but lies between two hundred and two hundred and fifty feet below the base of the conglomerate. This is evidently the sandstone which the oil well drillers on top of Rock City speak of as occurring about three hundred and fifty feet from the top of wells started above the conglomerate. The rock as found in places is of variable character. Below Rock City on the west (487 A^5 and 487 A^6) it appears in a few courses, none of which exceeds eighteen or twenty-four inches, of tough, yellowish, fine grained sandstone; some parts of these are marked by the borings of some worm similar to the *Fucoides verticalis* in the Portage sandstones below, but not more than a quarter as large, and occurring in great numbers, so that exposed and weathered slabs show as many as fifty of the small pittings, due to the deeper weathering of their exposed ends, in the space of a square inch. The lower layers of the sand are generally a little coarser and looser grain, more or less brown iron-stained. Above and below, red, argillaceous shales occur with the ordinary greenish shales, but at this exposure no conglomerate or pebbles were detected. Around on the north side, at the Cook quarry, the same zone is recognized, and at very nearly the same elevation, as determined by aneroid barometer. This is 487 C, the details of which will be given more fully beyond (p. 97). The particular sandstone in question is under a mass of red and green, argillaceous shales several feet thick; it is irregularly bedded, wedging rapidly in some layers from a

[1]See note, p. 87.

thin streak half an inch thick to a bed two feet or so thick and massive. Associated with it are beds of flat and small pebbles, beds containing fragments of plants in abundance, and in the upper layers are the fine vertical borings seen in 487 A^6 and also in the corresponding sandstones of Bradford, McKean County, Pa. The lower layers are of the more massive, fine grained, yellowish brown sandstone. The quarry, however, is principally worked for the excellent thin bedded, blue gray, micaceous flagstones lying below these yellow sandstones.

Above this zone of sandstone and conglomerate the rocks are green and red, coarse, mealy, micaceous shales and flags, and soft, argillaceous shales, until near the base of the conglomerate, where we meet the ferruginous sandstone containing the large *Rhynchonella Allegania* and the *Spirifera disjuncta* so characteristic of this zone.

Study of these sections and close comparison of the specimens from the various localities lead me to the opinion that serially there is a uniformity in the deposits for all of this region in Allegany and Cattaraugus Counties, however the minute details of the local sections may differ.

The characters marking the close of the Upper Chemung epoch are as follows: Deposits of thin bedded, alternating, argillaceous and arenaceous, bluish to greenish brown, fine grained shales containing the last Chemung fauna, with its characteristic variety of *Spirifera disjuncta*, with area high and overarching and not prolonged at the cardinal extremities, *Athyris Angelica* appearing in the softer, argillaceous deposits and *Rhynchonella contracta.*

As these conditions passed away the red shales gradually came in. These first occur as thin layers, appearing occasionally in the midst of the other rocks of soft, red shale; occasionally they contain one or two of the regular Chemung fossils. As we ascend, the red shales are accompanied by traces of the green, micaceous beds; but when the mica shales appear the fossils are very rare or wanting. When the prevailing character of the rocks is evenly laminated, loose textured, coarse grained, and micaceous, we look in vain for fossils.

At this stage in the sequence we look for the first sandy conglomerate. From examination of several sections in different places I am convinced that for these Southern New York outcrops, the first flat pebble conglomerate—carrying often jasper pebbles (with some variation in the thickness of the red shales above the last Chemung fauna and some difference in the extent to which Chemung species run up in the red bearing rocks)—occurs stratigraphically at this place in the series. It is not always a pebble conglomerate, but when only a gritty sandstone it generally contains a few scattered pebbles, and though Chemung fossils may not have entirely ceased at its arrival it is very rare in this region to find any of the characteristic species above it.

Above the flat pebble conglomerates, the red and green, argillaceous shales and the gray, micaceous, and flaggy shales prevail up to the

Olean conglomerate. In this interval are seen the coarse rocks which resemble the Catskill deposits of the eastern part of the State and contain *Holoptychius* and other fish remains. Just below the Olean conglomerate there is a ferruginous sandstone, as at Little Genesee, holding the same fauna, containing among other species the *Spirifera disjuncta.*

The Olean conglomerate is divided into two parts by a thin stratum of black shale, which doubtless represents the zone of the Marshburg upper coal or Sharon group of Mr. C. A. Ashburner (see Report of the Second Geol. Surv. Penn., R.); above this the conglomerate is less pebbly, the sandstone whiter and finer. This upper portion of the "rock city" section I regard as representing Kinzua Creek sandstone of the above mentioned report.

