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THE GEOLOGY OF SEMINOLE COUNTY, OKLAHOMA

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THESIS COMMITTEE

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THE GEOLOGY OF SEMINOLE COUNTY, OKLAHOMA

CHAPTER I

INTRODUCTION

Location

Seminole County lies in the east central part of Oklahoma, about 40 miles southeast of Oklahoma City and 65 miles southwest of Tulsa. Adjacent counties are Hughes on the east, Pontotoc on the south, Pottawatomie on the west, and Okfuskee on the north and northeast. The county is bounded on the south by the Canadian River; on the north by the North Canadian River. It includes approximately 620 square miles.

(See Figure 1, Index Map of Oklahoma, showing the location of Seminole County.)

Accessibility

Three railroads, one federal highway and five hard-surfaced state highways cross the county. The state also maintains several all-weather gravelled roads, and the county grades section line roads throughout most of the county. Except in very wet weather, nearly all of these are passable.

The economy of the county is undergoing a change from agriculture to ranching, and with it the land ownership pattern is changing. Half-section and quarter-section roads have been abandoned, except in a few cases; in some parts of the county, old roads have been fenced off so as to leave sections in blocks of four. Along the Vamoosa formation outcrop, and adjacent to the major streams, very few roads have ever been cut. However, it is usually possible to drive to within two miles of any point in the county.

Of the three railroads, only one--the Chicago, Rock Island, and Pacific, crossing the county in a northwest-southeast line, through Seminole and Wewoka--is a main line. The other two are branch lines: the Oklahoma City, Ada and Atoka, crossing the southwest corner of the county, and the St. Louis and San Francisco in the southeast corner.

Purpose

Field work in Seminole County was carried out as part of the state-wide effort preliminary to revising the Geologic Map of Oklahoma (Miser, 1926). The main purpose was to map accurately the formational contacts across the county. In addition, this study was designed to:

1. Solve certain troublesome correlation problems in the area, such as the subdivision of the Francis formation according to northern Oklahoma terminology, the relationships between the Ada and Pawhuska formations, and the

Fig. 1. Index map of Oklahoma, showing the location of Seminole County.

identity of the shale beds between the Belle City and Vamoosa formations.

2. Refine correlation of surface and subsurface formations in the area.

3. Clarify facies relationships developed along the strike of the strata.

4. Extend the accuracy with which the paleogeography and geologic history of east central Oklahoma are known.

Methods

Field, laboratory and library work were undertaken in connection with this study.

Field work was initiated in June, 1950, and concluded in August, 1951. Most of it was done in the summers of those two years. Field methods consisted of checking exposures, measuring sections with Brunton pocket transit and microaltimeter, collecting fossils, describing lithologies, and, in the case of very thin or otherwise poorly developed members, walking outcrops. Two hundred and sixty measured sections were made in and near Seminole County. Of these, some were intervals only, and were spaced, in a few places, as closely as 200 or 300 feet. Others involved detailed description of the rocks traversed. Township plats, scaled at three inches per mile, were used as field maps.

Laboratory work included many diverse activities. The township plats used for daily field work were constructed from air photographs. Culture and drainage were transferred to the plats. In addition, the air photographs were used for a rather detailed preliminary stratigraphic and geomorphic study of the county. For this purpose, a two-power magnifying lens stereoscope was employed. The information so gained was checked in the field by one or more of the methods listed in the paragraph above. This preparatory work obviated much walking of outcrops, and permitted most of the field time to be assigned to other enterprises. Eventually the township plats, with stratigraphic data entered thereon, were reduced photographically and retraced on to the final base map.

Laboratory work also included the cleaning and identification of fossils, the study of thin-sections from representative chert pebbles, the mechanical analysis of certain sandstones, the chemical analysis of certain limestones, the collation of thickness data and construction of stratigraphic cross-sections and isopach maps, the mathematical interpretation of truncation data, and the down-dip extension, by means of electric logs, of surface stratigraphy.

Library work was reserved, largely, until field work was complete and the conclusions therefrom had already been entered in the field notebooks. Prior to field work, only those papers which gave detailed stratigraphic locations, thicknesses and descriptions were consulted. Research in theory (i.e., the discussion of facies relationships in the lower Permian, by Dott (1930)) was not undertaken until after the final map had been drafted and most of the report had been written.

The above summary of methods is, of necessity, rather short. It does not mention occasional short term projects, such as the study of subsurface structure in a specific oil field, in an effort to check surface structural interpretation. This omission was made because the unravelling of structure was not one of the chief aims of this study. Structural anomalies in Seminole County in many instances consist of deviations, in position, by two or five or ten feet; such data can be obtained, accurately, only by plane table or similar methods. Time did not permit plane table mapping of so large an area.

Previous Investigation

A good topographic map of the entire area is not available. The United States Geological Survey at one time published an advance sheet (Seminole Quadrangle, undated) of much of the county, but this was never issued in corrected form, and in any case was not sufficiently detailed for a study of this nature. The Wewoka Quadrangle (1901), which includes a narrow strip of eastern Seminole County, did not overlap the area sufficiently to be useful.

Taff (1901) examined the strata of the Coalgate Quadrangle, to the southeast, and there named three formations (Wewoka, Holdenville and Seminole) which crop out in Seminole County also. Gould, Ohern and Hutchison (1901) studied the major units of rocks cropping out in east central Oklahoma. Girty (1915) identified the fossils in the fauna of the Wewoka formation. A discussion of structural materials in the county was included in a state-wide report by Gould (1911). All of this work was done prior to the first World War, and prior to the discovery of commercial oil in the area.

Snider (1917) described Seminole County in a geography of the state.

Jones (1922) examined the surface geology of the Wewoka area.

Morgan (1924) mapped the Stonewall Quadrangle, including the southern part of Seminole County. This proved to be the single most profitable source for descriptions, thicknesses and locations of exposures. With the exception of one unit (the Hilltop), Morgan worked every formation in the county.

Gould (1925) compiled an index to the stratigraphy of the state; this included most of the section in Seminole County, largely quoted from Morgan's previous work. Wilson (1927) summarized the paleogeography of the area.

The Geologic Map of Oklahoma (Miser, 1926) shows very well much of the areal geology of the east central part of the state.

The geology of Seminole and adjacent counties was reviewed by several authors (i.e., Levorsen, 1930) in a three-volume summary published by the Oklahoma Geological Survey in 1928 and 1930.

Green (1936, 1937) summed up the geology of the upper Pennsylvanian and lower Permian beds of the area. Sarles (1943) studied the DeNay limestone, and Ries (1943) mapped and collected fossils from the Sasakwa limestone. Oakes' work in northeastern Oklahoma (Oakes, 1952) contributed much to the writer's understanding of the regional picture.

The Skeltons (1942) compiled a bibliography of the oil fields of the state, including 30 pools in Seminole County.

In more recent years, Jackson (1948) studied the lower Pennsylvanian rocks in the subsurface beneath Seminole, Okfuskee and Hughes counties; Ries (1951) mapped in detail the stratigraphy of Okfuskee County; and Weaver (1952) worked out the geology of Hughes County.

CHAPTER II

GEOGRAPHY AND HISTORY

Climate

Eastern Oklahoma has a warm, humid, continental climate. Summers are long and hot, winters short and relatively mild.

The mean prevailing wind is from the south; the annual average velocity is 11.1 miles per hour.[1] The mean annual temperature is 61.8° F. The mean temperature for the three summer months is 78.7° F., for the three winter months, 44.8° F. The average maximum is 94.6° F. (August), the average minimum 29.3° F. (January).

The average annual precipitation is 43.26 inches, divided as follows:

Winter	-	6.51
Spring	-	17.15
Summer	-	11.62
Fall	-	7.92

(Snowfall - 4.2)

(See Table I.)

The average annual sunshine is 3,000 hours, or about 67% of

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[1]Most of the data in this chapter were furnished by the Tri-City Area Council, Wewoka.

TABLE I

METEROLOGICAL SUMMARY
TRI-CITY AREA

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Average Monthly Temperature from United States Weather Bureau Records												
1940	27.6	42.6	56.2	62.4	70.2	77.4	80.4	80.4	73.6	68.0	46.8	M
1941	M	M	M	M	M	71.6	81.1	81.0	74.6	65.5	52.2	46.0
1942	38.5	43.9	51.4	61.2	M	77.5	81.4	81.6	72.8	63.5	56.6	43.0
1943	41.6	49.6	47.9	66.4	71.0	81.6	88.0	92.9	77.2	62.0	52.4	39.4
1944	41.6	47.5	51.0	61.4	70.1	79.2	81.6	83.6	73.8	65.6	54.8	39.4
1945	41.0	43.8	57.4	61.4	68.2	75.7	80.2	79.7	73.4	63.1	55.2	38.4
1946	41.4	49.5	59.0	66.2	68.3	76.1	82.7	83.8	71.8	66.6	52.6	49.0
1947	42.2	43.3	47.6	63.8	70.0	77.8	78.9	84.8	78.3	70.2	48.9	44.4
1948	35.5	41.2	49.0	69.0	69.8	78.5	81.1	80.2	74.1	60.7	49.8	43.4
1949	33.3	40.4	49.9	59.7	72.1	78.9	84.4	79.5	69.3	61.2	53.3	43.7
1950	40.3	48.3	49.9	61.6	69.6	76.5	77.0	76.9	71.2	68.5	49.2	40.3
1951	40.7	45.2										
Average Monthly Precipitation from United States Weather Bureau Records												
1940	0.70	2.79	0.05	6.29	3.38	3.24	5.91	4.65	3.38	1.88	6.08	2.79
1941	M	M	M	M	3.43	6.74	1.77	3.19	4.38	19.50	M	1.73
1942	0.64	1.10	0.53	9.03	5.76	9.36	2.15	4.30	3.60	3.81	3.85	2.58
1943	9.20	0.42	3.00	2.49	10.39	3.42	1.34	0.03	4.91	2.00	0.23	4.27
1944	2.41	3.64	2.07	2.57	5.37	2.56	3.14	3.32	2.44	1.95	4.21	2.14
1945	1.32	3.26	6.33	6.75	2.65	11.37	6.13	1.60	10.15	0.67	0.55	0.72
1946	4.10	2.64	2.93	4.50	4.66	4.98	0.96	3.87	1.18	0.56	8.43	0.64
1947	0.50	0.03	0.76	7.48	6.96	6.59	3.63	0.44	4.55	2.02	3.04	1.99
1948	0.26	3.28	3.06	0.73	7.38	12.87	1.28	0.95	0.68	0.39	0.65	1.13
1949	6.50	4.75	3.08	1.56	12.66	4.21	1.46	3.31	6.12	4.93	0.28	0.78
1950	2.49	3.35	0.78	1.26	10.60	3.23	18.83	8.24	5.81	0.11	0.50	0.03
1951	1.79	2.53										

the total possible. The normal annual evaporation, from Class "A" pans, is about 70 inches.

Summertime temperatures have been known to exceed 112° F.

Despite the erratic rainfall, the writer found that, over a period of nearly two years, his field work was virtually unimpeded by bad weather.

Cities and Towns

The county seat is Wewoka, a town with a population, in 1950, of 6,753. The largest town in the county is Seminole, with 11,853 inhabitants. Villages and unincorporated communities within the county include Bowlegs, Cromwell, Hazel, Konawa, Lima, New Lima, Sasakwa, Schoolton, Snomac and Sylvian, with a total population of about 4,500. The figure for the entire county is 40,655, of which about 17,000 are rural (about 27 persons per square mile).

The population is about 85% native white, 10% negro and 5% Indian.

Soils

The Hanceville-Conway red-and-yellow podzolic soils occur throughout most of Seminole County ("Soils and Men," 1938). This soil group is found, in its widest development, in Arkansas, and is closely related to other soil groups east and south of Oklahoma. The appearance in Seminole and several adjacent counties is isolated to the east by a narrow belt of planosols.[2] Not very many miles west of the county, reddish prairie soils are found.

The alluvial plains and bottomlands do not fall in the above classifications. They are, instead, deep, coarse-textured sandy soils well adapted for many varieties of farm crops. Farms here are smaller, but more profitable, than those on the uplands.

The Hanceville-Conway soils are, in general, not cultivated, and the average standard of living on them is low. The vegetation cover is largely black jack, post oak and hickory. About two-thirds of the area is blanketed with shallow, stony or gravelly soils; elsewhere, the soils are fine sandy loams, and moderately productive. Where the ground is sloping or hilly, the soils are thin and rocky.

Most of the land is typically timber or pasture, perhaps one-fifth or less being cultivated. Corn yields 15 to 20 bushels per acre on the uplands, and cotton about one-third of a bale.

Agriculture

Approximately 8,000 farms are located in the Holdenville-Wewoka-Seminole area. The average acreage is about 140, and the annual gross income exceeds $20,000,000.

In 1948 the principal crop was peanuts, with cotton second. Peanut and pecan processing and packing plants are

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[2] Certain claypan soils.

located in the county.

Over 200,000 chickens are raised regularly by commercial broiler growers in the Wewoka area. Dairying is also important.

Industry

The chief source of income within the county is the oil industry. Between 1925 and 1948, oil production in Seminole County was 986,078,700 barrels. The production in 1948 was 12,176,731 barrels. Refineries are located at Cromwell, Sasakwa and Seminole. It has been estimated that one-third of the employable men in the county work in the oil industry and related trades. More than 85 oil field service and supply houses are located in the city of Seminole. Most of the acreage within the county is under lease.

Other industries produce boys' and girls' clothing, liquid propane and butane, brick and tile, furniture, leather goods and dairy products.

Water Supply

The town of Wewoka operates Lake Wewoka, with 4,800 acre-feet of storage. The town of Seminole uses 16 deep wells, eight of which produce 100 gallons per minute each, and eight 240 gallons per minute each. These vary in depth from 550 to 750 feet; they produce from sandstones in the Vamoosa formation.

Analysis of the Seminole municipal water gave the following data:

$CaCO_3$	34	ppm.
$MgCO_3$	15	
Na_2SO_4	87	
Na_2CO_3	134	
$NaCl$	20	
$NaNO_3$	2.5	
Solids	292.5	

History

Wewoka, one of the oldest towns in Oklahoma, was founded in 1866 in the heart of the Seminole Nation. The founder was Elijah J. Brown, who had been appointed by the federal government to bring Seminole Indians back from Kansas where they had taken refuge at the end of the Civil War because of split tribal allegiances. Brown established a trading post and became the first postmaster.

In his commission, the name of the town is given as "We-Wo-Ka, Seminole Nation, State of Arkansas." The word "We-Wo-Ka" means "barking water," presumably after a noisy creek flowing on rocky bed nearby.

In its early days Wewoka was a remount depot for the army. Both General Phil Sheridan and George Custer were stationed there.

The Seminole Nation selected Wewoka as the seat of government, and built a combination capitol and council house. Law-violators convicted by the council were shot at the foot of the "Execution tree" or flogged while tied to the "Whipping tree."

The Choctaw, Oklahoma and Gulf Railway came to Wewoka in 1895. Two years later the townsite was legally established within Indian territory, but no white man was allowed to own property there until 1902. In November of that year, the townsite was opened to whites without restriction. Chances on town lots were sold in many far-away lands, including Canada, England, South Africa and China. The drawing took place in front of the store of the Wewoka Trading Company, a territorial factor so powerful that it at one time issued its own money. The latter was known among the Seminoles as "choka sodka," and was redeemable in merchandise at the store.

With statehood in 1907, Seminole County was formed from parts of the Seminole and Creek nations, and Wewoka became the county seat.

The growth of the town of Seminole dates from 1926, its history paralleling that of the oil industry in the county.

In the last decade, the major operators have been pulling out of the area, and most drilling today is extension of known fields or semi-wildcatting by small independents. The early agricultural promise of the county has faded as the light, sandy soil has been depleted, and there is now a swing from agriculture to cattle-ranching and chicken-raising. Many cultivated fields have been abandoned, in some cases to natural reseeding from near-by forest. Concomitantly, the county's population has declined, from over 50,000 in 1940, to 40,655 in 1950.

CHAPTER III

PHYSIOGRAPHY

Introduction

Seminole County is an area of low-to-moderate relief, broken by an occasional high cuesta face or deeply-cut stream valley. A surprisingly large part of the county is masked by terrace deposits; much of the rest is shale topography, and therefore gently rolling.

Cuesta Belts

From the air, or on air photographs, the county proves to have a very definite grain, based on stratigraphic rather than structural control. The pattern seen from the air may be divided into five shale or cuesta "belts" trending slightly east of north, as does the regional strike.

These are, travelling from east to west and therefore climbing in the stratigraphic section, as follows:

1. The Holdenville-Seminole-Coffeyville cuestas. Developed on soft-to-medium-resistant sandstones interbedded with shales, these cuestas are spaced at various widths up to a maximum of about a mile and a half. They give the country a pronounced grain along the strike.

2. The Nellie Bly (or Upper Francis) shale belt. Cuestas are present in this interval, but they are generally not as well developed as in the two adjacent belts. Of those present, the more pronounced belong to the upper part of the section. Many of the thick shales of the typical Francis occur in this part of the county, developed as wide, gently rolling shale valleys. In the northern half of the county the sandstones grade to or interfinger with siltstones; there the cuesta pattern is locally distinct, locally subdued. Conglomerates which occur occasionally in this belt may be relatively resistant and appear as ledges, but more commonly are soft and therefore quite unlike most of the other conglomerates of the county.

3. The Belle City-Vamoosa cuestas. These two formations are, jointly, responsible for the most rugged topography in the county. In the southern half, where the Belle City limestones are relatively thick, the Vamoosa is rather thin; in the northern half, the Vamoosa has thickened greatly, but the Belle City has thinned to a few inches and disappeared. Immediately south of Wewoka Creek, the Belle City makes its last appearance as a cuesta-former. In about the same area the intervening shales are becoming much thicker; northward they are expressed primarily as a shale valley, more or less continuous with that of the Nellie Bly. For these reasons the Belle City-Vamoosa cuesta belt is hardly uniform north-and-south. Throughout its length, however, it is the domi-

nant physiographic feature, and provides the maximum relief of the county, rising in the northern half to about 1,200 feet. Rugged, less thickly populated, and poorer from an agricultural standpoint, the Belle City-Vamoosa belt can be outlined, roughly, on a roadmap as the strip where few section lines are marked by roads, and where the roads which do exist were laid out on a topographic basis.

4. The Ada-Vanoss shale belt. As is the case with Belt No. 2, above, these two formations contain several ledges sufficiently resistant to make cuestas. The ridges are broken, however, and the general impression is that of a high-level shale, protected primarily by the resistant, underlying Vamoosa. The Ada contains several sandstone, siltstone, limestone, and conglomerate members, but none of them forms prominent scarps. The Vanoss is more of a cuesta-maker in the southern part of the county, and more of a shale-belt in the northern part. The contrast with the two adjacent belts is generally strong enough, however, to be distinctive.

5. The Konawa cuestas. Slightly less rugged than the Vamoosa strip, the Konawa nevertheless stands clearly above the adjacent formations. It is, at a few places, marked by resistant chert conglomerates which dominate the topography thoroughly, lacking only the thickness of the Vamoosa to make it equal to the latter in relief. In the northern part of the county, the Konawa belt, though high, has lost much of its cuesta character. Here, too, agricul-

ture has been developed to a greater extent than on the same beds to the south.

Relief Statistics

Relief, measured within a square mile in any given area, varies up to a maximum of more than 275 feet. Within the shale belts it may be less than 50 feet. Maximum relief for the county (determined from United States Geological Survey quadrangles having a 50-foot contour interval) is approximately 500 feet. An important fraction of the area appears to be on hilltops at 1,000 to 1,050 feet.

More precise statistical values for Seminole County relief were obtained from the Seminole advance sheet (United States Geological Survey, undated), and the Stonewall Quadrangle (United States Geological Survey, 1901) and the Wewoka Quadrangle (United States Geological Survey, 1901). This required laying out a grid (spacing equal to one mile in both directions) and reading the elevation at each intersection. The contour interval determined class intervals. The total number of points taken was 652, broken down into separate counts for each of six areas.

Taking values at the mid-points of the class intervals, the county-wide distribution of elevations is as follows:

Contour interval midpoints	Percentages	Cumulative percentages downward	Cumulative percentages upward
1125	0.1	0.1	100.0
1075	1.6	1.7	99.9
1025	10.1	11.8	98.3
975	21.6	33.4	88.2
925	24.7	58.1	66.6
875	27.1	85.2	41.9
825	11.8	97.0	14.8
775	2.9	99.9	3.0
725	0.1	100.0	0.1

The median elevation is 890 feet, the mode 850 feet.

A plot of cumulative percentages on a bar-graph, with the bars lying horizontally (see Fig. 2) brings out clearly the fact that the county is primarily a gently rolling plain, 900 or more feet above sea level, incised by occasional streams down to about 750 feet above sea level. (See third column in the table, above.)

Counts for the six sub-divisions of the county indicate that the "rolling" character of the erosion surface is controlled by the underlying lithology. For a single lithologic unit (with the exception of the Belle City-Vamoosa cuesta belt, which boasts the greatest relief) the predominance of a single elevation is even more striking.