The records of oil wells drilled from the top of the Olean (Rock City) conglomerate agree in their general features with the facts developed by study of the outcrops along the hillsides. The drillers report about eighty feet, at the thickest point, for the conglomerate, including both members. At a depth of 350 feet they report the first strong sand seam of two screws' thickness; below this, "red streaks," but no thick red beds; at a depth of 1,250 feet is another sand of varying thickness, below which no red shales are found. Oil is struck in a sand at a depth of 1,860 to 1,865 feet.

Taking 2,340 feet as the altitude of the bottom of the conglomerate (see Report Second Geol. Surv. Penn., R), the top would be at 2,420 feet in altitude, and the first sandstone at 2,070 feet. The outcrop of this sandstone, as recognized on the hillside, was not so thick as the drillers reported.

At several places at about 250 feet, aneroid measurement, below the base of the conglomerate a massive sandstone was seen, varying greatly in thickness (see 487 A and 487 C). It is composed of a yellowish sand similar to that associated with the flat pebble conglomerates, with pebbles in some specimens. Along the hillside below this horizon were frequently seen large blocks of thick, massive sandstone of the same character, carrying traces of the same fauna met with in the flat pebble conglomerates farther north and east. These large blocks have been extensively used in and about Olean for building stone, and, although they are of an entirely different character from the Olean conglomerate, the actual ledge from which they came is not known, even by the most experienced quarrymen of the neighborhood. From study of the region I concluded that they were probably represented by the thin sandstone called C^3 and C^6 in the Milo Cook quarry. The blocks were found in several places nearly as high as this quarry and scattered on the hillside at all altitudes below, but I did not find one above. The wedge shaped beds of sandstone in that quarry explain the probable nature of the deposit throughout. It was doubtless thick and thin, as coarse sand might be expected to be deposited near a shore, with soft shale partings, which broke up the massive character wherever they were frequent or in thick layers. The more massive beds, when two or three feet thick, stood out during the general disintegration of the hillside, and breaking off finally rolled down the hill, but the massive portions were not continuous or uniform for any distance, and no regular ledge of the rock is detected along the slope of the hill. Seen along the hillsides at about the same horizon and loose below and reported at approximately the same position in the series by the well drillers, and by them found to be the only sand worth mentioning until passing below the red shales, these yellow sandstones show traces of both the flat pebbles and the fauna of the genuine flat pebble conglomerate, and they are the only rocks between the typical Chemung faunas and the Olean conglomerate which bear any resemblance to that zone.

I conclude therefore that, for the Olean section, these yellow sandstones are the representatives of the Wolf Creek, the Portville, and similar conglomerates farther north, east, and west, although they lie apparently higher stratigraphically in relation to Chemung marine faunas and in a more pronounced setting of red shales and green, micaceous shales than do any of the flat pebble conglomerates farther north and west.

This interpretation is further supported by comparison with the sections farther south and east, where the red and green shales and the coarser, micaceous deposits become more and more frequent and of greater thickness previous to the deposit of the great conglomerate, and as we go off in the southeastern direction the flat pebble conglomerate appears to lose its identity in the general increase of coarser deposits all through this part of the series.

Section 487 B.

Along the railroad, ascending the hillside from Olean toward Rock City, the rocks for the first hundred feet are gray, arenaceous shales and shaly sandstone, with some layers of softer, greenish, argillaceous shale, such as is common in the Chemung group. Rising above this, traces of the red shales appear. The lowest clearly marked red shale was seen at about 1,650 feet elevation, or something over two hundred feet above the valley, in the midst of ordinary shales with Chemung fauna. This is at an elevation but a few feet lower and in the same lithological associations as the first clearly defined red band of the section south of Cuba, 477 E.

The Chemung fauna, however, is not recognized much above this red shale; the species are very rare, and the fauna was rapidly disappearing when this six inch stratum of red shale was deposited. This Upper Chemung fauna is clearly marked by the prevailing presence of *Athyris Angelica*, the smaller variety of *Rhynchonella contracta*, and *Productella* of the type of *P. hystricula*. The *Spirifera disjuncta* is here the variety with high, overarching beak and narrow form.