Modes and medians across the various shale and cuesta belts in the northern half of the county are as follows:

	(West)			(East)
Mode	925	875	975	875
Median	875	925	925	875

(Values picked by inspection from the array.)

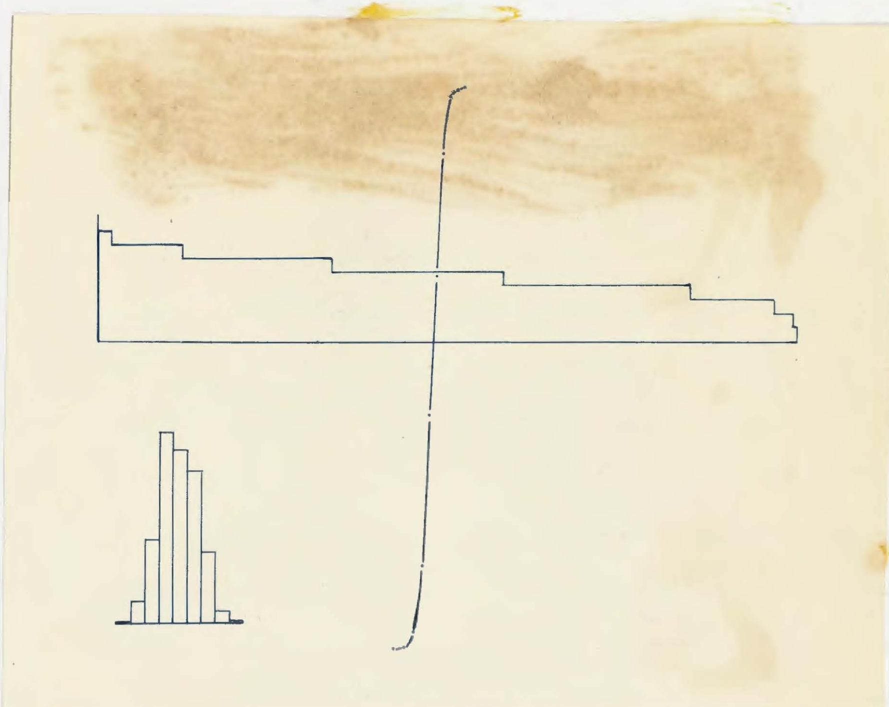

Figure 2. Histogram, cumulative percentage curve, and horizontal bar-graph showing the distribution of ground elevations in Seminole County. The data from which these figures were plotted are given on Page 21. The horizontal bar-graph was constructed to show elevation along the vertical ordinate, and hence to represent graphically the actual average relief of the county.

This variation according to lithology is responsible for much of the spread of the county-wide curve. Were the lithology more nearly similar, the present high erosion surface would probably be a rolling plain with much less than the 200 to 300 feet of relief actually exhibited. The original erosion surface undoubtedly was even more nearly featureless. This is the Pawhuska rock plain. (See Fig. 3.)

In addition to its gently rolling character, its very low relief, and its deep incision by occasional modern streams, the rock plain contains within Seminole County one area which probably stood even higher, perhaps as an erosional remnant. This rise, located in sections 1, 2, 11 and 12 of T. 9 N., R. 7 E., is apparently controlled by structure within the Vamoosa formation. It stands, today, 200 or more feet above the surrounding rock plain, and therefore probably had at least as much relief prior to the beginning of dissection.

Elimination of this high remnant, and the various deep valleys, from the array brings the one-time relief on the rock plain to a very low figure indeed.

Drainage

The main stream in or adjacent to the county is Canadian River, a superposed consequent let down from the Pawhuska rock plain. The Canadian flows now, as it did when on the high surface, in a general easterly direction, crossing

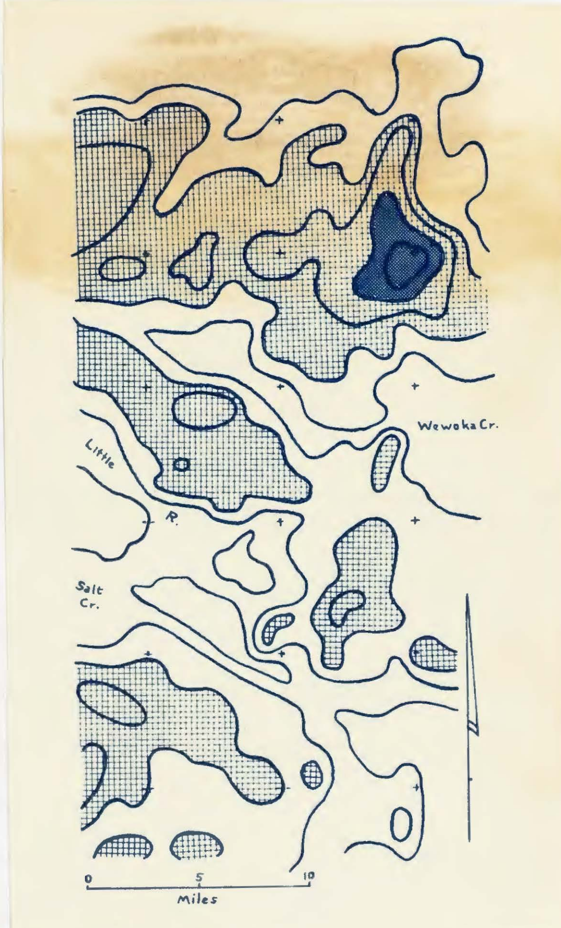

Figure 3. The Pawhuska rock plain in Seminole county, reconstructed by contouring a map showing only the highest hilltop elevation in each square mile. The lightly-shaded areas stand at or above 1,000 feet above sea level, the darkly shaded areas at or above 1,100 feet above sea level. The contour interval is 50 feet.

the strike almost at right angles, and apparently ignoring the structure or stratigraphy. This seemingly random pattern is misleading, however. Hendricks (1937) has described how a tributary of Little River tapped the Canadian, some 12 miles south of Holdenville, by working headward along a soft shale within the Wewoka formation. The present channel of the Canadian, as a result of this capture, parallels the strike for a distance of six or seven miles.

Other indications of structural control have also been noted.

The first order tributaries are North Canadian River, Wewoka Creek, Little River and Salt Creek. These, like the Canadian proper, seem to have been consequent on the high erosion surface. Structural control, although not rare, is of a highly localized nature.

Second order tributaries are chiefly subsequent streams; third order tributaries include obsequents and resequents. Fourth and higher order tributaries are largely gullies or intermittent branches.

From the foregoing it might be inferred that the overall drainage system shows a trellis or rectangular pattern. Although this is true in general, some of the drainage, especially in the shale belts, has a modified dendritic appearance; and fault (or fracture) control is observable on many of the tributaries of first, second or third order.

Stream gradients were not measured in the field.

They have been obtained from published topographic maps of east central Oklahoma, partly outside of Seminole County. The gradients thus determined[3] are summarized, in feet per mile, as follows:

River	Max.	Min.	Avg.	Miles Measured
Washita	7.70	3.03	4.00	42.5
Wewoka Creek	6.67	2.50	3.30	35
Little River	1.82	1.67	1.70	41
Salt Creek	12.50	2.86	6.36	11
N. Canadian	6.25	1.60	2.82	78
Canadian	20.00	3.70	6.86	51

The maximum gradient of the Canadian was measured across (in part) the Calvin sandstone, in the eastern part of Hughes County. The most resistant terrane in Seminole County--the Belle City-Vamoosa cuesta belt--is poorly developed at the point of the Canadian River crossing. The river apparently flows in a position north of Ada so located that minimum influence will be felt from either the Ada structural complex or the Belle City-Vamoosa belt. Canadian River gradients here range from 6.67 to 8.34 feet per mile.

Most of the permanent streams of the county are meandering, in one form or another. The Canadian River exhibits no well-developed floodplain, but shows a rough meander pattern which is now deeply entrenched. The radius of curvature of the individual loops is of the order of two to three miles. The modern river channel averages about one

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[3]Channel lengths measured with string and transferred to a suitable scale.

quarter of a mile in width, and the modern floodplain is ordinarily less than a mile wide. Details of the original meander belt must be inferred from high level terrace deposits; these indicate a possible width of about ten miles. Since meander belts are commonly 15 to 20 times as wide as channels, the earlier channel may have been about one half of a mile wide; that is, about twice the width of the modern channel.

Incision has been too recent, apparently, for the river to have done much toward carving out a new floodplain wide enough for free swinging of the meander loops.

Incised meanders which are well anchored or fixed, yet occupied by an important modern stream, seem to be limited to the Canadian River.

The North Canadian has a 200-foot channel swinging freely, although not complexly, across a floodplain a mile or more wide. Inasmuch as the earlier meander belt is about 10 miles wide, the earlier channel may have been about half of a mile wide. This is less than the width of the present floodplain, indicating that lateral swinging of the channel is responsible for the modern dimensions of the latter. The modern channel seems to be about one-twelfth as wide as the earlier channel.

The second and third order tributaries commonly show complicated meander patterns (altered, in some cases, by dredging operations).

Little River, where it crosses the resistant Belle City-Vamoosa cuesta belt, has developed--and in part abandoned--an impressive series of meander loops. (See Fig. 4.) These reveal, in clear detail, the earlier channel, but not the floodplain. The old channel is about 1,500 feet wide, with an average radius of curvature of less than a mile: a very tightly-weaving meander pattern indeed. Actual intersection of one incised loop by another is not rare; and in one case, the present Little River flows through such a narrows.

The modern channel, with a width of roughly 100 feet, meanders fairly freely along the flat, alluviated floor of the old channel. It now flows perhaps 150 to 200 feet below the surface below which the meander pattern was incised.

Passing from T. 7 N., R. 7 E. to T. 6 N., R. 7 E., Little River changes character. The dimensions of the old channel, given above, hold in a general way, except that the valley has been alluviated more deeply. The depth of incision was probably greater here than upstream; yet the relief is less, the steep valley walls so noticeable upstream having disappeared. This is due in part to a change in bedrock lithology, but deep fill is also indicated.

The contrast between the two channels is quite striking. It is so great, indeed, that it calls for a specific explanation not applicable to the other rivers of the region.

Bates (1939) concluded from a general study of mean-

Figure 4. The two channels of Little River where it crosses the Belle City-Vamoosa cuesta belt. The dotted lines outline the modern alluvium, which is confined to the floor of an older channel; the meander pattern of the latter is quite distinct. Sec. 1 is in T. 7 N., R. 6 E.

Figure 5. Bedrock outcrops in the same area shown in Fig. 4. Sec. 1 is in T. 7 N., R. 6 E.

ders and incised meanders that, for a stream having a channel width about that of Little River, the meander belt-channel width ratio should be 16:1 for floodplain meanders, and 41:1 for incised meanders (a factor of 2.56). This formula is applied to Little River only with some hesitation, because the modern meander belt is delineated by the old channel walls. Nevertheless, the floodplain loops seem to be migrating rather freely, and the formula may be of some value. In the case of Little River, the factor seems to be more nearly eight. "Auto-underfitness"--expected within the limits of Bates' factor--is probably inadequate to explain Little River's decrease in discharge.

Climate change, although probably effective throughout much of Oklahoma, fails to account for the Little River pattern because it appears on no other stream in the Seminole County area. Climate change, instead, seems to have been responsible for the oversize modern oxbows of Oklahoma and adjacent states (Melton, 1938). An excellent example of this may be found on the Little River floodplain, northeast of Sasakwa, and barely across the line in Hughes County (sec. 31, T. 6 N., R. 8 E.). (See Fig. 6.) This oxbow has about twice the width of the modern channel, and is located on the lowest (i.e., most recent) terrace level: the floodplain. It must be assigned to some origin other than that used to account for the larger abandoned loops further upstream.

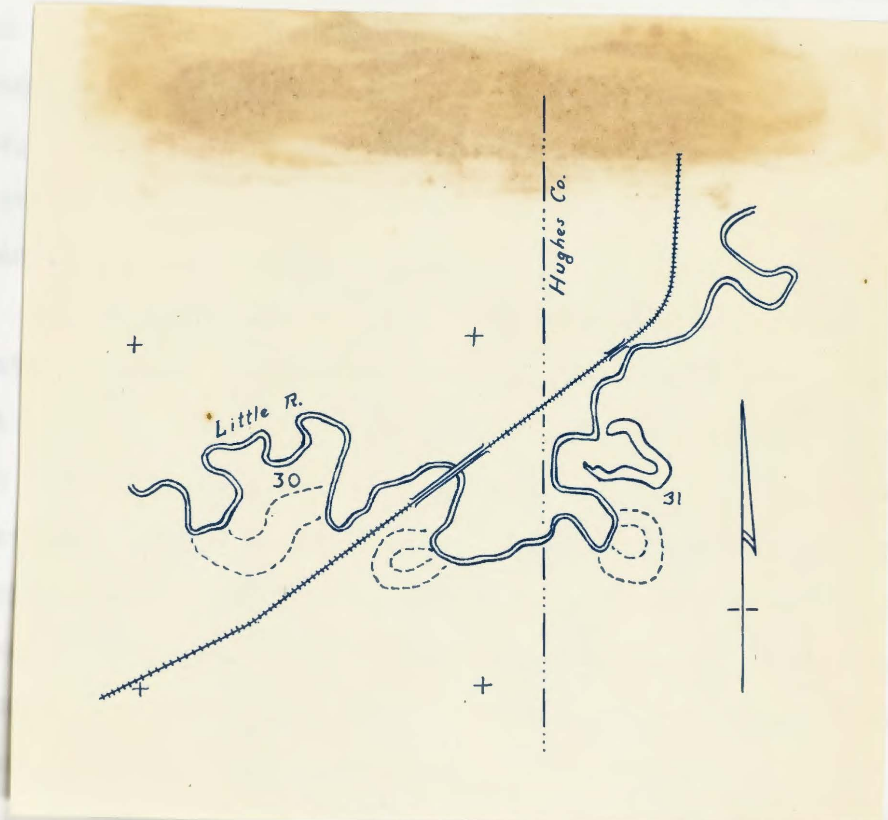

Figure 6. An oversize oxbow, and traces of a larger former channel, on the Little River floodplain, in sec. 31, T. 6 N., R. 8 E., Hughes County.

Stream piracy seems to be the most likely explanation for Little River's oldest meander pattern. Search for a possible point of capture was instituted, in the field, in Pottawatomie County (immediately west of Seminole County), and on 15-minute topographic sheets farther west. Lack of adequate map coverage prevented careful study of this problem, but it is possible that North Canadian River at one time flowed through the Little River channel, and has since been diverted northward.

Whatever the point of capture, the date of capture must be fairly late. The old channel of Little River had cut to an elevation very close to that achieved by the modern Canadian River, and perhaps more than 100 feet below the elevation of the elbow of capture where a Little River tributary tapped the Canadian. The beheading of Little River, then, must be much later than Gerty time. For some significant part of the Pleistocene, the two rivers must have been more nearly the same size.

Further, the late Wisconsin or Recent fill which has clogged the channel of the Canadian appears to be continuous with Little River fill for an airline distance of about 20 miles upstream from the confluence. It is probable that Little River was beheaded during Wisconsin time, prior to the deep alluviation of the valleys of east central Oklahoma.

Only three other streams in or adjacent to Seminole

County appear to contain deep fill: the Canadian, the North Canadian, and Wewoka Creek. It is estimated that this fill is of the order of 50 feet deep, at the most.[4]

The deep fill in the lower reaches of the Little River channel is probably controlled directly by the Canadian, to which Little River is tributary a few miles east of Seminole County.

At least one of the streams in Seminole County (Salt Creek) is aggrading at the present time. A small, recent fan, built where the creek passes under the Oklahoma City, Ada and Atoka Railroad bridge and debouches in time of flood upon an older but protected part of the floodplain, attests to this (sec. 13, T. 7 N., R. 5 E.) (See Fig. 7).

The fan is a product of deposition since the railroad bridge was built; this period coincides with the development and consequent erosion of much agricultural land along the Salt Creek watershed. Alluviation in this case may reflect poor farming practices, rather than a long-term trend in the behavior of the creek.

The oversize oxbow on the Little River floodplain (described above) indicates that this stream is cutting

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[4]Strain (1937) and Blanchard (1951) estimate Washita River fill at 35 to 40 feet. The Canadian, in that area, should be about the same. O.F. Evans has indicated, by personal communication, a similar depth for the Canadian fill in central Oklahoma. Fisk (1947) reported about 70 feet of fill at Ft. Smith, Ark.

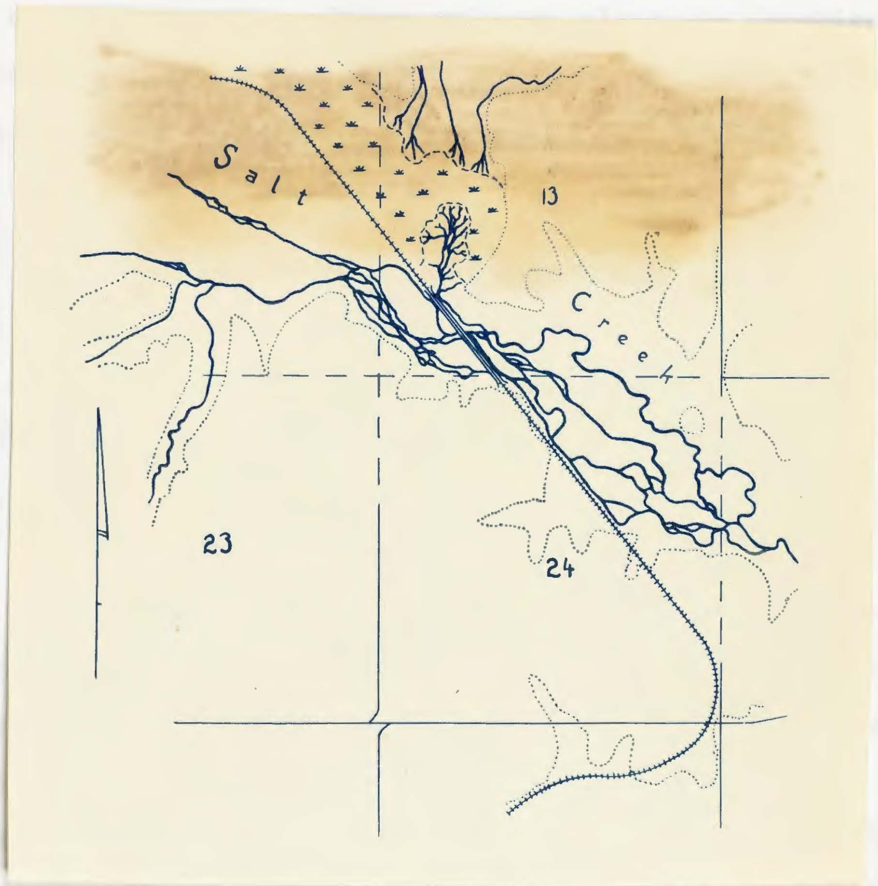


Figure 7. Aggradation of the Salt Creek Floodplain. The alluvial fan in sec. 13, T. 7 N., R. 5 E., is evidence that the unprotected floodplain (i.e., southwest of the railroad embankment) now stands appreciably higher than the protected floodplain (northeast of the embankment). The swampy character of the ground northwest of the fan is additional evidence. The Salt Creek floodplain has changed in this fashion since the railroad was built.

downward very slightly at the present. Since it is controlled almost immediately by the Canadian, the latter may be cutting slightly. Other evidence along the Canadian is related to highway and railroad bridge construction, and is not sufficiently old to indicate any long-term trends.

Stream Terraces

High-level terraces are common in Seminole County, but do not occur at easily recognized levels, as is the case in other parts of Oklahoma and adjacent states. Hendricks (1937) has described the Gerty sand--about 150 feet above the modern Canadian River water level--as such a terrace.

The Gerty is relatively easy to identify along much of the Canadian River watercourse, but in Seminole County, several complicating factors arise. One is the scarcity of the gravels which are considered diagnostic. These may be seen north of the river in southwestern Hughes County, or south of the river in northwestern Pontotoc County. They are not well-developed within the area of this study, however.

Another is the wide variation in elevation. Areas which have been mapped as Gerty occur as high as 210 feet above the modern river, and as low as 50 feet. Of many terrace elevations determined within the county, fewer than 10% fell in the range, 140-160 feet.

A third complicating factor is the existence of "draped" terraces (T. 5 N., R. 7 E.; T. 5 N., R. 5 E.). These are developed on slip-off slopes which have been widened as the river incised its meander loops. Each of these extends, without interruption or change in appearance, from maximum elevations of approximately 200 feet, down to the edge of the most recent floodplain or sandbar level. The meander loop, in each such case, is anchored or fixed (rather than migrating downstream); this, in connection with what was apparently a rather steady rate of downcutting, makes terrace designation precarious.

On Washita River, in the western half of the state, distinct terrace levels may be recognized. Strain (1937) and Blanchard (1951) have reported three distinct levels, and perhaps a fourth. These are younger than the higher, gravel-veneered erosion surface, but include the modern floodplain.

The second terrace stands at 30 to 35 feet above the modern Washita (both Strain and Blanchard); the third terrace at 70 to 80 feet (near Chickasha; Strain only); and the questionable "Smith Pit" terrace stands between the other two (Strain only).

The third terrace is early-middle Pleistocene, the "Smith Pit" intermediate terrace is late Pleistocene (based on fossils), and the second terrace, which was not reported to contain any fossils, must be very late Pleistocene or Recent.

Below the Arbuckle Mountains, Washita River exhibits sand terraces up to about 50 feet above the river, and sand and gravel terraces at about 100 feet above the river (Tishomingo Folio, 1903). The low range of levels is probably equivalent to the "second" terrace of Strain and Blanchard; the higher gravels may be the same as the "third" terrace reported by Strain.

The Washita is not precisely comparable with the Canadian, since they are controlled by two distinctly different local base-levels (the Washita flows into Red River). With the relatively low total relief across central Oklahoma, this difference should not be of great importance.

McAnulty (1948), working on Trinity River some 70 miles southeast of Dallas, Texas, reported upland gravels, three terrace levels, and the modern floodplain. The gravels occur at various elevations above the modern river; the three terraces stand at about 60 to 65 feet, 25 feet and 20 feet. As is the case along the Washita, the intermediate terrace exists in scattered fragments only. The three terraces are dated as post-Tazwell (i.e., post-Wisconsin 2), ?-Cary-Mankato interval, and ?-post-Mankato. Good fossil evidence is given for the post-Tazwell date only.

McAnulty reported the upland gravels at various elevations (but well above 75 feet); Strain gave instances at 100 and 110 feet; Blanchard considered them at least as high as 100 feet. Similar gravels are contained in third terrace materials (at 60 to 80 feet). Meade (1950) reported Aftonian (first interglacial) vertebrate remains from terrace gravels near Frederick, Oklahoma, 230 feet above Red River and 150 feet above North Fork.

The elevation differences between the several terraces would be expected to decrease upstream (as Strain reported), and increase downstream (as the author of the Tishomingo folio seems to indicate). Seminole County is some 80 miles down the slope of the upland surface from the localities where Strain and Blanchard worked; as a stream would flow, the distance is considerably greater. It is to be expected, then, that differences in terrace level would be greater in and near Seminole County than in western Oklahoma.

The lowest well-known gravel-bearing continuous or nearly continuous terrace in the general area is the Gerty surface, reportedly about 150 feet above the modern river. Although terrace deposits are found within the county along Canadian River at all elevations from above 200 feet down to the floodplain, not any of them form distinctly continuous terrace levels. Two of the best levels may be found at about 30 feet and 70 feet, respectively, and a third level may be found at about 90 feet, in T. 5 N., R. 7 E. This last-mentioned terrace contains pebbles, cobbles and even boulders derived from the Belle City limestone outcrop some four or five miles to the west; no quartz pebbles were found, however, as is typical in much of the Gerty. None of these three terraces can be traced more than a mile or two.

About 30 miles to the west, near Rosedale, on Canadian River, O. F. Evans has pointed out to this writer a well-developed terrace at 40 feet. In the same vicinity, hilltop silts, ostensibly terrace remnants, may be found between 90 and 110 feet above the river. The Gerty sand has not been traced westward into the Rosedale area, but hilltop gravels (higher than the silts) may prove to be Gerty. The Rosedale terrace is not continuous with any other terrace downstream.

West of about 97 degrees (west longitude), excellent terraces may be observed. East of that line, the terrace pattern becomes exceedingly complex. This may reflect longer periods of down-cutting, and shorter periods of relative still-stand.

The North Canadian is flanked by terraces at 35 to 40 feet, 65 to 75 feet, and 95 to 105 feet.

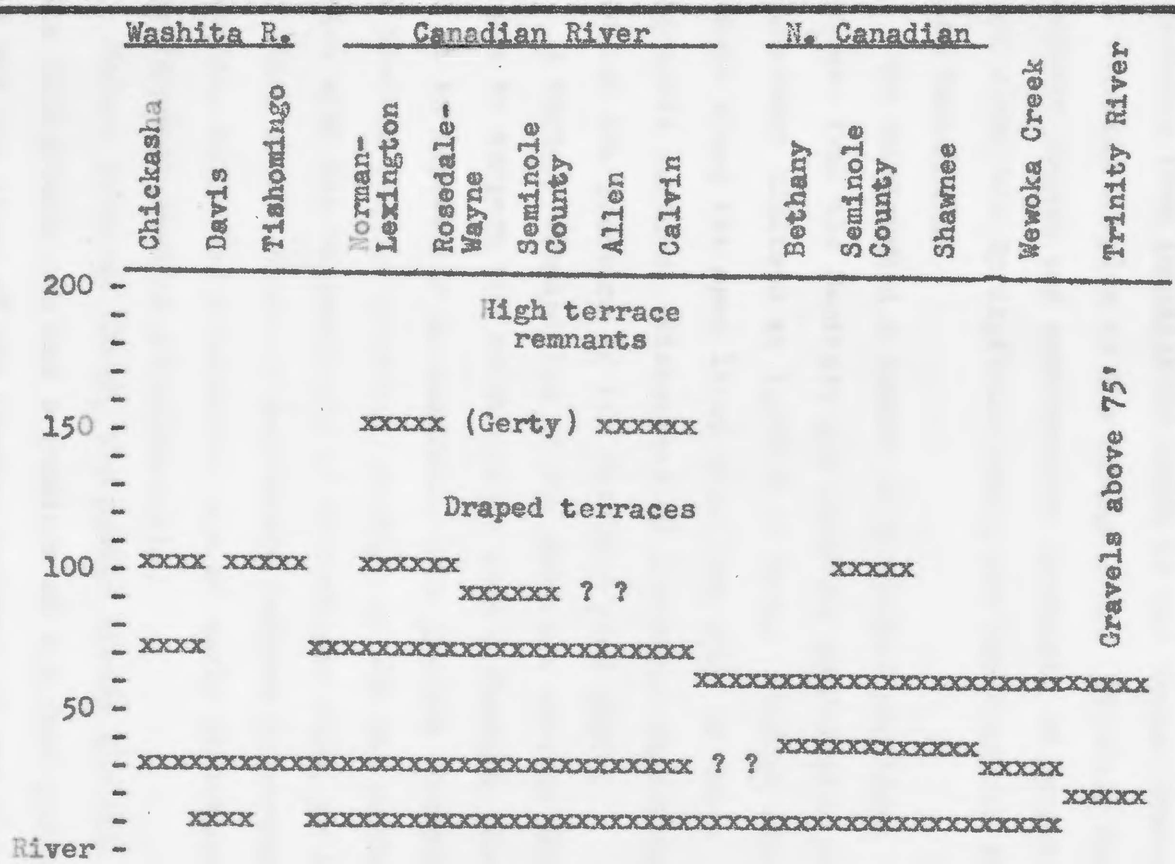
(See Table II for a summary of the various terrace levels.)

The Upland Erosion Surface

Melton (1935) and Ham (1939) have described the hilltop surface in considerable detail. Ham called it the Pawhuska "rock plain," a term which Melton defined as a surface of degradation, perched on resistant rock. The Pawhuska rock plain has been mapped by Ham, primarily from

TABLE II

SUMMARY OF TERRACE LEVELS IN SEMINOLE COUNTY AND ADJACENT AREAS



United States Geological Survey topographic sheets. It crosses Oklahoma in a north-south belt, lying between Oklahoma City and Tulsa, sub-parallel to the regional strike, and extending from immediately north of the Hunton Arch-Arbuckle Mountain complex to the Kansas line. Circling through southeastern Kansas and southwestern Missouri, it re-enters Oklahoma along the Springfield plain, and continues as far south as Tahlequah.

Ham constructed a number of projected profiles. Those taken from the Seminole and adjacent quadrangles reveal accordant hilltops at 1,000 ± 50 feet. Plotted dip components along the same lines show that this is not a stratigraphic surface. Histograms of elevation distribution also reveal the presence of the Pawhuska rock plain.

A cursory examination of the Seminole advance sheet leads one to suspect the existence of such a feature, although it is impossible to determine from the map (because of the 50-foot contour interval) whether or not the surface coincides with the regional dip of 90 feet per mile, or less.

Ham, on the basis of admittedly dubious long-range correlation, suggested a tentative age of early Pleistocene, perhaps Yarmouth (second interglacial).

Modern Arkansas River, the master stream for the Pawhuska rock plain, now has a gradient of 2.5 feet per mile. If this was the slope of the erosion surface, it has since been warped upward along its eastern edge by about 150 feet.

Such an uplift, deduced by Ham from intrenched meanders and other deep dissection, is just about enough to have tilted a 2.5 slope to a nearly horizontal position, across the 70 miles of intervening area.

Considering that the stream gradient figures reported earlier in this chapter were taken in a restricted area compared with the extent of the Pawhuska erosion surface, they agree fairly well with an initial slope as indicated by Ham.

The following characteristics, taken from Ham's study, hold true for the Pawhuska rock plain in Seminole County:

1. Smoothness.
2. Lack of higher hills (one exception mentioned above).
3. Uniform degree of dissection.
4. Stream-facing scarps across various lithologies.
5. Gently-dipping sedimentary beds are truncated.

Points 3 and 4 need further discussion for Seminole County. The degree of dissection, for example, is only relatively uniform as far as drainage density and depth of cutting are concerned. The different slope angles which have developed on the principal lithologies of the county stand in sharp contrast from one geomorphic belt to another. The steepest slopes are found in the Belle City-Vamoosa cuesta belt; here also may be found the blockiest limestones (with a few minor exceptions), the thickest, blockiest conglomerates, and the largest median particle size within the county. The gentlest slopes are found along "shale" belts where block-weathering is practically non-existent, and where median particle size falls in the silt or shale size range.

This difference in slope angle is reflected in appreciable departures from absolute uniformity of degree of dissection and local relief.

Weathering of Slopes

The steeper slopes of the Belle City-Vamoosa cuesta belt are accompanied by U-shaped or underfit valleys. These commonly occur on the second and third order tributaries; underfit characteristics of first order tributaries have been discussed earlier in this chapter. Stream piracy is hardly a general explanation of this phenomenon (except in a special case such as Little River); if adopted, it means that almost every stream, branch and brook in the county has been beheaded.

Certain streams may be underfit due to loss of water as a result of underflow through the alluvium (Wright, 1942). Field examination of the Seminole County streams does not make this explanation seem plausible, except possibly in the case of some of the larger, more deeply-alluviated valleys. For the second and third order tributaries, it seems an unlikely mechanism.

Highly seasonal rainfall may be responsible, in part, for the underfit streams. It is not thought to be of major importance, however, since during the wet season, these streams commonly do not attack the foot of the adjacent valley wall. The valley wall either has retreated in the past because of an agency no longer operating on it, or is now retreating more or less independently of the activity of the stream below.

That the latter may be the case is indicated by much of the gullying which cuts abandoned fields and pastures in Seminole County. The gullies seem to be of two types: those which have established a gradient lower than that of the slope on which they developed, and are now cutting the hill or ridge in two; and those which maintain the original slope, but cause it to retreat a foot or so. The latter type of gully is now quite common in the county. It is, of course, a manifestation of accelerated erosion due to agricultural and ranching activities. Nevertheless, it probably represents typical erosional activity within the county, if discrepancies in elapsed time are ignored.

Gullies of the second type--slope gullies--occur in sets, are sub-parallel, and have the same general depth throughout except for short distances at head and mouth. After extending a good part of the length of the slope, they begin to widen, destroying the narrow "divides" between them. As they grow wider, a stabilizing grass cover begins to grow along the gully floor. The result of such a gully cycle is the parallel retreat, for a distance of two or three feet, of the valley wall.

These walls, here and there marked by slope gullies in various stages of development, generally have fairly even gradients, convex upward at the top where they pass into the divide surface, and concave upward at the base, where talus, slump, soil creep and other evidences of the work of gravity may be observed. These processes lend to many of the slopes a modified sigmoid appearance, with long, relatively straight central sectors.

The valley walls seem to be reasonably uniform in slope within given lithologic boundaries.

Hence it is suggested that the "underfit" appearance of many of the tributaries is due to a roughly parallel retreat of the valley walls from the axial positions established by the incised streams.

This suggested mechanism is reminiscent of the Böschung-und-Haldenhang of Penck (1924), the pediment of Kirk Bryan (1922), the pediplain of Howard (1942) and King (1949), and the observations of many American geologists who, like Bryan and Howard, have worked primarily in New Mexico, Arizona or adjacent states.

A form of pedimentation, apparently operating under present Oklahoma climate conditions, has been observed by this author in the Wichita Mountains. A closely related process for Seminole County does not seem unreasonable.

The Deep Channels

Fisk, in his monumental studies on the Mississippi River (1947), describes the Wisconsin pluvial (or glacial) channels cut below the level of the present river. These are 400 to 450 feet deep at the modern coast line, about 215 feet at Natchez, and 70 feet at Fort Smith, Arkansas. The two intervals between the three identified points show fill-depth-decrease ratios of about eight inches per mile, and three inches per mile, respectively. If Canadian River fill along the south side of Seminole County is about 40 feet thick, the fill has been thinning westward from Little Rock at two or three inches per mile.

Such a correlation would establish the age of the cutting of the present bed-rock talweg as Wisconsin, or early Recent. Fisk dates the Recent history of the Mississippi as having taken place during the last 5,000 years, a figure not far out of line when compared with current radio-carbon figures.[5]

Pleistocene Geomorphology

The late physiographic history of Seminole County may be summed up in the following tentative schedule:

Late in the Tertiary or perhaps very early in the Pleistocene, east central Oklahoma was a gently rolling

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[5]The radio-carbon dates available at the time of writing were those published in Science (see Bibliography).

plain, crossed by widely-meandering streams having gentle gradients down to the east. A few erosional remnants, perhaps centered over structure, were scattered across this surface. Otherwise, the relief was a matter of some tens of feet locally, perhaps 100 feet or so over Seminole County.

The Pleistocene in Oklahoma was primarily a series of pluvial (rather than glacial) intervals. During these pluvial times, the vegetation probably became more luxuriant, and the hillside sheet-wash load lighter. Under such conditions, aided by increased discharge and therefore increased competence and capacity, the streams flowing across the erosion surface should have become incised.

An alternation of wet and dry cycles would, normally, lead to alternate periods of cutting and filling, each fill lacking somewhat of reaching the surface crossed by the river prior to the last previous cut. Hence a set of terraces would be developed in a more or less orderly stepped arrangement, with their relative degree of development dependent on the degree of climate change, and the vertical intervals between them dependent on the effectiveness of long-term scour in the bedrock.

If the Nebraskan (first glacial) pluvial had a climate not profoundly different from that of the Pliocene, the old erosion surface might have existed essentially intact through Aftonian (first interglacial) time.

Terrace dates from the area include the following:

Red River, 150-230 feet--Aftonian (Meade, 1950)

Washita River, 70-80 feet--early middle Pleistocene (Strain, 1937).

Washita River, 50 feet--late Pleistocene (Strain, 1937).

Trinity River, 50-55 feet--Wisconsin (McAnulty, 1948).

Canadian River, 150 feet--Pleistocene (Hendricks, 1937).

Cutting of the present bedrock talweg was accomplished during Wisconsin time, and construction of the present floodplain may be assigned to the Recent.

During the Recent, valley walls, especially in the Belle City-Vamoosa cuesta belt, have been retreating, giving the streams an underfit appearance. And at some instant--perhaps in Wisconsin time--Little River lost much of its water supply.

Stage of Development

The Seminole County area has been pictured as an incised rock plain. In fact, the very term "rock plain" carries the notion of incision. Despite frequent reference to this picture, the area has not been referred to as being in geomorphic youth.

The extremely low relief for such a large area has permitted many unusual situations to develop. For example, at several points between the Canadian River and Little River, a Canadian River terrace[6] (at 70 to 80 feet) stands higher than the divide between the two streams. That is, erosion has cut the divide down to a point lower than the top of the terrace. The terrace is relatively undissected, despite the fact that erosion in adjacent lithified shales and sandstones has been proceeding vigorously.

When the terrace was deposited, the divide must have stood significantly higher than water level; otherwise Little River would have tapped the Canadian. It is difficult to conceive of an erosion cycle which would permit the elimination (at places) of the divide, while the terrace stood relatively untouched.

The Pawhuska rock plain has been incised deeply, yet the region is neither mostly uplands, nor obviously mostly slope, nor mostly lowlands. Lowlands do not occupy an important part of the area, but it is not clear whether uplands or slope dominate. And, although lowlands may exist on as little as 10% or 15% of the area, that is a surprising range of values for an area in youth.

Despite the fact that lowlands are less extensive than uplands or slope, most of the permanent streams in and adjacent to Seminole County[7] meander fairly freely.

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[6]The city of Norman is located on this terrace.

[7]Exception: the Canadian River which has incised meanders only, no true flood plain.

Glock (1932) has discussed the situation where rejuvenation does not provide adequate relief for full development of the Davis cycle of erosion. In Glock's original paper, rejuvenation was considered in terms of uplift; in the east central part of Oklahoma, however, it may represent an "equivalent uplift" actually achieved by pluvial incision of the main streams. Whether rejuvenation is expressed in terms of actual uplift or equivalent uplift, the results are the same: if the newly-supplied potential relief is less than about 350 to 400 feet, the region will proceed through youth and then pass directly into old age. This supposes a transition period which is neither youth, nor old age, nor even maturity, but rather a mixture of the characteristics of youth and old age. A region in the transition stage might show both wide uplands and wide valley flats, incised streams which are now meandering freely, and relatively uncut uplands.

It is possible that east central Oklahoma is in late youth within Glock's "available relief" system.

For a more complete picture, however, due consideration must be given to the fact that many of the hillside slopes seem to be graded, and are retreating at more-or-less constant angles. The wide valley flats are in part due to the fact that all of the available relief is being utilized; but once this is conceded, it still must be recognized that additional widening of the valley flats proceeds by a mechanism not specified in the Glock scheme.

With these reservations, the region may be described as being in late youth. This does not imply, however, that the Davis cycle is accepted as being wholly applicable to the east central Oklahoma area.

Exposures

The presence of an old erosion surface suggests a deep profile of weathering (but not necessarily a thick top soil). This has had two effects in Seminole and adjacent counties. One is to make many outcrops somewhat more difficult to trace. The other is to make thicknesses difficult to measure, because of the bevelled character of many of the resistant ledges. The two or three feet of sandstone appearing along the ridge or crest of a cuesta may seem to be the complete ledge; however, the bed commonly thickens down dip, with the thickening masked under soils or shales of the backslope, until in the subsurface it appears several times as thick as when first seen.

Occasionally it is possible to note a difference between the dip and the angle of the backslope. This is not all shale interval; much of it may represent initial thickness (i.e., prior to bevelling) of the ledge. In many cases the depth of weathering has made it impossible to determine just how much of which may be present. In others, recent highway construction or other excavation has made the picture clear. And a comparison of surface and subsurface data often helps to bring out the true relative thickness of sandstone and shale.

Seminole County also has large areas masked by terrace materials. Most of this is fine to medium sand, some of it fine sand or silt. Such terraces are wide along the Canadian River and its first order tributaries (Salt Creek, Little River, Wewoka Creek and North Canadian River). Tributaries of higher order are occasionally accompanied by high-level terrace deposits.

A significant part of the county is masked by "first terrace" or floodplain deposits. In some places the floodplain-terrace combination is three or four miles wide. In view of the facts that most of the beds do not have distinctive lithologies, that fossils are rare and seldom diagnostic, and that thinning or truncation or structure may cause down-strike variations exceeding the average dip, a four-mile gap is a serious omission.

Generally it has been found possible to bridge gaps of this type on the basis of stratigraphic interval up or down from a known horizon; this has required measurement of an unusually large number of detailed sections. In at least one case, correlation across terrace deposits has proved unsatisfactory.

Of extremely high value in this connection have been the air photographs, made available through the courtesy of the Oklahoma Geological Survey.[8] On these appear much information not easily discernible in the course of ordinary field work. For example, in T. 5 N., R. 7 E., and in the lowest tier of sections in T. 6 N., R. 7 E., the DeNay limestone is masked for much of a three-mile stretch. The DeNay is, in this region, only two or three inches thick, and often soft or vuggy. It does not show through the overlying terrace deposits.

Morgan (1924) left the DeNay where it first passed under the terrace material, picking it up again along the line between sections 9 and 10, T. 5 N., R. 7 E. Here he mapped it for a few hundred feet across a hillside from which the alluvium had been stripped. The DeNay at this point, unlike where it had last been seen,

1. Occurred in several distinct layers, with shale partings between them,

2. Was laminated,

3. Had a light greenish-white color,

4. Was richly fossiliferous but not with the DeNay suite,

5. Was soft even in unweathered specimens, and

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[8]The pictures used, sold through the Production and Marketing Administration of the Department of Agriculture, Washington, D. C., are identified by the code letters BQL, strips 1 through 5. These were flown in 1938. More recent pictures have been flown, with markedly superior results, but these were not available at the time much of the field work was being done.