The fossil bearing, arenaceous shales are frequently strongly calcareous, and upon weathering, by solution of the fossils and the calcite, they become cavernous and often are stained brown by iron.

The fauna, as well as the general character of the rocks, shows this series to belong to the same general zone as that represented in the sections south of Cuba, particularly 477 E. The fauna is that which followed the Cuba sandstone, 477 A.

Fauna of 487 B, H, &c.:

Rhynchonella contracta; the large form is rare.

Rhynchonella contracta, var. *saxatilis*. This small form is the common one, and some varieties approach the form called *R. duplicata* Hall.

Athyris Angelica, with some small varieties approaching *A. cora* and *A. polita*.

Spirifera disjuncta. The prevailing form is that of the short, high-beaked type, of small size, figured in Geol. Surv. N. Y., Pal., Vol. IV, Pt. I, pl. 42, figs. 1, 2.

Productella hystricula. The larger specimens approach more nearly the typical form of *P. spinulicosta* (or *P. Shumardiana*) and *P. hirsuta* and *P. onusta;* but the large majority of specimens are small, the ventral valve alone greatly resembling that valve of *P. dissimilis* Hall of the Iowa Devonian and the Lower Chemung beds of New York.

Ceriopora, sp. The hollow casts left by solution of the substance of the organism are frequent, but in such a condition as to forbid certain specific identification.

Sanguinolites clavulus, several specimens, (= *Sphenotus clavulus* Hall, 1885).

Sanguinolites rigidus, or varieties of the other form.

Leptodesma potens and varieties in the direction of the forms *L. Mortoni* and *L. Maclurii*.

Mytilarca Chemungensis, a single specimen.

Fragments of fish bone.

Plant fragments.

Fragments of crinoid stems.

A small, low coiled gasteropod, too imperfect to identify.

A fragment, probably of *Schizodus rhombeus*, but not distinct.

In the greenish shales at the foot of section 487 A (the stratum A^9) the fauna is apparently the upper part of this same zone, the one seen at Clarksville and Portville just below the flat pebble conglomerate. This is made up almost entirely of *Spirifera disjuncta*, with a few *Rhynchonella contracta*, normal size, and a few *Chonetes scitula* of the later type. This part of the fauna was not reached in section B. In these upper fossiliferous strata the absence of certain species is worthy of mention: *Streptorhynchus Chemungensis* and *Orthis Tioga* and the *Orthis* of the first red beds above the Cuba sandstone are none of them present in these Olean shales.

The arenaceous character of the strata has become prominent, and from this point upward the argillaceous shales are generally red or red alternating with a bright green and contain no marine fauna.

Cook Quarry, south of Olean.—487 C.

This quarry exhibits some points of interest. The base of the quarry is somewhat over 200 feet below the base of the conglomerate at Rock City.[1] It includes the same zone recorded as A^5 and A^6 in the section going down the slope westward from Rock City. It is also the same zone in which occur the last (on ascending) blocks of the fine yellow sandstone extensively used for building at Olean.

Mr. Milo Cook, the owner of the quarry, told me that he had searched in vain for the outcrop of this thick bedded sandstone. His quarry contains a few thin seams of like sandstone, but the main quarrystone is flagging of very fine quality, separated by thin layers of mica and cleaving into large, even flagging stone. The quarry exposes 50 feet of strata for minute examination.

The top of the cliff is covered with earth, lying upon—

C^1. Three to four feet of red, argillaceous shale, soft and compact.

C^2. Two to three feet light green, argillaceous shale, grading above gradually into the red.

C^3
C^4 } Ten feet, unevenly bedded.
C^5

C^3. Heavy bedded, gray sandstone, with some mica, but working pretty free; in the thickest part are courses of over a foot thick, from two feet running out to ten or even six inches.

C^4. Thin stratum of fine grained, argillaceous shale, light green, similar to the lower part of C^2.

C^5. Coarse sand, yellowish color, filled with fragments of fossil wood and plant stems of *Ptilophyton* and *Rhodea*, &c., containing pebbles in streaks, flat, and one of them an inch in diameter. This mass is very unevenly bedded and is broken up occasionally by thin sheets of the fine green shale.

C^6. Coarse to fine sandstone, in some parts nearly white, very hard, silicious sand, the upper layers perforated by fine vertical borings filled by the fine green clay shale; surface when weathered pitted by the open mouths of the perforations; ripple marked in some places, with flat pebbles and a few plant fragments, as in C^5. This mass is very uneven; in this one quarry it thins out from four feet to less than an inch in thickness. At this thin edge it lies between sandy shales, with plant fragments and soft, green, mud shale, is folded into regular undulations or furrows

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[1] This Rock City is a station on the Olean, Bradford and Warren Railroad, six miles south of Olean.

about an inch and a half apart, the effect of ripple action, and is completely perforated by the small vertical borings above referred to. This is terminated below by a few inches of green argillaceous shale.

C^7. Thirty-five feet dark bluish gray, evenly bedded, micaceous sandstone, very flaggy, cleaving into broad sheets, from one-half inch to six inches thick, the partings glistening with mica. About half way down (sixteen feet from top) is a thin parting of soft, red shale.

C^8. Below the bottom of the quarry, at least ten feet, rock of the same character as C^7, but coarser and unevenly bedded, showing current action, with oblique bedding, the direction of obliquity changing several times in course of the deposition of five feet.

The break between C^7 and the sandstones above is very marked. The sands above are of light color, yellowish and brown gray, with traces of iron stain. Flat pebbles are frequent, though not here found in any large quantity. Although grains of mica are seen, they are merely peppered through the mass of the sand and not spread out in even sheets. The lower sandstones are dark bluish gray, with thin, flaggy bedding, no browning or iron stains, deposited in very smooth, thin sheets with partings of mica grains, making excellent flagging. The better part of the sandstones C^3 and C^6, especially the latter, are similar and equal in quality to the blocks obtained abundantly in the valleys and upon the hillside south of Olean.

The same characters and order of sequence were seen in the section on the hillside westward below Rock City. Below a red, argillaceous shale, A^5, came the thick courses of A^6, with the same fine vertical borings at the top. The sandstone is of the same color and texture as C^6, and below this for fifty feet, more or less, the prevailing rock is the mealy, micaceous flagstone represented by C^7. The elevation is approximately identical as determined by aneroid.

Comparing the lithological characters with those of the flat pebble conglomerates farther east at Portville, at Clarksville, (Wolf Creek), and at Little Genesee, also with that farther west and north, the "rock city" of Salamanca, there is little to distinguish them. Looked at stratigraphically, this is full a hundred feet above the Wolf Creek and equivalent flat pebble conglomerates; but, when we examine the sequence of the faunas, this is the first genuine conglomerate, terminating the Chemung fauna and separating it from the typical red and gray shales of the Catskill conditions. On passing southward along this meridian we find the reds, in relation to the composition of the embedded faunas, taking a lower and lower place in the series, and they become more frequent and thicker; also the gray and green, micaceous flags, presenting a coarse and mealy appearance from the larger size of mica and sand grains, are more frequent and more fully take the place of the finer green and brown

Chemung shales the farther south we go. We also meet more frequently single pebbles in the ordinary fossiliferous shales going the same direction. All these facts point to an approach to the shore line and shallower water. Associated with this change we should expect thicker deposition for each of the strata, and hence the upper strata should not exhibit so great a dip southward as the lower. Thus, in attempting to solve the problems of equivalency between the New York sections of these rocks and those farther south in McKean County, Pennsylvania, I trust to this line of interpretation, based upon the following fundamental proposition, which I believe to be substantially sound: That, for deposits within a single geographical area presenting varying conditions in the nature of the deposits and in the fossils, a more reliable guide for determining equivalency will be found in the continuity of a well marked fauna with persistence of slight varietal characters, than in any uniformity, either in the nature of the sediments, or in their thickness, or in their order of sequence, except for very short distances of separation. And, in general, the coarser the ingredients composing them, the more restricted geographically will be found the specific characters of a continuous deposit.

A mile or so beyond Rock City the upper member of the conglomerate 487 F appears. There are twenty or thirty feet of this sandstone here exposed, which I regard as the representative of the Kinzua Creek sandstone of the Report of the Second Geol. Surv. Penn., R. It is here a coarse sandstone, with few or no pebbles; in the upper layers, particularly, it is purer white than the Olean conglomerate below. At its base I detected streaks of ferruginous shale and sandy shale, and at a point somewhat northeast of the Rock City station, on the top of the Olean conglomerate, I obtained some pieces of slaty coal and arenaceous shale, which Mr. Milo Cook, of Olean, informed me he himself saw dug out in making an excavation when the roads were being cut at the first oil excitement in this region. At that time he saw this black shale in place, and there were some two or three feet of the black shale with streaks of coal, which at the time caused hope of finding coal, but the digging revealed no solid coal, so the search was abandoned. The samples of this shale are marked 487 E^2, and attention is drawn to them as marking the horizon of the Marshburg coal of Mr. Ashburner's report. The whole mass of upper sandstone is of a white color, free from iron stain, and contains little cementing material, and what there is of it appears like fine clay or decomposed feldspar.