6. Was silty rather than limy.

It is possible, of course, that the DeNay had changed character, although Morgan said nothing of such a change. This author determined to start anew from the DeNay exposure, and work southward. This necessitated a great deal of photo work, since outcrops were not visible for a distance of nearly three miles.

In this area, the DeNay can be found, generally, 60 to 65 feet below the lowest sandstone in the Francis formation (i.e., No. 1). This, in turn, is a few feet below the No. 2. The DeNay was traced into the northeast corner of sec. 3, T. 5 N., R. 7 E. At this point, the intervals up to the No. 1 and No. 2 were confirmed by field measurement. These levels were picked up on the air photographs and traced southward. It was recognized that these levels, out on the alluvium, might turn out to be terrace levels, but this was a risk which had to be taken. Further, the levels soon became indistinct, and tracing on the photos became largely a matter of projecting an outcrop which was not there.

Projection was carried south across sec. 3, at which point the photograph positions were checked in the field. There was no evidence along the section line that the photo points were either right or wrong, so they were continued south across sec. 10. Both lines emerged from the terrace materials at the edge of a river-facing cliff which stands more than 100 feet high. Since both levels were near the top of the cliff, it was thought likely that the DeNay might be exposed there.

A check in the field confirmed this expectation: although only an inch or so thick, the DeNay was a typical dull bluish-gray limestone, weathered to a dirty mustard yellow on the surface, with few fossils but occasional calcite-lined vugs. Further, it was at the correct interval below the No. 1 sandstone, higher on the cliff. (See Fig. 8 to make these relationships clear.)

It must be emphasized that at no point in the two-mile distance did so much as a piece of DeNay "float" appear. Nor was there any good terrace level "break" to follow.

The same problem could have been solved, probably, with plane table and alidade, but not in the time necessary to make the projection on the photographs.

In many other parts of the county, photo work was of very high value. On beds easy to follow, it eliminated a great deal of ledge-walking, thus speeding the field work materially; and on beds difficult to follow, it made possible a more accurate map than could have been compiled from field data alone.

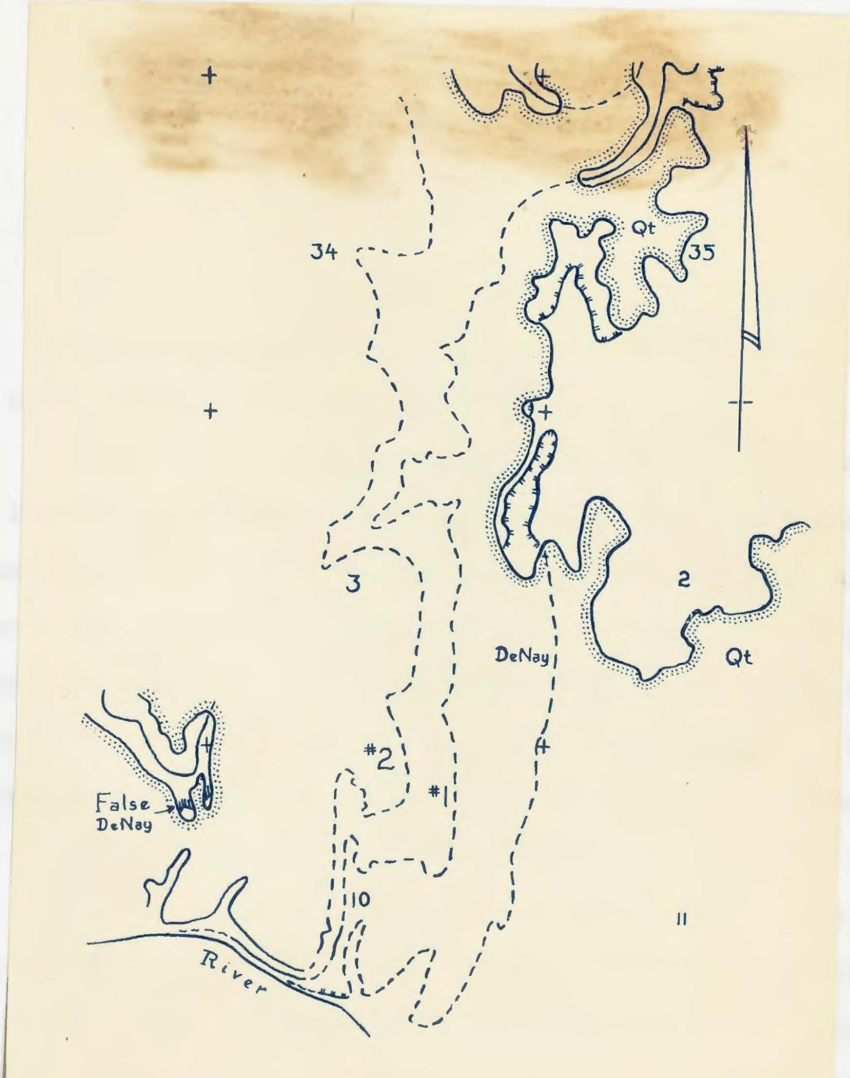

Figure 8. Correct and incorrect positions of the DeNay limestone in T. 5 N., R. 7 E. Most of the area is blanketed with terrace sands and silts. Extension of the DeNay southward from the outcrop was made easy by the use of air photographs.

CHAPTER IV

SURFACE STRATIGRAPHY

Introduction

Surface strata in Seminole County are of Pennsylvanian, early Permian and Plio-Pleistocene age.

The Plio-Pleistocene sediments are, largely, low to high level unconsolidated river terrace deposits consisting of sand or sandy clay. Terrace levels are not always clearly defined, and thicknesses are generally unknown but not great. The lowest terraces, including the modern floodplains, are composed of very late Pleistocene to Recent alluvium. No effort has been made in the course of this study to subdivide, correlate, measure or date terrace materials.

Permian sediments are exposed in a narrow strip along the west boundary of the county, and a somewhat wider area in the northwest corner. All of the Permian deposits within the county are included in a single formation--the Konawa--and its various facies. The Konawa is basal Permian by definition.

Pennsylvanian strata within the county represent three series: the Des Moines (about 350 feet thick; older rocks of Des Moines age may be found in Hughes County, to the east), Missouri (750 to 1,000 feet thick), and Virgil (700 to 1,100 feet thick). Pennsylvanian formations, with a few exceptions, thin and coarsen southward toward the Hunton Arch-Arbuckle Mountain complex. The latter was intermittently active throughout the time interval represented by Seminole County rocks, and the interrelationships between the two are both intimate and obvious.

The two main unconformities within the county occur at the base of and near the middle of the Virgil series. Other unconformities are minor; most of these involve members rather than formations. The Des Moines-Missouri contact is, to all appearances, conformable; the more important boundary at the top of the Pennsylvanian shows only local evidences of unconformity, if any at all.

It is not possible to make many sweeping and rigorous statements regarding the differences between the several series. There are noteworthy lithologies, to be sure, and certain regular changes, but these commonly do not coincide closely with series or even system boundaries. In general, however, the following points may be noted:

1. The southern part of the county is marked by limestone conglomerates, which thicken and coarsen southward. The source may be found in areas of modern exposures of the Ordovician, throughout the Hunton Arch-Arbuckle Mountain complex. These conglomerates are found in all four series exposed in the county, but their maximum development took

place in middle Virgil time.

2. Some of the southward thinning in the county is probably due to non-deposition, but the most spectacular thinning toward the south is the result of erosion, in the same area as indicated in item No. 1, above.

3. The arkose line of Morgan (1924) has been used, previously, to mark the base of the Pontotoc terrane (an assemblage of formations, including the Vanoss of uppermost Pennsylvanian age, and the Konawa). In the central and northern parts of Seminole county, the arkose line is useless or actually misleading; in the subsurface, arkose has been reported from many horizons below the Vanoss (Patterson, 1932; Moore, 1953).

4. Multicolored pastel shales are generally restricted to the upper Virgil (Ada and Vanoss formations).

5. Dark chert conglomerates are prominent only in the lower Permian (including strata exposed in Pottawatomie County, to the west). Pale chert conglomerates, on the other hand, are found throughout the section.

6. Permian, Virgil and uppermost Missouri sediments are, at most places, barren of macro-fossils. Good collections may be obtained from Des Moines and lower to middle Missouri strata, but even in these instances most of the species are probably facies forms. Paleontologic correlation is, therefore, not very helpful.

7. The emphasis on special lithologies, as above,

may well obscure the fact that most of the rocks exposed in the county are shale. Shales make up about 82% of the section, and sandstones and conglomerates about 13%. The remaining 5% includes siltstones and limestones. In the southern part of the county the sandstones and conglomerates are somewhat more important, perhaps exceeding 15% of the total; in the northern part, the shales may be as much as 90% of the entire section. This northward gradation from coarse clastics, to fine, is thought to be highly significant.

8. The limestones are rare and thin. The linear length of exposure of a limestone bed is rarely more than a few miles, and commonly only a few hundred feet. Many of the so-called limestones prove, by laboratory analysis, to be well over 50% insoluble residues.

9. With one exception (the Hilltop formation), distinctive red or maroon shales lie above the base of the Virgil.

10. Appreciably thick and continuous black or very dark gray shales are restricted to the middle of the Missouri series.

11. Biotite flake sandstones have been mapped from the middle Virgil, as much as several hundred feet below the arkose line which is supposed to mark the base of the Vanoss. Because of the susceptibility of biotite to weathering, such sandstones were not expected--nor were they found--except in

the extreme southern part of the county. It is thought that the arkose and the biotite were derived from the same source area, to the south.

12. Most of the pale cherts had an organic origin.

Eleven formations were mapped, in whole or in part, across the county.

Pennsylvanian System

Des Moines Series

Only two formations, both of upper Des Moines age, crop out in Seminole County. Of these, only the Holdenville (uppermost Des Moines) is fully exposed. The Wewoka formation lies largely in Hughes County, to the east, and appears only in part in the extreme southeastern corner of Seminole County. The sequence of Des Moines beds within the county is approximately 350 feet thick.

The entire Des Moines series is 2,500 to 3,000 feet thick and in the subsurface rests unconformably on Atoka rocks. The upper contact, at the base of the Seminole formation, does not show any convincing evidence of unconformity within the county.

Wewoka formation.

First reference: J. A. Taff, 1901.

Nomenclator: J. A. Taff, 1901.

Type locality: None specified. The town of Wewoka, after which the formation was named, is about seven miles from the nearest outcrop of the formation.

Original description: Taff (1901) first described the Wewoka formation as follows:

> Above the Wetumka shale there is a succession of massive and, for the most part, friable sandstones and shales, seven in number, in alternating beds 40 to 130 feet thick. These beds together are about 700 feet thick and are named the Wewoka formation, from the town of the same name in the Wewoka quadrangle to the north. The separate massive beds composing the formation are of sufficient thickness to be mapped, but on account of the obscurity of the contact lines, due to the friable nature of the beds, it is not possible to accurately distinguish them.
>
> The lowest of the four sandstone divisions of the Wewoka formation is thinner, though generally harder, than the succeeding ones. At its base there are local indurated beds of sandy chert conglomerate. These conglomerates are most prominent near the western border of the quadrangle where they form bluffs facing Boggy Creek valley. This group of sandstones and conglomerates becomes thinner eastward and northward, so that its outcrop is hardly perceptible on the border of the Canadian River valley.
>
> Above this sandstone and conglomerate there is fossiliferous friable blue clay shales for 120 feet, ending locally in thin white fossiliferous limestone. This shale is exposed in many deep gulches bordering the Canadian River on the south, and outcrops in the rolling prairie land between Allen and Leader. Especially good exposures may be seen in the deep ravines in the N. E. ¼ of Sec. 23, T. 5 N., R. 8 E., where abundant fossil shells weather out free and occur in calcareous clay concretions.
>
> The succeeding sandstone member is about 110 feet thick. It caps the high land near the western border of the quadrangle, south of the Canadian River and forms high bluffs surmounting the escarpments, facing eastward upon the north side of the river. Its beds are massive and friable, breaking down readily into loose sand and weathering into rounded ledges.
>
> Above this sandstone, and near the middle of the formation, there is a soft fossiliferous blue clay shale nearly 130 feet thick. This shale is remarkable for the abundant and perfectly preserved fossil shells which it contains. Its full section is exposed on the Memphis

and Choctaw Railroad, 2 miles north of the mouth of Little River. Above this thick shale there is a sandstone 60 feet thick, which is succeeded by 45 feet of shale. Next above comes the highest sandstone member of the formation, which is estimated to be about 100 feet in thickness. The uppermost beds of this sandstone are shaly and culminate in a shelly sandy limestone. The uppermost strata of the Wewoka formation are concealed for the most part in the valley of Little River, across the northwest corner of the quadrangle.

On account of the friable nature of the sandstone, fine loose sand derived from it is spread over the whole surface of the formation north of the Canadian River, as well as over the western parts of its outcrop south of that stream. The soil is a loose sandy loam and the country is covered by heavy forest.

Other descriptions: Morgan (1924) studied the Wewoka formation farther west, where he found it to be as follows:

Several sections measured in the Stonewall quadrangle show a total average thickness of 400 feet for the Wewoka. The top and bottom of the formation are marked by definite sandstone ledges that were mapped without difficulty. The basal sandstone, as well as several other members, locally grades into chert conglomerate. The most extensive development of such conglomerate in the basal member of the formation occurs at the top of the escarpment in the northern part of Sec. 18, T. 3 N., R. 7 E. A little over a mile northeastward a thick chert conglomerate also caps the high point that projects southward from section 4, into the northern part of section 9. This deposit represents a local development in what is normally a sandstone that occurs about 90 feet above the bottom of the formation. Many other sandstones in the formation also carry small quantities of chert conglomerate, but by far the greatest development of this type of clastic material is in the two members that occur at the base and approximately 90 feet above the base of the formation, respectively.

In the upper part of the formation there are several very characteristic beds among which there is a thin limestone that is rich in specimens of _Fusulina_. Near the center of the formation in Sec. 5, T. 4 N., R. 8 E., several cross-bedded sandstones were observed.

The top of the sandstone bed, which marks the top of the formation, locally grades into limestone. This development is quite common from the southwestern part of T. 4 N., R. 7 E., northeastward to the edge of the quadrangle. In the vicinity of the fault in the northern part of T. 3 N., R. 6 E., no lime was observed at the top of this bed, but southward, beyond the fault, it again appears. A limestone also occurs at the top of the sandstone which is thought to represent the top of the Wewoka in the Franks graben.

In the northern part of T. 3 N., R. 6 E., limestone conglomerates are quite common in the upper part of the Wewoka formation. That these conglomerates were derived from the Arbuckle Mountains is indicated by the contained fragments, many of which closely resemble the Hunton and Viola limestones.

Just east of the center of Sec. 32, T. 5 N., R. 8 E., southwest of Allen and beyond the limits of the Stonewall quadrangle, there is a conglomerate that is very unusual. It differs from the sediments below the Pontotoc terrane in that it carries pebbles of igneous material. The bed could be traced for only a few hundred yards. The igneous material contained is darker and more fine-grained than the average arkosic material which is so common in the Pontotoc beds and it seems improbable that the two were derived from the same source. The nature of the igneous material in the Pontotoc strata and the fossiliferous limestone fragments associated with it clearly indicates that it was derived from the Arbuckle Mountains. The source of the igneous pebbles in the Wewoka occurrence, however, is unknown. The pebbles are mostly small and well rounded and may have been brought in from a distant region.

Ries (1951) mapped the Wewoka formation in Okfuskee County. His description follows:

The Wewoka formation consists of a succession of thick shales with friable sandstones and a few local limestones. In all, 17 units were mapped, 13 of which were traced across the entire county. Generally speaking, these 17 units may be found out-cropping in four distinct escarpments. . . .

The uppermost Wewoka sandstone is the most massive of all the Wewoka sandstones and can be traced across the entire county. The sandstone is soft, friable, fine-grained, and reddish-brown in color. It is 42 feet thick in the southeastern part of Sec. 27, T. 11 N., R. 10 E. The sandstone thins northward. . . .

The Wewoka formation has a composite thickness ranging from 780 feet in the southern part of the county to 730 feet along the northern boundary.

Weaver (1952) examined the Wewoka formation in Hughes

County. He wrote the following description:

> In Hughes County the Wewoka formation consists of four massive to thin-bedded sandstone units with thick, interbedded and intertonguing shales. The average thickness of the formation is 680 feet. Though these sandstone units may be traced completely across the county, many of the individual sandstone beds in each unit are discontinuous, often intertonguing with the overlying or underlying shale zones. Typically the base of each sandstone unit appears to be continuous along its outcrop. However, closer examination shows that often the lower sandstone units wedge out northward and that the overlying bed immediately thickens and replaces it in the same approximate horizon. . . .
>
> South of Atwood in the southeast corner of sec. 34, T. 6 N., R. 9 E., a heavy chert conglomerate occurs in the lower sandstone unit. The chert gravels average one-fourth inch in diameter and are sub-rounded. The largest chert fragments found were slightly more than one-half inch in their longest dimensions. Coarse to fine-grained sandstone and silty, gray-brown clay served as the matrix. . . .
>
> The uppermost Sandstone unit of the Wewoka formation supports a high scarp which trends northeastward across the county just east of Spaulding and Holdenville and west of Yeager. The sandstone averages 60 feet in thickness and varies little from south to north across the county. It is usually massive but may be medium to thin-bedded near its lower and upper boundaries. It is medium to very fine-grained, light brown, and contains numerous argillaceous siltstone lenses at irregular intervals. A highly-leached, red-brown, sandy limestone about two feet thick occurs near the top of the sandstone unit in sec. 15, T. 9 N., R. 9 E., and is exposed in a roadcut 500 feet east of the southwest corner of that section. Other thin limestones occur irregularly at or just above the top of this upper sandstone, and the question often arose as to whether some of these limestones should be included in the Wewoka formation or the overlying Holdenville formation.
>
> A dense, blue-gray, fossiliferous limestone occurs just above the uppermost sandstone of the Wewoka 100 feet east of the southwest corner of sec. 29, T. 8 N., R. 9 E. This limestone is believed to be equivalent to the limestone that is exposed immediately west of Holdenville in a roadcut in the extreme southeast corner of sec. 13, T. 7 N., R. 8 E. The latter limestone is traceable to the south and is definitely in the lower part of the Holdenville formation.

Distribution: In Seminole County, the Wewoka formation crops out in the southeast corner in a strip about five miles long (north and south) and a mile wide. Throughout much of its extent it is masked by floodplain and terrace deposits. Actual exposures total somewhat less than two square miles.

Outside of the county, the formation extends in a broad belt from the Ahloso fault, southeast of Ada, northeastward to the Arkansas River in Tulsa County. Southwest of the Ahloso fault, a thin band of uppermost Wewoka is exposed for more than three miles. It also crops out in the Franks graben, south of Ada (Morgan, 1924).

Character and thickness: Only two members are present within the county, the No. 4 sandstone (which here marks the top of the formation), and the shale immediately beneath it. Because two thirds, or more, of the outcrop area is masked by terrace materials, correlation of individual beds, or even detailed measurements, are extremely difficult. Where the No. 4 sandstone is well exposed, it is composed of shales interbedded with thin layers or laminae of siltstone or very fine sandstone. The colors of the sandstones include brown, buff and tan. The interbedded shales, as well as the thick underlying shales, are commonly green when fresh.

Because of its development as many thin beds, the

No. 4 sandstone does not provide sharp topographic relief. Nevertheless, because of its overall thickness (the entire zone varies up to about 60 feet thick), it supports a high and fairly distinctive cuesta. The continuity of this feature is impaired, however, by strong faulting, plus the work of Little River, Canadian River and several tributaries to each.

The siltstones near the top of the No. 4 sandstone are commonly greenish and limy. Fossil collections were made from this part of the member. Thin limestone lenses, of relatively local extent, occur near the top of the No. 4 sandstone, and in the overlying Holdenville shale.

Stratigraphic relations: The base of the Wewoka formation is not exposed in Seminole County. In Hughes County, to the east, it is conformable above the Wetumka shale. The upper contact is exposed, in Seminole County, for a distance of perhaps less than one mile. In this distance, there is no evidence for anything but a conformable relationship.

Paleontology: Girty (1915) described and figured the fauna of the Wewoka formation. Morgan (1924) listed 107 species from the Wewoka formation in the Stonewall quadrangle. Ries (1951) listed 103 species from the Wewoka of Okfuskee County, and Weaver (1952) identified 95 species from Hughes

County.

Only 17 species were collected from the small outcrop of Wewoka in Seminole County. Of these, most were collected from the shale immediately below the No. 4 sandstone. (See Table III for the fauna of the Wewoka formation.)

Age and correlation: Southward, the Wewoka formation is continuous until it is cut out by faulting, south of Ada. No equivalents are known immediately beyond the faults.

Northward, the Wewoka formation has been traced to the Arkansas River, beyond which its equivalents are (from bottom to top) the Labette shale, the Oologah formation, the Nowata shale and the Lenapah limestone (Oakes, 1952).