Several large stems were seen in this sandstone; one is a fragment of a *Sigillaria* stem.

The lower member, or true Olean conglomerate, corresponding to the conglomerate so defined in McKean County, is better defined as a coarse conglomerate with a sandy matrix and occasional streaks of sand.

Bradford, McKean County, Pa.—488.

After the careful and exhaustive work of Mr. Ashburner in McKean County it would be difficult to add much to the stratigraphical geology of this county as set forth in Report Second Geol. Surv. Penn., R. Mr. Ashburner in 1880 found the rocks from the Olean conglomerate to the bottom of the deepest valley, paleontologically considered, essentially one group, incapable of subdivision (op. cit., p. 292, § 388). But paleontologically the strata are certainly poorly provided with means of discrimination. As, however, the sections in this county, and especially the Dennis well section near Bradford, are authoritative and are extensively used for comparison, I took some pains to locate the fossiliferous zones of the corresponding series of Southern New York in this rock series exposed at Bradford. I examined such rock outcrops as I could find from the valley up the side of Mount Raub to the Olean conglomerate capping it. This is section 488 C; also along the hillside towards the Dennis well, 488 A. The materials collected, while not extensive, were sufficient to illustrate the general succession and position of the several fossiliferous zones. In the valley (1,440 feet at the railroad depot) and running up a couple of hundred feet are found the characteristic bluish gray, argillaceous and sandy shales and the thin sandstones of the Upper Chemung horizon, and in them, abundantly in some of the layers, the species of the upper fauna of the Chemung group.

In 488 C^8, A^1 and B^1, are seen the following species:

Spirifera disjuncta, with high, overarching area.
Rhynchonella contracta.
Productella arctirostrata, running into the type of the var. *lima* of *P. lachrymosa*, are the more common forms.
Ceriopora, sp.
Fragments of crinoid stems.
Leiorhynchus ? globuliformis, or one of that type.
Leptodesma, near *L. Mortoni* Hall.
Grammysia communis.
Palæoneilo.

This is the combination of forms frequently met with in the softer shales of the upper fossiliferous zone of the Chemung. Above this are red shales, gray and green, micaceous, flaggy shales, and sandstones.

A hundred feet or so above the last traces of this Chemung fauna a fine sandstone (A^3 and C^6), with the small vertical worm borings near the top, is clearly distinguished in both sections. This is mainly composed of sand, but also contains stratified layers of pebbles. The pebbles are generally small and smoothly polished, with a few larger flat pebbles and an occasional jasper. This I interpret to be the stratum No. 15 of the Dennis well, described as "S.S. gray, fine, mixed with slate, a few pebbles, specs. 26, 27; —23 feet, elevation 1,817 to 1,840 feet, and referred to the Red Catskill group" by Mr. Ashburner. (Op. cit., p. 288.)

At this zone a few fossils were detected, enough to show to what fauna they belong:

Spirifera disjuncta.

A small fish tooth.

A *Leptodesma* of the *L. Mortoni* type.

Palæanatina typa.

A cast of a lamellibranch, resembling *Schizodus oblatus*, but too imperfect for identification.

There is no place in the more northern sections to which such a fauna in such a rock can be referred, except the flat pebble conglomerate. Between this and the Olean conglomerate the prevailing characters are red and gray shales, greenish, micaceous, thin bedded shales, and sandstones. Not far above the sandstone A^3 and C^6, at C^4, *Holoptychius* scales and *Sauropterus Taylori* were found in thin bedded, shaly sandstone. Above this the only fossiliferous stratum detected is a band of ferruginous sandstone, C^3, in which were found the *Rhynchonella* and *Spirifera* characteristic of a similar ferruginous sandstone underlying the conglomerate at Olean and at Little Genesee.

In the present section this sandstone is separated by over fifty feet from the base of the conglomerate, and it is apparently in the horizon called by Mr. Ashburner the sub-Olean conglomerate of the Dennis well section; but it is not a conglomerate, nor did I discover any stratum of conglomerate except the one mentioned above on the hillside of Mount Raub. The Olean conglomerate is clearly represented at the top, having the same characters as at Olean.

Whatever may be said of the differences between the stratigraphical conditions of this Bradford section and the corresponding five or eight hundred feet under the Olean conglomerate of Rock City, I am persuaded that the sequence of faunas was the same in both cases. The faunas are sparse, both in species and in individuals, but they are clearly recognized in the same order of succession as that borne by them in the sections fartner north. They are not confused: *Spirifera disjuncta*, though found at each zone, presents varietal characters, clearly distinguishing the upper zone from those below. The Lower Chemung form is of the narrow type, with short or rounded cardinal extremities, with high, overarching beak, strong dental lamellæ, and strongly defined fold and sinus, the front produced, as in Figs. 1, 3, 11, 16, and 17 of Plate 42, Geol. Surv. N. Y., Pal., Vol. IV, Pt. I. This type prevails up to the zone of the flat pebble conglomerate, where it is occasionally seen. But in the ferruginous sandstone under the second Olean conglomerate the elongate type occurs, with mucronate cardinal extremities, the plications rather finer, the fold and sinus less strongly defined, the front not produced, approaching the typical characters of the Carboniferous *S. striata*.

I have called them all *Spirifera disjuncta* because a study of the forms appearing in the successive zones, as they are traced step by step, presents variations which link the prevailing type of one zone with the prevailing type of the succeeding zone. There is a variety in the Upper Chemung faunas which is indistinguishable from some specimens of the Iowa *Spirifera Whitneyi*, but its associations show, indisputably, that it is but a variety of *S. disjuncta* of our Upper Devonian.

Similar statements may be made in respect to many other species, but since it can be plainly demonstrated that the prevailing characteristics assumed by a species at one stage are very frequently, to say the least, not those assumed by it at the next succeeding stage, it will certainly lead to less confusion to use present specific names with some elasticity until the laws of modification shall be clearly distinguished in their relations to both geological range and geographical distribution. At the same time it has been my intention in these preliminary papers to point out any marked variation from the prevailing characteristics of species recorded.

The stratigraphical conditions are not uniform for the Bradford and Southern New York sections. In the Bradford sections there is a greater preponderance of red shales and green, micaceous, flaggy sandstone. Taking, however, the Olean conglomerate above and the gray and green shales with Chemung faunas below as two well defined boundaries, the differences in the intervening deposits for the northern and southern sections seem to me to be best explained as geographical variations in the nature of synchronously deposited sediments. Uniformity in the faunas and in the order of their appearance should testify more positively for equivalency of horizon than difference in the nature of the deposits should against it.

Alton, McKean County, Pa.—489.

The rock exposures south of Bradford lead rapidly up into the conglomerates, and in Lafayette Township we reach the first heavy coal seams of this area.

At Alton and at Buttsville I made a rapid survey of the sandstone and coal deposits and gathered materials for comparison with the sections farther north. No fossils except coal plants were detected. In the coarse sandstone underlying the first Alton coal are coarse stems of *Sigillaria*, apparently identical with those of the upper member of the Olean conglomerate at Rock City.

In regard to the lithological and stratigraphical features of this region little can be added to the excellent work of Mr. Ashburner (see Report Second Geol. Surv. Penn., R.). His Kinzua Creek sandstone is evidently the representative of the upper member of the Olean conglomerate, and the thin mass of black shale and shaly sandstone separating the conglomerate from the coarse sandstone capping the "rock city" represents the Marshburg upper coal of the Pennsylvania reports. The representative of the Olean conglomerate in Lafayette Township I found less massive and with smaller pebbles than the characteristic Olean conglomerate of

Rock City, Cattaraugus County, N. Y., or than that on Mount Raub, above Bradford.

The elevation of the bottom of the Olean conglomerate at Alton is 1,878 feet and at Buttsville 1,924 feet, as given by Mr. Ashburner (op. cit., p. 185). This gives an average dip of about twenty-five feet to the mile from Rock City southward, which agrees with the estimates I had made of the average dip of the upper strata in Allegany County. From all the evidence accumulated from surface exposures and position in the salt wells of Wyoming County of the Corniferous limestone from Genesee County to the edge of Allegany County the average dip is not far from fifty feet to the mile.

CONCLUSIONS.