Wewoka equivalents in the Ardmore basin include those Deese formation beds between the Rocky Point and Williams members, and perhaps those between the Williams and Natsy members (Alexander, 1952). The former interval is about 900 feet, the latter about 250. These two intervals do not include the uppermost 600 feet of Deese, which in this report is considered as equivalent to the Holdenville formation.

Only the Holdenville formation, within the Des Moines series, overlies the Wewoka.

<u>Holdenville formation</u>.

First reference: J. A. Taff, 1901.

TABLE III

FAUNULES OF THE WEWOKA FORMATION

	Localities: 3023	3042	3043
Incertae sedis			
Conularia crustula White	x		
Bryozoa			
Rhombopora lepidodendroides Meek			x
Brachiopoda			
Chonetes granulifer Owen	x	x	x
Chonetinella cf. flemingi (Norwood & Pratten)		x	x
Cleiothyridina orbicularis (McChesney)	x	x	x
Composita subtilita (Hall)			x
Crurithyris planoconvexa (Shumard)		x	x
Derbyia crassa (Meek & Hayden)	x	x	x
Dictyoclostus americanus Dunbar & Condra	x	x	x
D. portlockianus (Norwood & Pratten)			x
Neospirifer dunbari King	x	x	x
Nudirostra rockymontanum (Marcou)		x	
Marginifera splendens (Norwood & Pratten)		x	
Mesolobus mesolobus var. decipiens (Girty)	x	x	x
M. mesolobus var. euampygus (Girty)			x
M. mesolobus var. lioderma Dunbar & Condra		x	x
Pelecypoda			
Nuculopsis ventricosa Hall		x	
Gastropoda			
Glabrocingulum grayvillense (Norwood & Pratten)	x		
Cephalopoda			
Pseudorthoceras knoxense (McChesney)			x

Nomenclator: J. A. Taff, 1901.

Type locality: Holdenville, in Hughes County, Oklahoma.

Original description: Taff (1901) described the

Holdenville formation from outcrops in the Coalgate quadrangle:

This shale, 250 feet in thickness, rests upon the Wewoka formation, and its crop in this quadrangle is limited to a small triangular area in the northwestern corner. The surface of the formation becomes broader northward in the more level country around Holdenville, 3 miles north of the border of the quadrangle.

The formation is composed of friable blue clay shale, with local thin beds of shelly limestone and shaly calcareous sandstone in the upper part. The sandstone ledges outcrop in terraces around the slopes of hills bordering the north side of Little River. The thin limestone occurs about 35 feet below the top of the formation, and its outcrop is usually covered by the sandstone and conglomerate debris from the overlying formation. In its usual exposure 1 to 2 feet only of shaly limestone may be seen. At other places a bed of shell breccia loosely cemented is found, representing the thin hard plates of the shelly rock. The shales are rarely exposed. The smooth grass-covered prairie soil, however, even in the steep slopes, bears evidence of the friable shale beneath.

Other descriptions: Morgan (1924) examined the more extensive Holdenville outcrops in the Stonewall quadrangle, and named two members:

The Holdenville formation consists largely of shale, but also contains numerous sandstone beds and two mappable limestone members. Some of the sandstones locally develop into massive chert conglomerates that are lithologically identical with the conglomerate at the base of the Seminole in the type area of that formation.

In the northeastern part of the quadrangle the Holdenville is approximately 235 feet thick. It thins southward, however, and at its southern extremity, where it is overlapped by the Seminole, does not exceed 100 feet.

SASAKWA LIMESTONE MEMBER

The upper of the two limestones occurs 35 feet below the top of the formation. Its outcrop passes through the town of Sasakwa and the member is named after that town. . . . Southwestward from the crossing on the Canadian River the member can be traced without much difficulty to the southern part of sec. 9, T. 3 N., R. 6 E., at which place it grades into a limey shale and from there westward was not identified with certainty. The thickness of this bed is quite variable. At the northeast corner of the quadrangle it is about two feet; just south of Sasakwa it is at least 15 feet, but from there southward gradually thins to a thickness of about one foot. The latter average thickness is maintained to the point at which the bed could no longer be mapped. The Sasakwa limestone is fossiliferous throughout, but carries its largest fauna in the northern part of the quadrangle.

HOMER LIMESTONE MEMBER

This limestone lies below the Sasakwa limestone and is also best developed in the northeastern part of the quadrangle. The bed shows a pronounced change from north to south, but at the foot of the bluff in the south central part of sec. 25, T. 4 N., R. 6 E., the stratum shows a combination of the characteristics common to it, both to the north and south. This point is one-half mile west of Homer school and the name of the school is therefore applied to the bed.

In the northeastern part of the quadrangle the Homer limestone is approximately three feet thick. It occurs 70 feet below the Sasakwa limestone and there constitutes a reef of Chaetetes. The color of the limestone in this area is dark gray or almost black. The reef-like character of the stratum is maintained southward to the vicinity of Homer school where the quantity of Chaetetes begins to diminish and a few specimens of Fusulina appear. In this locality the interval between the Homer and the Sasakwa members has decreased to about 40 feet. . . . The limestone is never light in color, but with the advent of the great numbers of Fusulina, toward the south, it becomes even darker than it is toward the north. The bed is well exposed in the little stream valley just south of the railroad crossing in the southern part of sec. 10, T. 3 N., R. 6 E. . . . At the railroad crossing just mentioned the interval between the Homer and Sasakwa limestones is only 17 feet.

Between these two beds, throughout all the northern portion of the Holdenville outcrop, there are a number of sandstones. One or several of these quite often develops into a massive chert conglomerate that sometimes attains a thickness of 30 feet.

Ries (1951) described the Holdenville as it occurs in Okfuskee County:

The Holdenville formation consists of a succession

TABLE VI--Continued

	Localities: 3026	3035	3040	3041	3044
Mooreoceras tuba (Girty)		x			
Pseudorthoceras knoxense (McChesney)			x	x	x
Trilobita					
Ditomopyge parvula (Girty)			x		

Two rather general lithologic changes may be noted within the series. One consists of a coarsening of clastic ledges southward toward the Hunton Arch; certain lenses provide exceptions to this generalization. The other, best observed in the middle and northern parts of the county, and in the subsurface, is a coarsening upward.

Seminole formation.

First reference: J. A. Taff, 1901.

Nomenclator: J. A. Taff, 1901.

Type locality: Seminole Indian Nation, now Seminole County, Oklahoma.

Original description: Taff (1901) first described the Seminole formation from an outcrop north and west of the Coalgate Quadrangle:

> About 50 feet of the lower part of the Seminole conglomerate is exposed in a small area in the northwestern corner of the Coalgate Quadrangle. This part of the

> of shales, sandstones, and a few local limestones. Generally speaking, the shales are very thick and the sandstones are thin. The limestones vary up to 2 feet in thickness.
>
> The shales are yellowish-brown to grayish-green in color. At many places they contain small concretions. These shales carry a prolific fauna in places.
>
> The sandstones have an erratic nature. They thicken and thin in short distances, and in many places, they are friable and poorly developed, making surface mapping difficult.
>
> The limestones are thin, fossiliferous, and on weathering, the surface becomes a yellow brown in color due to the high iron content. . . .
>
> Two Holdenville sandstones were mapped across the county. The lowermost of these . . . lies 15 to 60 feet above the top of the Wewoka formation. This variation is due to a thickening of the underlying shale to the south. . . . This sandstone varies in thickness from 2 feet to 12 feet. . . .
>
> The upper Holdenville sandstone is more uniform in thickness and lateral extent. In the northern part of the county this sandstone is well developed and forms large escarpments. In the southern portion, the sandstone is more friable and therefore forms lower escarpments. . . . The sandstone varies from 3 to 12 feet in thickness. Generally speaking, this sandstone thickens southward.
>
> The thickness of the Holdenville formation varies from 280 feet in the southern part of the county to 200 feet in the extreme northern part.

Weaver (1952) gave the following description of the Holdenville formation in Hughes County:

> Across most of Hughes County the Holdenville formation consists of blue-gray, fossiliferous shale which is divided into upper and lower units by one or more sandstone beds. The Homer and Sasakwa limestones which are well developed in the lower and upper parts of the formation respectively in Seminole County to the west thin rapidly northward after entering Hughes County and are absent north of the vicinity of Spaulding. The formation has an average thickness of 250 feet across the county.
>
> The lower shale unit averages 100 feet thick and contains two limestones, the Homer, and an unnamed limestone. The Homer occurs 26 feet below the base of the middle sandstone unit in the northeast corner of sec. 9, T. 6 N., R. 8 E. There it is 2.7 feet thick, massive,

blue-gray, coarsely crystalline and weathers into red-brown slabs. The Homer thins to less than 3 inches in the southeast corner of the northwest corner of sec. 10, T. 6 N., R. 8 E., and could not be traced northward from this area. One mile north of Spaulding in the extreme southwest corner of sec. 35, T. 7 N., R. 8 E., a dense, medium-crystalline, fossiliferous limestone occurs 100 feet below the base of the middle sandstone unit and just above the upper sandstone unit of the Wewoka formation. This limestone does not resemble the Homer limestone to the south. . . . .

A sandstone lens occurs near the base of the lower Holdenville shale unit in the vicinity of Holdenville. . . . This sandstone rises rapidly in the section north of Holdenville and possibly merges with the lower sandstone of the middle Holdenville sandstone unit. . . .

The middle sandstone unit of the Holdenville is massive to thin-bedded, often calcareous, and forms a high scarp in the south part of its outcrop across the county. Irregularly occurring limestone lenses are common. It is about 59 feet thick in the area west of Spaulding and contains a shale bed about 12 feet thick 8 feet below its top. To the north of Deep Creek this middle sandstone splits into three sandstone bodies with two intervening sandy shale zones. . . .

The upper shale unit is composed of soft, gray, waxy, fossiliferous shales and averages 80 feet thick. It contains the Sasakwa limestone 35 feet below its top . . . about 3 miles south and west of Spaulding.

The Sasakwa limestone is typically medium-crystalline, blue-gray and highly fossiliferous. Its average thickness in its limited outcrop in Hughes County is 0.7 foot. It weathers into thin slabs of yellow-gray color.

Distribution: The Holdenville formation crops out in a strip about one mile wide in the southeast corner of Seminole County. The formation underlies an area of about 10 square miles, but over half of it is masked by alluvium and stream terrace deposits.

The southernmost outcrops of the Holdenville occur southwest of Ada, in Pontotoc County, where it is overlapped by the Seminole formation, and to the south of Ada, in the

Franks graben (Morgan, 1924). To the northeast, the Holdenville has been traced into Tulsa County, where it is truncated by the Seminole formation. North of Tulsa County Holdenville outliers have been found. In Kansas Holdenville remnants beneath the Seminole have been mapped as the Memorial shale (Oakes, 1953).

Character and thickness: In Seminole County, the Holdenville formation consists largely of three shale units, separated by two limestone members. The upper, the Sasakwa limestone, is light gray to chalky white, fine-grained, hard, and richly fossiliferous. Its weathered surface looks much like that of the Snomac limestone member of the Ada formation, or the upper Belle City limestone. The Sasakwa member is 30 or more feet below the top of the formation, and a few inches to about 15 feet thick. It is generally thin-bedded.

The maximum thickness of the Sasakwa may be found in the southwest quarter of sec. 36, T. 6 N., R. 7 E. Here the limestone is exposed in an abandoned quarry, in a railroad cut, and along hillsides and creek banks. The quarry is a well-known fossil-collecting site. The Sasakwa is also exposed in the village of that name, but from here northward it thins rapidly. It caps an occasional hill, and is found plentifully in "float" along steep hillsides overlooking Little River and several of its tributaries. The bleached white limestone fragments in the soil make the outcrop easy to follow. In sec. 8, T. 6 N., R. 8 E., the member is locally typical, locally darker and softer, furnishing an abundant supply of weathered-out fossils in gullies and roadside ditches.

The lower member, the Homer, is a thin *Chaetetes* limestone with a black or dark gray color, or a dark brown sandy pelecypod-bearing limestone two to 10 feet thick. The *Chaetetes* facies occurs south of Little River, and south of the Canadian River where it is replaced by a *Fusulina* facies. North of Little River, the Homer is a very dark, dirty brown sandy limestone up to 10 feet thick. Coarse secondary calcite crystals make up much of this facies. Where the growth of calcite has not been pronounced, light brown silt and sandstone stringers are found. The excellence of fossil preservation also varies with the amount of secondary replacement; where crystal growth has been great, fossil structure is largely destroyed, but the general outlines can be seen on weathered surfaces. Although this pelecypod-bearing facies is commonly both massive and resistant, it is exposed well down on the face of the Holdenville cuesta, rather than at the top.

The Homer lies 70 to 130 feet above the base of the formation.

Both limestone members thin northeastward into Hughes County, where they vanish, the Homer into a shale section, and the Sasakwa against a coarse chert conglomerate. In the shale interval between the two limestones may be found local sandstone and chert conglomerate lenses. These reach a combined thickness, locally, of 33 feet. Brown siltstones, light brown sandstones, and pockets of chert conglomerate occur in these lenses. The matrix for the conglomerates is, occasionally, a dark hematite red.

Southward from Seminole County, as the interval between the two limestone members decreases, the zone of coarse clastic lenses thins and vanishes. Northeastward in Hughes County, the zone splits into three distinct sandstone ledges, the uppermost of which has been traced into Okfuskee County (Ries, 1951). The most massive development, however, is in Seminole County and adjacent parts of Hughes County. Here the sandstone lens, the overlying Sasakwa and underlying Homer, support a cuesta having 200 to 250 feet of relief.

The shales are gray to green, and commonly barren of fossils.

The true thickness of the Holdenville is uncertain. In the Sasakwa area, Morgan (1924) found about 235 feet. In Okfuskee County, Ries (1951) reported a thickness varying from 200 feet in the north to 280 feet in the south. His electric log cross section, however, shows a scaled thickness of 150 to 210 feet. In Hughes County, Weaver (1952) measured 240 to 250 feet of Holdenville, but shows 185 to 200 feet on his electric log cross section. The apparent discrepancy between surface and subsurface values is roughly 40 feet.

Electric log studies in Seminole County yielded thicknesses, with a few exceptions, between 135 and 180 feet. Surface measurements in Seminole County are not reliable because of partial masking by terrace materials, and the probable presence of a concealed fault system under the terraces. A composite section, compiled from several fragmentary measured sections, may be interpreted as giving a total thickness of 260 feet or more. In no case can this figure be reduced appreciably below 210 feet. This latter value leaves an average discrepancy of about 40 feet.

It is possible that the present outcrop occurs along a line of marked eastward thickening in the Holdenville formation, perhaps partly as a result of pre-Seminole erosion.

A careful study of measurements taken from Morgan, Weaver and the field notes compiled for this report, indicates that the maximum southern thickness of the Holdenville occurs in ranges 5, 6 and 7 north, and that the formation thins, from this area, both to the north and to the south (see Table IV). Subsurface studies show that thinning also takes place in a westward direction. The northward thinning is replaced, in Okfuskee County, by thickening. The westward thinning is perhaps less than five feet per mile. The southward thinning is of the same order of magnitude. In the last mentioned instance, over nearly all of the outcrop,

TABLE IV

CHANGES IN THICKNESS IN THE HOLDENVILLE FORMATION AND IN SOME OF ITS MEMBERS IN PONTOTOC, SEMINOLE AND WEST CENTRAL HUGHES COUNTIES

(Seminole formation)

35' [a]	35' [a]	35' [a]	32' [b]	35' [c]	
Sasakwa					
			44'	45'	
17'	40'	70' {30'	33'	60'	Coarse clastics
			14'	26'	
Homer					
50'	?	120'	70'-130'	73'	
South and southwest				North and northeast	

[a]Morgan, 1924. [b]This report. [c]Weaver, 1952

this thinning is by loss of section in the lower and middle thirds of the formation; the Sasakwa member stays at a relatively constant interval below the top of the formation, and little or no section is lost from above until the last mile or two of exposure.

Stratigraphic relations: Both upper and lower contacts are exposed for only short distances in Seminole County. The lower contact seems to be entirely conformable.

The upper contact, however, may be one of unconformity. In the northeast part of sec. 8, T. 6 N., R. 8 E., in Hughes County, a coarse chert conglomerate lens extends about 30 feet up into the overlying Seminole formation, and 50 or more feet down into the Holdenville. The Sasakwa limestone member disappears, northward, at about the southern limit of this lens. It is possible that the Sasakwa here abuts against a Seminole formation channel which was later filled with chert pebbles and sand.

In Pontotoc county, the Holdenville is truncated abruptly by the Seminole formation. In northern Oklahoma and southern Kansas, Holdenville (i.e., Memorial) shale outliers are preserved beneath the Seminole formation.

Elsewhere, however, the two formations seem to be conformable. Ries (1951), in Okfuskee County, and Weaver (1952), in Hughes County, report no specific evidence for unconformity.

Paleontology: Morgan (1924) listed 87 species from the Holdenville formation. Ries (1951) identified 98 species, and Weaver (1952) 87 species. Fifty-seven species were collected from the Holdenville outcrop described in this report. Most of these were obtained from the Sasakwa limestone member, and the rest largely from local fossiliferous pockets within the Holdenville shales. The Homer limestone member is fossiliferous, but most of the specimens are unrecognizable pelecypods. (See Table V for the fauna of the Sasakwa member, and Table VI for the fauna of the Holdenville shales.)

Age and correlation: The Holdenville shale is continuous northeastward into Tulsa County, where it is truncated by the overlying Seminole formation. Beyond Tulsa County, Holdenville shale remnants are found below the Seminole. In Kansas remnants of Holdenville have been mapped as Memorial shale (Oakes, 1953).

South of Ada, the Holdenville is overlapped by the Seminole formation on the west side of the Lawrence uplift, and occurs in an isolated outcrop in the Franks graben (Morgan, 1924). No known equivalents are found farther south on the Hunton Arch or in the Arbuckle Mountains.

In the Ardmore basin, the uppermost 600 feet in the Deese formation are considered to be correlative with the Holdenville formation (Alexander, 1952). An additional interval of 250 feet, here tentatively assigned to Wewoka time, may actually have been deposited contemporaneously with part of the Holdenville. The Natsy limestone marks the base of the upper unit of 600 feet, and the Williams member marks the base of the 250-foot unit.

The Holdenville is the youngest formation within the Des Moines series.

Missouri Series

The Missouri series is represented in Seminole

TABLE V

FAUNULES OF THE SASAKWA MEMBER OF THE HOLDENVILLE FORMATION

	Localities:				
	3027	3036	3091	3095	3101
Coelenterata					
Astrodiscus sp.			x		
Lophophyllidium hadrum Jeffords			x		
L. cf. *spinosum* Jeffords			x		
L. wewokanum Jeffords			x		
Incertae sedis					
Conularia crustula White	x				
Bryozoa					
Aulopora prosseri Beede			x	x	
Polypora sp.			x		
Rhombopora lepidodendroides Meek	x				
Brachiopoda					
Chonetes granulifer Owen	x	x			
Chonetinella flemingi (Norwood & Pratten)	x				
Cleiothyridina orbicularis (McChesney)			x	x	
Composita subtilita (Hall)	x		x		
C. trilobata Dunbar & Condra			x		
Crurithyris planoconvexa (Shumard)	x	x			
Dielasma bovidens (Morton)			x		
Hustedia mormoni (Marcou)		x			
Juresania nebrascensis Owen			x		
Lindstromella patula (Girty)			x		
Lissochonetes geinitzianus var. *senilis* Dunbar & Condra	x				
Marginifera sp.				x	
M. muricatina Dunbar & Condra			x		
M. splendens (Norwood & Pratten)	x				
M. wabashensis (Norwood & Pratten)	x				
Mesolobus mesolobus var. *decipiens* (Girty)	x				
M. mesolobus lioderma Dunbar & Condra	x				
Neospirifer dunbari King	x	x	x		
Phricodothyris perplexa (McChesney)	x		x	x	
Punctospirifer kentuckiensis (Shumard)			x	x	
Teguliferina armata (Girty)			x		
Wellerella osagensis (Swallow)			x		

TABLE V--Continued

	Localities:				
	3027	3036	3091	3095	3101
Pelecypoda					
Astartella concentrica Conrad		x			
Myalina slocomi Sayre					x
Nuculopsis ventricosa (Hall)			x		
Septimyalina perattenuata (Meek & Hayden)	x				
Gastropoda					
Glabrocingulum grayvillense (Norwood & Pratten)		x			
Meekospira peracuta choctawensis Girty			x	x	
Naticopsis remex (White)			x		
"*Pleurotomaria*" *spironema* Meek & Worthen			x		
Cephalopoda					
Mooreoceras cf. *tuba* (Girty)			x		
Pseudorthoceras knoxense (McChesney)		x	x		
Trilobita					
Ditomopyge parvula (Girty)			x		

County by five formations; in ascending order these are: the Seminole, the Coffeyville, the Nellie Bly, the Belle City and the Hilltop. The series thickens from about 750 feet, in the southern part of the county, to 1,400 feet in the northwestern corner. The maximum surface thickness for the series is slightly less than 1,000 feet.

Evidence for the unconformity at the base must be sought in adjacent counties. The unconformity at the top of the series, however, is one of the two major erosion breaks within the Paleozoic section in Seminole County.