Prof. I. C. White, in the Report of the Second Geological Survey of Pennsylvania (QQQQ, p. 77), calls the sub-Olean conglomerate of Mr. Ashburner the equivalent of his Shenango sandstone, and, as a sandstone, puts it in the midst of equivalents of Cuyahoga shales of Ohio. The shales below it graduate eastward into the Pocono groups. A study of the reports of Messrs. White and Ashburner, taken with my own examination of the rocks about Bradford, suggests the following conclusions:

(1) The Olean conglomerate is the equivalent of beds lying under the coal in Pennsylvania.

(2) There is a second conglomerate, with flat pebbles, under the Olean conglomerate, which must be regarded as of wide extent.

(3) The Pennsylvania geologists regard this lower flat pebble conglomerate (the "sub-Olean," "sub-Garland," &c.) as lying under the "Catskill" and in the midst of deposits equivalent to the Lower Carboniferous beds of Ohio and the West.

(4) It is recognized by them as lying in the midst of the Pocono group of the Eastern Pennsylvania section.

(5) My section shows it to be at the top of the Chemung and containing a fauna of decided Chemung type, which is distinct in some features, but appears in the shales below.

(6) These underlying shales in New York gradually run into genuine Chemung rocks and fauna and cannot be discriminated from them by any sharp line of distinction.

I have traced the conglomerate and the faunas coming up to it continuously from north to south and observe (*a*) an increase of green, micaceous slates, (*b*) the appearance of red shale (1) lower and (2) thicker, and (*c*) the sand deposits more conspicuous the farther south the section is made.

I conclude, therefore—

(7) That with the geographical passage southward the Upper Chemung beds grow coarser in their sands, the argillaceous bands become more micaceous, and the red bands are intercalated, and are present lower in the series;

(8) That probably the same thing occurred in regard to the higher deposits of the Carboniferous;

(9) That the total deposits were thickened on passing southward by increase in the coarse sands, but that the red and green shales may only take the place of the brown and blue shales farther north;

(10) That the sands are purer and whiter by becoming coarser and freer from the brown clay and mud forming the ordinary shaly deposits of the Chemung, in New York;

(11) That with the purer deposit of sand the sands themselves become more massive, and are thus more easily distinguished as sands from the shales between; and

(12) That the increased thickness of the total mass affects the dip of the rocks based upon that of the Corniferous, so that the upper strata are more nearly horizontal over Southern New York and Northern Pennsylvania.

(13) I judge from the numerous facts here arrayed that the conditions for the deposition of red shales were not congenial to the marine fauna of the Upper Chemung group. So long as they were but temporary—represented by thin layers or occasionally intruded in the midst of the ordinary green shales—the Chemung fauna was only temporarily disturbed by their presence, but when they became the prevailing sediment, associated with micaceous, flaggy sandstones and green shales, the Chemung fauna departed.

PLATES.

EXPLANATION OF PLATE III.

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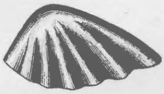
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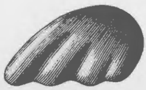
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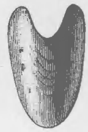
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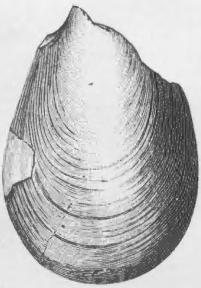
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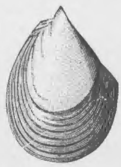
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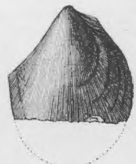
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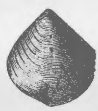
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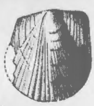
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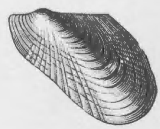
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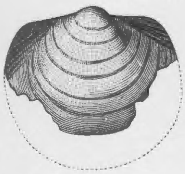
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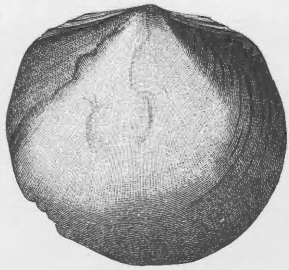
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UPPER DEVONIAN LAMELLIBRANCHS, ETC.

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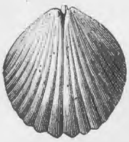

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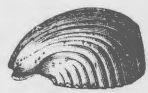

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UPPER DEVONIAN BRACHIOPODS AND ANNELID

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