TABLE VI

FAUNULES OF THE HOLDENVILLE SHALES

	Localities: 3026	3035	3040	3041	3044
Coelenterata					
Cleistopora sp.			x	x	
Lophophyllidium proliferum (McChesney)		x			
L. wewokanum Jeffords					x
Stereostylus cf. *pelaeus* Jeffords			x		
Incertae sedis					
Conularia crustula White		x		x	
Brachiopoda					
Chonetes granulifer Owen		x			
Chonetina sp.				x	
Cleiothyridina orbicularis (McChesney)		x			
Crurithyris planoconvexa (Shumard)		x	x		
Juresania sp.		x			
Lindstromella patula (Girty)				x	
Marginifera splendens (Norwood & Pratten)		x			
Mesolobus mesolobus (Norwood & Pratten)		x			
M. mesolobus var. *lioderma* Dunbar & Condra	x				
Neospirifer dunbari King	x	x			
Streptorhynchus affinis Girty	x				
Pelecypoda					
Astartella concentrica Conrad					x
Nucula anodontoides (Meek)					x
Nuculana bellistriata (Stevens)			x		
Nuculopsis ventricosa (Hall)			x		
Gastropoda					
Euphemites vittatus (McChesney)					x
Glabrocingulum grayvillense (Norwood & Pratten)		x			x
Pharkidonotus percarinatus (Conrad)			x		
Trepospira depressa (Cox)					x
Worthenia tabulata Conrad			x		
Cephalopoda					
Metacoceras sinuosum Girty			x		

TABLE VI--Continued

	Localities: 3026	3035	3040	3041	3044
Mooreoceras tuba (Girty)		x			
Pseudorthoceras knoxense (McChesney)			x	x	x
Trilobita					
Ditomopyge parvula (Girty)			x		

Two rather general lithologic changes may be noted within the series. One consists of a coarsening of clastic ledges southward toward the Hunton Arch; certain lenses provide exceptions to this generalization. The other, best observed in the middle and northern parts of the county, and in the subsurface, is a coarsening upward.

Seminole formation.

First reference: J. A. Taff, 1901.

Nomenclator: J. A. Taff, 1901.

Type locality: Seminole Indian Nation, now Seminole County, Oklahoma.

Original description: Taff (1901) first described the Seminole formation from an outcrop north and west of the Coalgate Quadrangle:

> About 50 feet of the lower part of the Seminole conglomerate is exposed in a small area in the northwestern corner of the Coalgate Quadrangle. This part of the

formation is composed of laminated or stratified sub-angular chert, with a sprinkling of quartz pebbles from 3 inches in diameter to small grains in a cement of fine brown and usually ferruginous sand. The coarse conglomerate in the beds at the base is loosely cemented and on weathered surfaces breaks down into rounded boulders and loose gravel. Forty to 50 feet from the base the conglomerate grades into brown sandstone which continues upward about 100 feet to the top of the formation. The Seminole formation crops in a rugged hilly country northwestward in the Seminole Nation making rough timbered lands.

Other descriptions: Morgan (1924) extended the Seminole formation into the Stonewall Quadrangle, to the southwest:

The Seminole outcrop extends from the northeast corner of the Stonewall quadrangle southwestward to the vicinity of the town of Fitzhugh in the north-central part of T. 3 N., R. 5 E. East and north of Fitzhugh the Seminole is overlapped by the Ada formation which normally occurs about 800 feet higher in the section. . . .

The presence of Seminole strata in the Franks graben is not clearly established. On the basis of evidence which indicates the outcrop there of the underlying Holdenville and the overlying Francis formation, however, it seems probable that it is there represented in some part of the interval between the upper Wewoka and the lower Francis formation.

Although defined by Taff the upper limit of the Seminole was not mapped by him. . . .

By definition then, the Seminole of the type area has a thickness of "about" 150 feet. Since no definite bed is named as marking the top of the formation there can be no question as to the original measurement and the definition must be taken literally.

In measuring upward and westward from the bottom of the 50 foot chert member, that occurs at the base of the type section, it was found that in the extreme northeastern part of the Stonewall quadrangle is a thin limestone that is separated from the base of the Seminole by an interval which in that area averages 150 feet. This is a definite and persistent limestone and in the present work its base is taken as the top of the Seminole. This is the DeNay limestone.

Ries (1951) described the Seminole formation in Okfuskee County as follows:

> The Seminole formation contains a succession of thick shales with sandstones, a conglomerate, and a thin local limestone.
>
> The Seminole conglomerate lies at the base of the Seminole formation, above the Holdenville formation. This bed was traced across the entire county. It varies in thickness from 4 feet in Sec. 36, T. 11 N., R. 9 E., to 21 feet in Sec. 36, T. 13 N., R. 10 E. In the southern part of the county, this unit consists mostly of a medium to coarse-grained yellowish-brown sandstone. In the southeastern corner of Sec. 3, T. 11 N., R. 10 E., there is an extremely abrupt change. At this point, this bed is a coarse conglomerate with chert fragments as large as two inches in diameter. The conglomerate is about 17 feet thick at this point. The thickness of the bed and the size of these chert particles becomes progressively smaller northward, and in Sec. 13, T. 10 N., R. 10 E., no chert particles were observed and this unit again consisted of a coarse to medium-grained sandstone.
>
> Overlying this basal Seminole member is a yellowish-brown shale which is 50 to 80 feet thick. It is very fossiliferous in places.
>
> Above this shale is a bed of sandstone which was mapped from the north-central part of Sec. 35, T. 11 N., R. 9 E., to about Sec. 33, T. 12 N., R. 10 E. This sandstone changes lithology and becomes a sandy limestone in the area between the northeastern corner of Sec. 19, T. 11 N., R. 10 E. and Sec. 4, T. 11 N., R. 10 E. This member is 1 to 5 feet thick, and is overlain by 30 to 45 feet of yellow shale.
>
> Above this shale is sandstone which has been traced from the southeastern corner of Sec. 3, T. 12 N., R. 10 E. to the northwestern corner of Sec. 3, T. 12 N., R. 10 E. to the northwestern corner of Sec. 3, T. 10 N., R. 9 E. South of this point the sandstone is friable and poorly developed. It reappears again in the south-central part of Sec. 20, T. 10 N., R. 9 E., and extends to the south-central part of Sec. 31, T. 10 N., R. 9 E.
>
> The above sandstone is overlain by 100 to 140 feet of grayish-green to yellowish-brown fossiliferous shale. In the area south of Sec. 23, T. 11 N., R. 9 E., shale equivalent to the Checkerboard limestone, about 5 feet thick, and the basal shale member of the Coffeyville formation, about 12 feet thick, are mapped with this member.

Weaver (1952) mapped the Seminole formation in Hughes County. His description follows:

The Seminole formation in Hughes County consists of three conglomeratic sandstone units, each with an overlying sandy to silty gray shale. Each of the sandstone units contains fine, gray-white chert flakes throughout its outcrops in the county, but chert conglomerates are present in the sandstones only south and west of the northern part of T. 7 N., R. 8 E. This is the approximate northern limit in Hughes County of the occurrence of coarse to fine chert conglomerates so common farther to the south.

The formation averages 300 feet thick in its outcrop across Hughes County.

The lower sandstone unit is about 49 feet thick, massive, and highly conglomeratic in the center of the south line of sec. 3, T. 6 N., R. 8 E. The chert fragments composing the conglomerate are sub-rounded, gray-white to brown, and average one-fourth inch in diameter. Fragments up to two inches were found, however. To the north and south of this immediate area the coarse sands and gravel of the conglomerates grade to medium to fine-grained sandstone and siltstone. The occurrence of these conglomerates is not continuous along the strike of the bed, and the conglomerates are usually coarsest and thickest in the middle part of their exposure in the sandstone unit with which they are associated. North of Deep Creek this lower sandstone unit splits into two sandstone bodies. A silty gray shale averaging 30 feet in thickness separates these two sandstones as they outcrop across the central part of T. 7 N., R. 8 E. and the southeast part of T. 8 N., R. 8 E. The upper unit remains about 10 feet thick across this area, but the lower unit thins rapidly north of the south half of sec. 11, T. 7 N., R. 8 E., where it is 46 feet thick and highly conglomeratic. In the eastern half of sec. 23, T. 8 N., R. 8 E., this lower sandstone has thinned to 6 feet and is silty and thin-bedded. As interpreted by this writer, this sandstone wedges out immediately to the north, and the sandstone occupying its position in the section to the north of Wewoka Creek is the overlying sandstone unit. This sandstone averages 30 feet in thickness and is continuous northward to Okfuskee County.

A sandy shale zone which averages 80 feet in thickness overlies this lower sandstone unit.

The overlying sandstone unit is massive, highly conglomeratic, and averages 20 feet thick in its southernmost exposure in the county in the western half of sec. 5, T. 6 N., R. 8 E. It thickens slightly to the north in the eastern half of sec. 16, T. 7 N., R. 8 E. and then thins northward and appears to wedge out immediately under, or to be cut out by, the upper Seminole sandstone unit in the vicinity of the western half of sec. 14, T.

8 N., R. 8 E. Correlations are difficult in this area because of the wide belt of alluvial and terrace deposits of Wewoka Creek.

The upper sandstone unit of the Seminole is only 7 feet thick in the extreme northeastern part of T. 6 N., R. 8 E., in east-central Seminole County. It thickens to the north as it passes into Hughes County and is 13 feet thick in an exposure in the center of the north line of sec. 4, T. 7 N., R. 8 E. Here the unit is thin-bedded, fine-grained and contains thin sandy shale lenses. The sandstone reaches a maximum thickness of 60 feet in sec. 36, T. 9 N., R. 8 E., where a 23-foot silty shale zone occurs 7 feet above the base of the unit.

As defined by Morgan from its exposures to the southwest in southern Seminole and northern Pontotoc counties, the top of the Seminole formation is considered to be at the base of the DeNay limestone. This limestone occurs 11 feet above the upper sandstone unit in the extreme northeastern part of T. 6 N., R. 8 E., in east-central Seminole County. There the upper zone of the Seminole formation consists of 11 feet of gray, sandy to silty shale. The DeNay was traced northeastward into the northwestern corner of sec. 20, T. 7 N., R. 8 E., Hughes County. There it is approximately 22 feet above the upper sandstone unit of the Seminole formation. The DeNay could not be traced north of this area, though Sarles earlier had mapped the limestone into the center of sec. 17, T. 7 N., R. 8 E. The limestone mapped by Sarles in this locality as "DeNay" is a sandy limestone which is associated with the top of the upper Seminole sandstone unit. It is well below the horizon of the DeNay and does not resemble it lithologically.

North of the last occurrence of the DeNay limestone, the base of the lower sandstone of the overlying Coffeyville formation was mapped as the base of the Coffeyville. Thus, all of the shale zone lying between the top of the upper Seminole sandstone unit and the base of the lower Coffeyville sandstone unit is mapped northward with the Seminole formation. This shale zone averages 85 feet thick in its outcrop across the northwest part of T. 7 N., R. 8 E. but thins northward and is only about 24 feet thick on the north county line. . . .

Distribution: The Seminole formation crops out in a strip one to two miles wide in the southeast and east central parts of Seminole County. Because of an east-west offset in the county line, the outcrop is not continuous within the county. The formation occurs over an area of about six square miles in the southeast part of the county, and over an area of four to five square miles east and southeast of Wewoka. For a distance of more than three miles between these two areas, the outcrop is entirely within Hughes County, to the east.

The southernmost appearance of the Seminole formation is at the point of overlap by the Ada, about 10 miles southwest of the City of Ada (Morgan, 1924). From there the Seminole can be traced northward into Kansas (Oakes, 1953). An isolated outcrop of Seminole is found in the Franks graben in Pontotoc County (Morgan, 1924).

Character and thickness: In Seminole County, the Seminole formation consists of six units--three sandstone and three shale--plus conglomerate lenses. In the southern part of the county, there are two resistant ledges; east of Wewoka, along the Hughes County line, there are three, with the basal member locally splitting into two distinct sandstones. The uppermost (No. 3) sandstone is, at a few places, yellow, limy and crinoidal, and therefore easily mistaken for the DeNay member of the Coffeyville formation above (i.e., Sarles, 1943). Yellow limestone lenses also occur in the upper Seminole shales.

In general, the resistant members are yellow to buff, locally contorted, siltstones and fine sandstones. The

Figure 9. The cuestas of the Seminole formation are clear-cut in the southeastern part of Seminole County. This picture was taken, looking north, from the hilltop in the center of sec. 36, T. 6 N., R. 7 E. The highest cuesta--the one in the middle of the horizon--is held up by the Seminole No. 1 sandstone. To the right, and immediately below the largest cloud, is a series of hills supported in part by the Homer member of the Holdenville formation. The lower hills along the horizon in the left part of the picture are developed on the Seminole No. 2 and No. 3 sandstones.

shales are green to gray green, and sparingly fossiliferous. A few thick lenses of coarse chert conglomerate convey the impression that the formation is coarser-grained than it actually is.

The Seminole formation thickens from about 120 feet, west of Sasakwa, to a maximum of 375 feet southeast of Wewoka. From there it thins northward to about 200 feet at the Hughes-Okfuskee county line (Weaver, 1952). Ries (1951) reported 250 to 350 feet of thickness in Okfuskee County. In the middle part of T. 6 N., where Taff, and later, Morgan measured the Seminole, it is indeed close to 150 feet thick.

The lower (No. 1) sandstone, the middle (No. 2) sandstone, and the intervening shale comprise a unit having a relatively uniform thickness of 100 to 110 feet; of this, about 80 feet is in the shale section. The upper (No. 3) sandstone truncates consecutively, going southward, a middle shale (maximum thickness, 60 feet), the No. 2 sandstone, and half of the lower shale.

The problem of determining the thickness of the upper shale unit is complicated by the fact that the overlying DeNay member of the Coffeyville formation is not everywhere present. From the standpoint of the field geologist working in Seminole and Hughes counties only, the logical place to map the top of the Seminole formation is at the base of the first sandstone above the DeNay limestone. In the light of the exploratory suggestion, made by Oakes and Jewett (1943), that the Checkerboard formation to the north may occupy the same stratigraphic position as the DeNay, this redefinition has not been attempted. Hence the thickness of the upper shale unit changes abruptly at the point where the DeNay vanishes. The maximum thickness of this shale is 125 feet (T. 7 N.); the minimum, 11 feet (T. 6 N.).

In addition to the truncation within the formation, and the erratic behavior of the upper shale, the Seminole has at its base, along the Seminole-Hughes county line, what appears to be a channel. This unit extends from about 50 feet below, to about 30 feet above, the Seminole-Holdenville contact. It is most likely the same basal member, "about 50 feet" thick, which led Taff to apply the term "conglomerate" to the formation.

Near Wewoka, this lowest resistant member thickens locally and separates into two distinct ledges, one of which seems to pass downward and vanish into the Holdenville shales (Weaver, 1952).

The Seminole is, primarily, a sequence of alternating sandstones and shales, with the latter making up about 70% of the section. The shales are gray-green on freshly-washed surfaces, and commonly barren in Seminole County, although a few fossils were found in them.

The coarse clastics are yellow to brown, thin-bedded and flaggy, fine sandstones to siltstones. At places they are cross-bedded. Pale buff chert flakes are common; locally the chert particles are large enough to be pebbles, especially in lenses such as the channel mentioned above.

Perhaps the most spectacular characteristic of the Seminole formation is the development of "contortions" within the sandstones (see Figs. 10, 11, 12). These also occur in the Coffeyville, Nellie Bly, Vamoosa and Ada sandstones higher in the section.

In each case the dip of the bed does not vary appreciably from the regional dip; the contortion is apparently a plastic-flow phenomenon which took place prior to the tilting of the bed to its present dip of approximately one degree. In many of the contortions, individual laminae or coarser layers stand vertically or are even overturned. The radius of curvature of such features is on the order of a few inches to a few feet.

A set of photographs, mailed to W. O. Thompson, educed the following comments (Thompson, 1951):

> As you may know, we have a formation here locally entitled, "The Crinkled Sandstone Member of the Lykins Formation." This formation extends for approximately fifty miles on the east side of the Front Range and most outcrops show contortion similar to that shown in your photographs, except that most of the contortions are accompanied by intraformational breccia. . . .
> I have managed to convince myself that these structures are penecontemporaneous structures. . . . In the Journal of Sedimentary Petrology, Volume 20, No. 2, page 111, you will find some contorted beach strata. I happen to have seen these particular outcrops, and I believe the man knows what he is talking about. We have a Master's thesis on the origin of the Crinkled Limestone,

Figure 10. Beach-type "contortion" in the basal Ada sandstone, northwest quarter of the northeast quarter of sec. 14, T. 7 N., R. 6 E.

Figure 11. Close-up of beach-type "contortion" in the basal Ada sandstone, northwest quarter of the northeast quarter of sec. 14, T. 7 N., R. 6 E.

Figure 12. Beach-type "contortion" in the Seminole No. 3 sandstone, east central part of sec. 31, T. 7 N., R. 8 E. The Brunton pocket transit, near the center of the picture, is resting on the floor of a "cave" beneath one of the folds within the sandstone.

> and the author, Chuck Iglehart, under my direction, reached the conclusion that nearly all of the structure is developed as a result of minor sliding along the primary dip of sediments slippery enough to permit such sliding early in their history. The examples you sent me appear to be in the same general category. . . .
> I didn't intend to convey the idea that contorted structures are limited to beach sands; I merely wanted to call your attention to the fact that I found some in sands which later were diagnosed as beach sands. Actually, I think most of the structures I have seen are in limestones or siltstones.

This writer has worked on the Lykins formation, in Colorado, during two field seasons. In addition to the intraformational breccia found in the crinkled members there, the contortions did not seem to be developed to the same extent as those found in Seminole County. The pictures sent to Thompson (see Figs. 10, 11, 12) may not be representative, however, inasmuch as the best contortions are developed in uniformly-cemented sandstones, hence show no ridges due to differential weathering, and do not photograph well. The appearance of the crinkled members of the Lykins suggests sliding plus some buckling; the involved convolutions in the Seminole formation sandstones are more nearly the result of some kind of a churning process.

The literature on "crinkling" and "contortions" is extensive. Some of the mechanisms which have been suggested to account for these features are turbidity currents (Natland and Kuenen, 1951), recrystallization (Shrock, 1948), subaqueous slump or gliding (Pettijohn, 1949), drag of grounded icebergs (Pettijohn, 1949), hydration (Pettijohn, 1949), and differential sinking without sliding (Emery, 1950). The environment of deposition has been described as deep sea (Natland and Kuenen, 1951), delta-like accumulations of geosynclines (Pettijohn, 1949), open beach (Emery, 1950), "clino" (Rich, 1951), and others (i.e., periglacial soils).

The contortions in the five above-mentioned beds are here assigned to an open beach or off-shore bar environment. This is based on several considerations. First, the grain size involved is commonly in the medium sand to silt range. Second, many of the contorted sandstones are basal members, unconformably overlying lower truncated beds, and therefore representing overlap. Third, cross-bedding and ripple-marking are relatively common. Fourth, the southern shore, during Missouri and Virgil time, crossed Seminole County many times, and probably at no time was more than ten or twenty miles distant. Fifth, the contorted sediments are associated with, or actually are, beach or continental deposits bearing land plant remains. Sixth, the initial dips were very low, perhaps only a few minutes, and hence no deep-water environment seems to be indicated. Seventh, no specific evidence for a deep-water environment has been adduced.

An additional problem in mapping and describing the Seminole formation is that of tracing the overlying DeNay member of the Coffeyville formation. As indicated previously, the DeNay vanishes northward into a thick shale section, in T. 7 N., in Hughes County. Along its outcrop in

Seminole County, it varies in its position in the section by more than 50 feet within short distances (i.e., three miles or so). This makes stratigraphic interval, alone, unreliable in any effort to extend the DeNay. Furthermore, the Seminole shales immediately below the DeNay, and even the upper (No. 3) Seminole sandstone, contain yellow, crinoidal, limy lenses which can be mistaken for the DeNay. And, finally, in the areas where the lenses are present, considerable faulting is also present, with outcrops often isolated on fault slices only a few hundred feet wide.

To solve this problem, measured intervals in the Seminole and Coffeyville formations were taken at more than a dozen places (see Plate VII). The results show that the DeNay, when considered in relation to the lowest Coffeyville sandstone, climbs steadily in the section toward the north, finally disappearing in what may well be a sandy, leached phase of the Seminole-Coffeyville shale sequence.

The bed which Sarles (1943) mistook for DeNay is actually a lens in the Seminole, some 60 feet below the projected DeNay horizon, 80 or 90 feet below the lowest Coffeyville sandstone, and immediately above the uppermost Seminole sandstone.

East of Wewoka (in T. 8 N.), the No. 1 sandstone in the Seminole formation occurs as two separate ledges; the lower is a yellow to brown siltstone and sandstone, grading westward into a chert flake conglomerate or very coarse chert flake sandstone, and the upper is buff siltstone and sandstone. Both are locally soft, and occasionally difficult to trace. The shale interval between them is 48 feet, thinning westward to about 35 feet in one mile. The entire No. 1 unit is here 66 feet thick and is overlain by about 125 feet of shale.

The No. 2 sandstone is yellow to brown, thin-bedded, flaggy and silty; it is 10 feet thick. The overlying shale has a thickness varying from 10 feet (sec. 15, T. 8 N., R. 8 E.) to 60 feet (sec. 34, T. 8 N., R. 8 E.). The No. 3 sandstone is locally contorted, thin-bedded, cross-bedded, yellow to buff siltstone and fine sandstone, about 21 feet thick. The Seminole shales are gray-green.

Stratigraphic relations: Evidence for an unconformity at the base of the Seminole formation has been cited above. The evidence within Seminole County is not conclusive.

Ries (1951) recognized no unconformity in Okfuskee County. Although the present writer interprets a lens in Hughes County as a channel at the base of the Seminole, Weaver (1952) did not so interpret it. The best evidence is found south of Ada and north of Tulsa, where the Seminole overlaps the underlying Holdenville and Lenapah formations.

The most obvious unconformity in the Seminole section in Seminole County is found at the base of the upper (No. 3) sandstone, which truncates more than half of the underlying portions of the formation. The angle of truncation is about 10 minutes.

The upper contact poses a difficult problem. In Okfuskee County, the Seminole is overlain by the Checkerboard limestone. In Seminole and Pontotoc counties, the overlying bed is the DeNay member of the Coffeyville formation. In Hughes County, the upper contact is at the base of a Coffeyville sandstone which extends northward above the Checkerboard and southward above the DeNay. From these relationships can be inferred the idea that the DeNay-Checkerboard horizon has been truncated across Hughes County; hence there is an unconformity present. Ries (1951), working in Okfuskee County, described the Checkerboard as passing southward into a thick shale section, with no evidence of unconformity at the point of disappearance. And in Seminole and Hughes counties, the DeNay vanishes northward in the middle of a shale sequence, with no indication of truncation. This writer would prefer to think of the termination of the DeNay as due to non-deposition or leaching or both. If the Seminole formation is limited as defined by Taff (1901) and Morgan (1924), the upper contact appears to be conformable.

Paleontology: Morgan (1924) listed 19 species from the Seminole formation in the Stonewall Quadrangle; of these, 10 were described as "rare," and six as "abundant." Ries (1951) reported the Seminole formation in Okfuskee County to be "very fossiliferous." His list contains 52 species. In Hughes County, Weaver (1952) found 42 species.

The Seminole formation yielded 13 species in Seminole County. One, an ichthyodorulite, was collected at Station 3102. The other 12, collected at Station 3032, are listed below:

Coelenterata
  Lophophyllidium sp.
  L. spinosum Jeffords

Bryozoa
  Rhombopora lepidodendroides Meek

Brachiopoda
  Crurithyris planoconvexa (Shumard)
  Hustedia mormoni (Marcou)
  Lindstromella patula (Girty)
  Linoproductus oklahomae Dunbar & Condra
  Neospirifer dunbari King

Pelecypoda
  Allorisma terminale Hall
  Nucula anodontoides (Meek)

Gastropoda
  Glabrocingulum grayvillense (Norwood & Pratten)

Crinoidea
  Columnals and other fragments.

Age and correlation: The Seminole formation extends continuously northward through Tulsa County and thence into Kansas. North of Tulsa, the Seminole loses section from the lower part of the formation by onlap, so that only the higher beds are represented (Oakes, 1953).

South of Ada, the Seminole is overlapped by the Ada formation near Fitzhugh, and occurs in an isolated outcrop within the Franks graben (Morgan, 1924). Seminole formation equivalents in the Ardmore basin include about 500 feet of Hoxbar beds below the Crinerville member (Alexander, 1952).

The Seminole is the lowest formation in the Missouri series of east central Oklahoma.

Francis formation.

First reference: George Morgan, 1924.

Nomenclator: George Morgan, 1924.

Type locality: The town of Francis, in northeastern Pontotoc County, and "all that portion of the outcrop which extends for a distance of three miles north, and for a similar distance south, of Canadian River" (Morgan, 1924).

The Francis formation is shown on the Geologic Map of Oklahoma (Miser, 1926) as extending northward across Seminole County and into Okfuskee County. Near the town of Okemah, the name "Francis" is dropped, and other terminology (Coffeyville, Nellie Bly) is adopted.

In the course of field work carried on by Ries (1951) and Weaver (1952), and in the preparation of this report, the northern names were carried south to Canadian River. The interval designated by Morgan as "Francis" is, therefore, herein described under the headings "Coffeyville" and "Nellie Bly."

Coffeyville formation.

First reference: Schrader and Haworth, 1905.

Nomenclators: Schrader and Haworth, 1906.

Type locality: Near Coffeyville, Kans.

Original description: Schrader and Haworth (1906) gave the following original description:

> The name Coffeyville formation, after the town of Coffeyville, is here adopted for the portion of the geologic section included between the base of the Drum and the top of the Parsons (Lenapah).

Other descriptions: Morgan (1924) did not subdivide the Francis formation according to the terminology here used, but his description is sufficiently clear to permit quotation of that part which applies to the Coffeyville:

> In the type area and northward the Francis formation has a thickness of 500 feet. In the vicinity of Ada and southward only the lower part of the formation is exposed, the upper part being overlapped by the Ada formation.
>
> At the base, but within the Francis formation, is the DeNay limestone member, the lowest part of which marks the top of the Seminole formation. Above this limestone is an interval of about 30 feet that is represented by dark blue and black shales. These grade upward into sandstones which on the creek bluff northwest of Sasakwa have a thickness of nearly 20 feet. This is the sandstone that outcrops in the railroad cut below the viaduct in the northeastern part of Francis and is also correlated with the sandstone ledge in the road cut just north of the brick plant and railroad crossing near the southeast corner of Ada. Above the sandstone member is a series of thick, dark and sometimes calcareous shales. The average thickness of this part of the formation is 250 feet. In the northern part of the type area it is slightly more than this, but in the southern part it seems to be slightly less. West of Sasakwa the surface of this deposit extends to beyond the residence of the former Governor Brown of the Seminole Nation. Most of the town of Francis is located on these shales

and they are typically developed around the water tower there. Shales of this member are utilized by the brick plant at Ada. As is clearly shown in the pit at the latter place, the lower part of the shale is much darker and is more calcareous than the upper part. One of the most characteristic features of the shale series is the abundant limestone concretions which it contains. These vary in size from less than an inch in diameter up to as much as a foot. When freshly broken the central mass consists of a dense, dark blue limestone, on weathering, however, the color becomes yellow or yellowish-brown. The concretions are often very fossiliferous. Other concretions collected from the shales were of the cone-in-cone type.

Morgan (1924) also described the DeNay member in greater detail:

From the northeastern corner of the area, southwestward to a point several miles beyond Ada, this limestone has an intermittent outcrop that was mapped without difficulty. . . .

In sec. 5 T. 4 N., R. 7 E., this limestone is typically developed on the side of an eastward facing bluff. The name of the member is after DeNay school that is located about one-fourth mile east of this point.

The DeNay limestone has an average thickness of a little more than one foot. In the region north of Canadian River the bed is rather dense and breaks out in elongated blocks. In the road about one-half mile east of Francis the bed is slightly crinoidal. Crinoid stems become more abundant in the stratum toward the southwest and in the region south of Ada it is often almost entirely composed of these organisms. In the northeastern part of T. 3 N., R. 5 E., the crinoids become less abundant and the limestone develops a bright yellow color. The latter characteristic must be used with discretion, however, because there are in the area several beds of this color.

Ries (1951) mapped the Coffeyville in Okfuskee County, and described it as follows:

The Coffeyville formation consists of a succession of three shales and two sandstones. The shales are, generally speaking, thick, whereas the sandstones are thin. The shales are yellowish-brown to grayish-green in color. They contain small concretions at many places.

The shales carry a prolific fauna in places. The sandstones are well indurated and very resistant to erosion. They form long dip slopes and have steep escarpments. The sandstones are generally yellowish-brown in color.

The basal Coffeyville shale lies directly above the Checkerboard limestone. It varies in thickness from 5 to 20 feet. It is yellowish-brown in color and is fossiliferous. . . . South of Sec. 23, T. 11 N., R. 9 E., where the underlying Checkerboard limestone grades into shale, this member is mapped with the Seminole formation.

Overlying this shale is the basal Coffeyville sandstone. It is a well-indurated, 2 to 20 foot yellowish-brown sandstone. It was mapped across the entire county. North of Sec. 8, T. 12 N., R. 10 E., it is directly overlain by the upper Coffeyville sandstone. Both are found in a single escarpment. Farther north they unite to form a single sandstone. South of Sec. 8, T. 12 N., R. 10 E., the lower Coffeyville sandstone forms long dip slopes, and in Secs. 11, 12, 13, and 14, T. 11 N., R. 9 E., the dip slope is over 2 miles long. This sandstone contains a ubiquitous Linoproductus prattenianus fauna near its base.

Overlying this lower Coffeyville sandstone is a yellowish-brown shale. This shale is extremely fossiliferous in the western part of Sec. 31, T. 12 N., R. 10 E. It is thickest in the southern part of the county where it is 80 feet thick. It becomes progressively thinner northward and finally disappears in Sec. 8, T. 12 N., R. 10 E.

The upper Coffeyville sandstone overlies the aforementioned shale. It is 10 to 30 feet thick. It extends northeastward from the south-central part of Sec. 35, T. 10 N., R. 8 E., to Sec. 8, T. 12 N., R. 10 E., where it and the lower Coffeyville unite to form a single sandstone.

A 135 foot shale overlies this upper Coffeyville sandstone. It is fossiliferous, soft and yellowish-brown in color. It is overlain by the Hogshooter limestone north of Sec. 35, T. 12 N., R. 9 E. To the south, this shale is overlain by the basal beds of the Nellie Bly. South of Sec. 35, T. 12 N., R. 9 E., this shale as mapped, includes shale equivalent of the Hogshooter formation, about 2 feet thick, and the basal shale member of the Nellie Bly formation, about 5 feet thick.

From Hughes County Weaver (1952) described the Coffeyville as follows:

Only the lower 160 feet of the Coffeyville formation is exposed in Hughes County. As mapped across most of its outcrop, the formation consists of two sandstone units with thick overlying shales. Total thickness of the formation is about 250 feet. In the extreme southwestern part of its exposure in the county the DeNay limestone is present and is mapped as the base of the formation. It is a medium-crystalline, fossiliferous limestone which averages one foot thick in its limited exposure in Hughes County. Typically, it weathers into orange-brown slabs about eight inches thick and presents an irregular surface where crinoid stems and other fossils stand out in bold relief. . . .

The lower sandstone unit of the Coffeyville averages 35 feet thick across its outcrop in Hughes County. It is, however, widely variable from one area to another. It is composed chiefly of fine-grained, thin-bedded, light brown friable sandstone beds, and forms an easily traceable scarp across the northwestern part of T. 7 N., R. 8 E. and the eastern part of T. 9 N., R. 8 E. . . .

Above this lower sandstone unit is a thick shale zone which is but briefly exposed in the eastern half of T. 9 N., R. 8 E. There the shale is about 90 feet thick, gray-brown, and contains numerous thin siltstone beds near its top and base.

Only the middle and lower parts of the succeeding Coffeyville sandstone are exposed in Hughes County. The lower 41 feet of this sandstone is exposed in the extreme northwestern part of the county where it is composed of fine-grained to silty, cream-gray to brown sandstone. A silty, gray shale zone 17 feet thick occurs about 12 feet above the base of the unit in the southeast corner of sec. 11, T. 9 N., R. 8 E. Though not present in Hughes County, Ries reported the overlying shale zone of the Coffeyville to be about 135 feet thick.

Distribution: The Coffeyville formation crops out in a north-south strip, nearly 30 miles long and one to two miles wide, close to the east boundary of Seminole County. Much of the outcrop area is masked by floodplain and terrace deposits of Wewoka Creek, Little River and Canadian River, but exposures are generally good on the divides between the main streams.

The Coffeyville has not been traced southward from

Seminole County. Morgan (1924) states that southwest of Ada, the Ada formation overlaps that part of the Francis which is here interpreted as being Coffeyville equivalent. Rocks of Coffeyville age are, apparently, found in the Franks graben.

Character and thickness: The Coffeyville formation in Seminole County is made up of six lithologic units: the DeNay limestone member, a shale, a middle (No. 1) sandstone, a shale, an upper (No. 2) sandstone, and a shale. In the southern part of the county the two sandstones are sufficiently close together, locally, to be mistaken for one; Morgan (1924) included them in a single sandstone zone. Limestone, siltstone and chert conglomerate lenses are found in the upper sandstone member, and occasionally in the shales. The latter are generally dark.

The base of the formation is marked, in the southern part of Seminole County, by the DeNay limestone, a dense but vuggy, mustard yellow to brown, fossiliferous limestone a few inches to a few feet thick. West of Sasakwa the DeNay member is about 65 feet below the No. 1 sandstone; from there northward it rises in the section until, in western Hughes County, it vanishes in shale 20 to 30 feet below the sandstone. Northward for a distance of 15 miles, the middle (No. 1) sandstone is considered to mark the base of the formation. Near the Hughes-Okfuskee-Seminole County corner the Checkerboard limestone formation appears, much in the same manner as the DeNay disappeared. The Checkerboard does not, however, extend as far south as Seminole County.

Throughout most of its outcrop within Seminole County the Coffeyville formation is between 150 and 200 feet thick. The maximum thickness obtained was 260 feet.

As was the case with the Seminole formation, the matter of thickness is complicated by the behavior of the DeNay member. Were this limestone and its overlying shale included in the Seminole, the thickness of the entire Coffeyville would be reduced by 20 to 65 feet in the southern part of the county.

The DeNay member is one of the easiest beds to locate and identify in the county. Its color makes it distinctive among the more continuous limestones, although several limestone lenses are also yellow. The Homer and Sasakwa limestones below and the Belle City limestone above, together with the DeNay, form (in the southern part of the county) a distinctive sequence of key horizons, from which other stratigraphic identifications are easily made.

Not many of the DeNay outcrops are both typical and easily accessible. West of Sasakwa (secs. 34 and 35, T. 6 N., R. 7 E.) the DeNay can be found in roadside ditches in several locations; it is, however, only a few inches thick, soft and crumbly. From here south it is largely masked by high level terrace deposits. West of Kight (secs. 12 and 13, T. 6 N., R. 7 E.) the DeNay is exposed in ditches along both county and private roads; again it is relatively soft, although considerably thicker than farther south. Perhaps the best DeNay exposures may be found between the highway and the county line in secs. 19, 30 and 31, T. 7 N., R. 7 E. Here it varies in thickness up to five or six feet, has a typical color, is extremely hard, and yields a characteristic fauna which is difficult to collect. On steep hillsides the limestone is responsible for a definite slope break; elsewhere it is found as brownish slabs scattered through the deep grass a few feet from the actual line of outcrop (see Fig. 13). In this area, the exposure is not continuous because of the rather complex system of faults.

Where hard and more than a few inches thick, the fresh surface of the DeNay is often a dull blue-gray; where soft and thin, the typical limonite yellow color continues completely through the bed.

The shale between the DeNay and the middle (No. 1) sandstone of the Coffeyville is similar to the Seminole formation shales already described. In T. 8 N. this shale is mapped with the latter formation. From the middle of T. 7 N., where the DeNay disappears, southward, the shale interval varies in thickness from about 20 feet to a maximum of 68 feet.

The middle (No. 1) Coffeyville ledge is at places a fine sandstone, at places a siltstone. Although typically buff and highly cross-bedded, it is commonly thin-bedded and flaggy, locally massive, and in some instances interbedded with layers of shale less than a foot thick. In the east central part of the county this ledge appears, in road-cut exposures, to be soft and friable, yet it upholds a fairly high cuesta with a long back slope. The thickness of the ledge varies from a maximum of about 20 feet, in T. 7 N., to a minimum of seven feet.

The overlying shale, similar to the gray-green shales of the Seminole formation, has a maximum thickness of 130 feet (T. 8 N.) and a minimum thickness of almost zero. An occasional thin sandstone lens, less than half a mile long, occurs in this part of the section. North of Middle Creek church (sec. 2, T. 6 N., R. 7 E.) the shale is cut out by what may be a channel deposit. Where the shale is present, it and its immediately adjacent sandstone members sometimes reach a minimum thickness of about 25 feet.

The upper (No. 2) ledge is also either a siltstone or sandstone, but, unlike the No. 1, contains a number of lenses composed of either chert conglomerate or limestone. The minimum thickness obtained by field measurement was three feet; the maximum 27. Where sandy, this unit is massive and buff, and contains pockets of secondary limestone and occasional clay flake conglomerates. Locally the massive sandstones are highly contorted. Other colors found on this ledge are brown and yellow. Thin streaks of red are due to the presence of thin red shales.

Figure 13. Slabs of hard, yellow, fossiliferous DeNay limestone occur in the grass near the outcrop in the northeast corner of sec. 31, T. 7 N., R. 8 E.

In the cut where the county road climbs from the valley floor to the cuesta top (east central part of sec. 11, T. 6 N., R. 7 E.) where Dunbar School and Middle Creek Church are located, the No. 2 ledge contains a yellow, fossiliferous limestone which has been misidentified as DeNay. Sarles (1943) called this lens the "New" limestone, and placed it correctly in the section. In this general area, both the No. 1 and No. 2 ledges are exposed on the same cuesta face.

In the southern part of T. 7 N., the upper (No. 2) ledge is locally developed as a coarse sandstone and chert pebble conglomerate; this feature, somewhat less than half a mile wide (north and south), is here interpreted as a channel which cuts out the underlying shale and extends for an unknown depth into the No. 1 sandstone.

Blue crystalline limestone lenses, chert pebbles, clay flakes, and scattered chert flakes mark the upper (No. 2) sandstone in the southern part of T. 8 N. Here the ledge is about 14 feet thick, although only about half of this is commonly resistant enough to appear on weathered or washed slopes. The limestone lenses are only a few hundred feet long, at the most.

Northeast of Wewoka (northern part of T. 8 N.) the No. 2 sandstone is brownish-gray, very fine grained, and massively bedded or cross-bedded. Dark brown siltstones and thin shales and small lenses of hard gray limestone may be found here. The member is at least 27 feet thick, but the lower part is a flaggy, thin-bedded and soft buff siltstone which does not appear in many good exposures. Generally this softer unit seems to cap the cuestas formed by the upper sandstone.

The uppermost shale (overlying the above-mentioned ledge) marks the first departure from the sequence of pale gray-green shales found throughout the Holdenville, Seminole and lower and middle Coffeyville formations. This topmost Coffeyville shale is a thick, dark, calcareous and highly fossiliferous unit, marking the advent of an entirely new and distinctive clay-accumulation environment. Although locally it is as thin as 20 feet, it probably averages 100 feet or more in thickness, and in the central part of T. 9 N., approaches 200 feet. In the northern part of this shale outcrop, within Seminole County, a sequence of silt ledges appears in the lower part of the section. In the southern part of the county (T. 6 N.), the upper Coffeyville shale contains thin limestone lenses, and thick lenses of either coarse chert conglomerate, coarse limestone conglomerate, or siltstone.

Most significant of these lenses is that of limestone conglomerate, exposed around the Seminole governor's mansion (in the west central part of sec. 34, T. 6 N., R. 7 E.) about two and a half miles west of Sasakwa. This ledge is overlain by the Nellie Bly No. 1 sandstone.

Underneath the sandstone is a resistant unit, two to

10 feet thick, composed of limestone pebbles and cobbles. The conglomerate is lenticular and cross-bedded. Gray or white on the weathered surface, it is at places markedly yellow on a fresh surface. Fossil fragments, including recognizable pieces of Neospirifer dunbari King, are fairly common. The pebbles and cobbles include yellow or green clay plates, soft dark yellow siltstone chunks up to 5 inches in diameter, and limestone pieces up to 5 inches in diameter. The mean grain size, however, is probably close to one quarter inch.

The lens is about two miles wide, north and south. Although it differs (i.e., limestone fragments instead of chert) from the conglomerates found lower in the section in Seminole County, and neither variety of lens in this part of the section is continuous to the source, it is nevertheless concluded that both lithologies were derived from the same source, and that that source lay in the Hunton Arch-Arbuckle Mountain complex to the south. Support for this interpretation is adduced structurally, lithologically, and otherwise, in several parts of this report.

Along the highway between Sasakwa and the old mansion one may examine a typical section, roughly 110 feet thick, of the black, dark gray and dark green shales of the upper Coffeyville. Near the base, these shales are flaggy and quite black. Near the top, this shale unit yields a highly varied faunal suite.

Northward across the county, the dark shale occurs underneath a wide, grassy or cultivated valley between Coffeyville cuestas to the east and Nellie Bly formation cuestas to the west.

Stratigraphic relations: Weaver (1952), Oakes (1953), and probably many others, have aptly remarked that if all possible evidence for unconformity is accepted in east central Oklahoma, an erosion interval can be found at the base of nearly every sandstone. This is true for the various members of the Coffeyville formation. For the purposes of this report, however, a stricter usage of the term "unconformity" will be adhered to. In line with this practice, the top and bottom contacts of the Coffeyville are considered to be conformable within Seminole County.

Paleontology: Morgan (1924) did not subdivide his Francis formation into Coffeyville and Nellie Bly units. However, he did state that he obtained 50 species from the Ada brick plant, and the latter is thought to be operating in the uppermost Coffeyville shale. Forty-nine other species are listed from the Francis formation.

Ries (1951) identified 66 species from the Coffeyville formation in Okfuskee County. Weaver (1952) collected 54 species from the Coffeyville of Hughes County. In Seminole County, the Coffeyville yielded 60 species, of which 12 were found in the DeNay.

The largest single collection of DeNay fossils, obtained at Station 3094, contained the following:

Bryozoa
Rhombopora lepidodendroides Meek

Brachiopoda
Chonetinella flemingi var. *crassiradiata* Dunbar & Condra
Crurithyris planoconvexa (Shumard)
Hustedia mormoni (Marcou)
Marginifera sp.
Neospirifer sp.
Phricodothyris perplexa (McChesney)
Punctospirifer kentuckiensis (Shumard)

Trilobita
Ditomopyge parvula (Girty)

Crinoidea
Columnals and other fragments

The collection made at Station 3097 included:

Brachiopoda
Crurithyris planoconvexa (Shumard)
Mesolobus mesolobus var. *decipiens* (Girty)

Crinoidea
Columnals

The following forms were found at Station 3100:

Coelenterata
Astrodiscus sp.

Brachiopoda
Neospirifer dunbari King

The DeNay fauna is notable chiefly because the same forms are also found, with four exceptions, in the Sasakwa limestone. (For the fauna of the Coffeyville formation exclusive of the DeNay member, see Table VII.)

Age and correlation: The Coffeyville formation can be traced northward into Kansas (Oakes, 1940). To the south it is overlapped by the Ada formation near Fitzhugh, southwest of the town of Ada, and occurs questionably in the Franks graben (Morgan, 1924).

Francis equivalents in the Ardmore basin consist of 600 feet of Hoxbar strata between the Crinerville and Anadarche members (Alexander, 1952). The lower part of that interval is correlative with the Coffeyville formation.

Nellie Bly formation.

First reference: Charles N. Gould, 1925.

Nomenclator: D. W. Ohern, 1914.

Type locality: Along Nellie Bly Creek, in Washington County, Oklahoma.

Original description: Gould (1925) published the first description of the Nellie Bly formation:

> Alternating shales and hard, gray sandstones, the latter ranging in thickness from a few inches to several feet, from 15 feet on the Kansas line to 200 feet in southeastern Osage County. Middle formation of the Drum group. Rests on the Hogshooter limestone and is overlain by the Dewey limestone.

Other descriptions: Oakes (1940) described the Nellie Bly in Osage and Washington counties as follows:

> Except in the area where the top was removed by pre-Chanute erosion, the Nellie Bly formation ranges from 80 feet thick, in T. 28 N., Rs. 14 and 15 E., to 180 feet thick in T. 23 N., R. 13 E. The lower part consists of clay shale, with thin, silty sandstone beds appearing in the south part of the area. The clay shale grades upward into sandy shale with thin, silty sandstone beds, and at the top are prominent ledges of sandstone, some of which are relatively coarse-grained and tree-bearing,

TABLE VII

FAUNULES OF THE COFFEYVILLE FORMATION
(exclusive of the DeNay member)

	Localities:				
	3037	3083	3085	3087	3096
Coelenterata					
Lophophyllidium spinosum Jeffords		x			
L. wewokanum Jeffords	x	x		?	
Bryozoa					
Rhombopora lepidodendroides Meek	x		x	x	
Brachiopoda					
Chonetes granulifer Owen				x	
Chonetinella flemingi (Norwood & Pratten)	x	x	x	x	
Cleiothyridina orbicularis (McChesney)				x	
Composita sp.	x				
C. subtilita (Hall)	x			x	
C. trilobata Dunbar & Condra		x		x	
Derbyia crassa (Meek & Hayden)	x	x	x	x	
D. plattsmouthensis Dunbar & Condra				x	
Derbyoides nebrascensis Dunbar & Condra				?	
Dictyoclostus americanus Dunbar & Condra		x		x	
D. portlockianus (Norwood & Pratten)	x	x			
Juresania nebrascensis (Owen)		x		x	
J. symmetrica (McChesney)		x			
Lindstromella patula (Girty)			x		
Linoproductus sp.		x			
L. insinuatus (Girty)	x	x	x	x	
Marginifera muricatina Dunbar & Condra				x	
M. splendens (Norwood & Pratten)			x		
Meekella striatocostata (Cox)				x	
Neospirifer dunbari King	x		x	x	x
N. texanus (Meek)		x		x	
Orbiculoidea missouriensis (Shumard)				?	
Schuchertella pratteni (McChesney)				?	
Wellerella osagensis (Swallow)				x	
Pelecypoda					
Astartella concentrica Conrad		x		x	
A. vera Hall		x		x	
Nuculana bellistriata (Stevens)		x		x	
Nuculopsis ventricosa (Hall)		x		x	

TABLE VII--Continued

	Localities:				
	3037	3083	3085	3087	3096
Gastropoda					
Amphiscapha catilloides (Conrad)			x		
Bellerophon crassus var. *wewokanus* Girty		x		x	
Euphemites vittatus (McChesney)		x			
Glabrocingulum grayvillense (Norwood & Pratten)		x	x	x	
Pharkidonotus percarinatus (Conrad)		x	x		
Strobeus sp.		x	x		
Trepospira depressa (Cox)		x	x		
Worthenia tabulata Conrad		x	x	x	
Cephalopoda					
Metacoceras cornutum Girty		x	x		
M. perelegans Girty		x			
Pseudorthoceras knoxense (McChesney)		x		x	
Crinoidea					
Columnals	x	x	x	x	

especially in Tps. 27 and 28 N., R. 14 E.

Ries (1951) mapped the Nellie Bly in Okfuskee County, and described it as follows:

> The Nellie Bly formation consists of a succession of sandstones and shales. One thin limestone was observed. In all, 6 sandstones and 7 shales were mapped. Generally speaking, the sandstones of the Nellie Bly are thick and well developed. A few of the thicker sandstones are, however, friable and therefore do not form pronounced escarpments. The shales are generally thin and are yellowish-brown in color. Small concretions are found in places. There is a marked decrease in the abundance and distribution of the fauna as compared with the fauna of the underlying beds.
>
> The basal member of the Nellie Bly formation is a thin shale. This shale is yellowish-brown in color. It contains very few fossils. It varies in thickness

from 0 to 16 feet. South of Sec. 35, T. 12 N., R. 9 E., where the underlying Hogshooter formation is not mappable, this shale is mapped with the Coffeyville formation.

Overlying the lowermost shale of the Nellie Bly is a light brown sandstone. This sandstone has been traced across the entire county. It varies in thickness from 4 to 12 feet. The base of this sandstone lies from 0 to 16 feet above the top of the Hogshooter formation. This sandstone contained few fossils.

A greenish-yellow to yellowish-brown shale overlies the above sandstone. This shale varies from 70 to 90 feet in thickness. This shale contains very few fossils.

Above the aforementioned shale is a thin sandstone. It is light brown in color but weathers to a dark brown. This sandstone was traced across the entire county. The base of this sandstone is 111 feet above the base of the Hogshooter formation. It varies in thickness from 3 to 10 feet. In the north, it forms low-lying scarps, and in the south, it may be found in the middle of an escarpment formed by an overlying sandstone. Few fossils were observed in this sandstone.

Overlying the above sandstone is a thick shale. This shale is yellowish-brown in color. It varies in thickness from 60 to 90 feet. This shale contains few fossils.

The above-lying sandstone is very massive. It is light brown in color but becomes a deep red on weathering. This sandstone formed high escarpments across the county. In a few places, the sandstone was friable and formed only low lying ridges. The base of this sandstone is about 196 feet above the base of the Hogshooter formation. This sandstone varies in thickness from 18 to 80 feet. . . .

Overlying this sandstone is a yellowish-brown shale. This shale varies in thickness from 20 to 80 feet. Few fossils were observed.

A thin sandstone overlies the aforementioned shale. This sandstone is a light-brown in color. On weathering, it becomes a reddish-orange. Although this sandstone was mapped across the entire county, it seldom forms high escarpments. The base of this sandstone is 296 feet above the base of the Hogshooter formation. Only a few fossils were observed in this sandstone.

Overlying this sandstone is a yellowish-brown shale. This shale varies in thickness from 30 to 90 feet. It is fossiliferous in places.

A thin sandstone overlies the above shale. This sandstone is light-brown in color. It weathers to a deep brown. The base of this sandstone is 306 feet above the base of the Hogshooter formation. It varies in thickness from 3 to 15 feet. It is generally found in the escarpment which is capped by the more massive sandstone above. No fossils were observed in this sandstone.

Overlying the above sandstone is a thin shale. This shale is yellowish-brown in color and contains few fossils. It varies in thickness from 5 to 25 feet.

A massive sandstone overlies the aforementioned shale. This sandstone is light-brown in color. On weathering, the sandstone becomes a rust-brown. The base of this sandstone is 406 feet above the base of the Hogshooter formation. It varies in thickness from 20 to 50 feet. The sandstone generally forms high escarpments throughout the county. It contains few fossils. Of special interest is a thin 6 inch to 2 foot limestone which occurs at the base of this sandstone. This limestone is persistent and can be found at most places.

The uppermost member of the Nellie Bly formation is a greenish-yellow shale. This shale overlies the aforementioned sandstone. It is overlain by the Dewey limestone. This shale varies in thickness from 60 to 90 feet. It contains some fossils.

The Nellie Bly varies in thickness from 450 to 475 feet.

Morgan (1924) described the upper Francis formation, now known as the Nellie Bly, in Pontotoc and adjacent counties within the Stonewall quadrangle:

> Above the shale series is a thickness of almost 100 feet within which coarse brown sandstones and chert conglomerates predominate. Only occasional fossils were found in this member. Although much higher in the geologic column some of these conglomerates greatly resemble the conglomerates at the base of the Seminole in the type area of that formation. For that matter, however, they also closely resemble the conglomerates of the Wewoka, Holdenville, and Vamoosa formations, and were it not for the presence of arkose in the Pontotoc strata, hand specimens of Francis conglomerate could probably not be distinguished from similar specimens of the chert conglomerates in that terrane. All the very similar chert conglomerates in the Pennsylvanian section must have had a similar source. The writer is in agreement with Taff's suggestion that this source was the Ouachita area.
>
> The upper part of the Francis formation is a shale that is about 100 feet thick. This part carries a few thin sandstones and one rather persistent conglomeratic limestone. The limestone is often very fossiliferous

and is typically exposed in the road about 100 yards west of the school house in the southeast corner of sec. 19, T. 6 N., R. 7 E. In the vicinity of Ada this shale and a part of the underlying sandstone member is overlapped by the Ada formation.

Distribution: The Nellie Bly formation crosses Seminole County in a north-south belt one to four miles wide. The average width of outcrop is approximately two miles. Exposures in this area are generally good except where sandstone or siltstone members are too friable to permit the development of well-capped cuestas.

Southward in Pontotoc County, the Nellie Bly is truncated by the Ada formation in and near the city of Ada (Morgan, 1924). The Nellie Bly can be traced northward on the surface at least as far as the Kansas line (Oakes, 1940).

Character and thickness: The Nellie Bly formation, as exposed in Seminole County, consists of shale, sandstone, siltstone, chert conglomerate, limestone and limestone conglomerate. Only a single ledge, the basal (No. 1) sandstone, is continuous across the county. The sandstones are commonly massive but soft, buff to brown in color, cross-bedded and ripple-marked (ripple index, about 10). Siltstones and very fine sandstones are common both in exposed ledges and in covered intervals. The chert conglomerates occur as soft lenses in soft sandstones (see Fig. 14), rather than as ridge or cuesta-makers. Cross-bedding, lensing, channeling and rapid facies changes are common.

The 100-foot interval above the basal (No. 1) sandstone member is generally a black or very dark gray shale. This can be traced great distances in the subsurface on electric logs. It is easily distinguishable, by virtue of the thick overlying coarse clastic section, from the shale intervals of the Coffeyville formation. This coarser section, largely unbroken by shale, is 200 to 300 feet thick, and contains nearly all of the conglomerate and limestone lenses in the formation.

In the southern part of the county are found limestone lenses--some of them very pure--and coarse limestone conglomerates. The limestones increase in number and thickness toward the top of the formation, where some of them rival, for short distances, the overlying Belle City formation. In the subsurface, the two are often confused. On the surface, the best limestones are developed in T. 6 N.

The Nellie Bly has a thickness of 300 to 400 feet. Within Seminole County, the maximum thickness occurs in T. 6 N., the minimum in T. 9 N. The formation thins southward into Pontotoc County, and thickens northward into Okfuskee County.

Unlike the formations already discussed, the Nellie Bly is not constituted of a regular sequence of relatively thin alternating shales and coarser clastics. The basal (No. 1) sandstone and the overlying dark shale are easily distinguished in the field; the rest of the section, how-

Figure 14. Soft chert conglomerates of the Nellie Bly formation, in the southeast part of sec. 6, T. 9 N., R. 8 E.

ever, does not lend itself to easy field analysis.

In T. 10 N., 12 of the 13 members established by Ries (1951) are readily recognized; the thirteenth has been mapped, by both Ries and this writer, in the upper shales of the underlying Coffeyville formation. The 12 members which are retained as distinct units include six sandstones, four of which wedge or shale out in the same township. A fifth sandstone vanishes in T. 9 N. Only one of the original six sandstones (specifically, the basal member) can be carried, by ordinary field methods, as much as half way across Seminole County. It was traced southward to Canadian River.

With the disappearance of five of the six ledges found in Okfuskee County, the identity of the intervening shales becomes questionable. Meanwhile, new sandstone ledges have appeared, and the formation as seen in central Seminole County presents quite a different aspect from the one reported by Ries in Okfuskee County.

The following tentative correlation between the two counties is offered:

Seminole County	Okfuskee County
	Shale
	Sandstone
	Shale
Upper, coarse clastic zone	Sandstone
	Shale
	Sandstone
	Shale
	Sandstone

Seminole County	Okfuskee County
Lower, calcareous shale zone	(Shale (Sandstone (Shale
No. 1 sandstone	Sandstone
Coffeyville	Shale (in upper Coffeyville)

In Pontotoc County, to the south, the upper Nellie Bly includes a sequence of alternating shales and limestones. Morgan (1924) described this "upper shale" unit as being about 100 feet thick. In the southern part of Seminole County (i.e., T. 6 N.), it is between 150 and 200 feet thick, and contains at least eight well-developed lenses of either limestone or limestone conglomerate.

The Nellie Bly sandstone zone of central Seminole County appears to be a cross-bedded, contorted, lenticular, channeled facies intermediate in position between the more evenly bedded section in Okfuskee County to the north, and the thinner, perhaps lagoonal sequence in Pontotoc County to the south.

The Nellie Bly shales are usually gray or green, weathering to a brown or reddish brown color. Locally, however, they are blue, red or purple. Fossils are generally rare, although a few good collecting sites were found.

The basal Nellie Bly (No. 1) ledge is, variously, chert conglomerate, sandstone or siltstone, up to about 20 feet in thickness. The coarsest phase occurs in the northern half of T. 6 N., where a chert pebble conglomerate--perhaps a channel deposit--is developed. This bed may be seen in the vicinity of the Middle Creek Church, in sec. 2, T. 6 N., R. 7 E. Occasional streaks of limestone, one to three inches thick, are found in the sandstone phase, which is thin to massive and at places contorted. The basal sandstone is buff to yellow.

The Nellie Bly sandstone zone contains many features indicative of a shore or near-shore environment. Extreme variations in lithology and poor lateral continuity are common, along with the lensing, channeling and cross-bedding already mentioned. Penecontemporaneous contortion (see page 94) is especially typical of the sandstones and siltstones. "Bar" structure--cross-bedding in which the dip directions, for individual layers, are at 180°--is found in the northern half of the county. Chert conglomerates make up, by volume, only a small proportion of the total in the sandstone zone; where present, they are very coarse, and probably are channel-fillings. Individual cobbles with diameters as great as four inches have been found; two inches is, in most cases, the maximum diameter.

Colors in the sandstone zone include buff, brown, grayish-brown, white or pale green, the latter especially in siltstones. Sand grains and chert flakes are generally angular and clear, at places frosted.

Ripple marks occur in larger numbers in the Nellie

Bly than in any other formation in the county. Both oscillation and water-current ripple profiles were observed; in each case, the ripple index was approximately nine or 10. Oscillation ripple marks trended roughly N. 20 W., and N. 40 E. to N. 50 E. Asymmetrical ripple marks were developed as a result of currents flowing, locally, in two different directions: ripples trending N. 60 E., due to currents flowing from the southeast; and ripples trending N. 10 W. to N. 15 W., due to currents flowing from the northeast.

Limestone conglomerates, although none is thick, become relatively important toward the top of the Nellie Bly formation. Maximum pebble diameters are commonly less than two inches. Pebble colors include white, pink, red, yellow, buff, purple and even very dark gray, on weathered surfaces; fresh surfaces are red, yellow, white, green or black. The pebbles are well-rounded; the mean size is in the range, two to five millimeters. Chert flakes are not common in these limestone conglomerates. Laterally, the conglomerates grade into fine-grained arenaceous limestones. Cross-bedding and lenticularity are pronounced.

In the southern part of the county (T. 6 N.), the upper part of the sandstone zone grades into a shale, 150 to 200 feet thick, bearing limestone lenses. These latter commonly have a lateral surface extent of only one or two miles, but the uppermost limestone, locally about 17 feet thick, extends for at least seven miles (T. 6 N.; the northern part of T. 5 N.). These limestone lenses, with the overlying Belle City formation, constitute a sequence of calcareous deposits of increasing thickness and lateral extent, the Belle City exhibiting the best development of any member of the sequence. In each instance, the limestone passes northward into cross-bedded and contorted sandstone, or other coarse clastics, which may well have been beach or near-shore deposits.

The limestone lenses of the upper Nellie Bly are multicolored, contorted and cross-bedded, and contain chert pebbles and sand grains. The $CaCO_3$ content varies from 25% to 80% (six samples). Fine-grained, hard, non-fossiliferous, and occasionally vuggy, the limestones include well-developed crystals of secondary calcite. Individual layers within each lens are thin-bedded to massive. Colors on weathered surfaces are generally dark brown or black, rarely yellow. Fresh surfaces exhibit many colors, including yellow, light gray, white, green, red, dark blue, and pastel shades of blue, green and purple. The uppermost limestone lens lies below the Belle City formation by an interval varying from 12 to 56 feet, increasing northward.

Stratigraphic relations: The Nellie Bly formation is considered to be conformable, within Seminole County, above the Coffeyville formation and below the Belle City. The contact between the Nellie Bly and the Hilltop, in the northern part of the county, will be discussed in connection with the latter formation.

Paleontology: Morgan (1924) listed 99 species from his Francis formation in the Stonewall quadrangle. Of these, 50 were obtained from Coffeyville equivalents. Ries (1951) identified 19 species from the Nellie Bly in Okfuskee County. Thirty-three species were identified from the Nellie Bly of Seminole County (see Table VIII).

Age and correlation: The Nellie Bly has been traced northward from Washington County to the Kansas line (Oakes, 1940), and southward through Tulsa County (Oakes, 1952). South of the Canadian River, it occupies the position of the upper Francis formation, to the latitude where it is truncated by the Ada formation near the city of Ada (Morgan, 1924).

Nellie Bly correlatives in the Ardmore basin are found in the upper part of the 600 feet of Hoxbar sediments between the Crinerville and Anadarche members (Alexander, 1952).

Belle City formation.

First reference: Boone Jones, 1922.

Nomenclator: Boone Jones, 1922.

Type locality: The village of Belle City, in Semi-

TABLE VIII

FAUNULES OF THE NELLIE BLY FORMATION

	Localities: 3047	3048	3049	3059
Coelenterata				
Lophophyllidium wewokanum Jeffords		x		
Bryozoa				
Rhombopora lepidodendroides Meek			x	
Brachiopoda				
Chonetes granulifer Owen			x	
Chonetinella flemingi (Norwood & Pratten)		x	x	
C. rostrata ? Dunbar & Condra		x		
Cleiothyridina orbicularis (McChesney)		x	x	
Composita sp.			x	
C. subtilita (Hall)		x		
C. trilobata Dunbar & Condra			x	
Derbyia crassa (Meek & Hayden)	x			x
Dictyoclostus portlockianus (Norwood & Pratten)		x		
Juresania symmetrica (McChesney)		x		
Lindstromella patula (Girty)		x		
Linoproductus carinatus (Dunbar & Condra)	x			
L. oklahomae Dunbar & Condra				x
Lissochonetes geinitzianus var. *senilis* Dunbar & Condra			x	
Marginifera splendens (Norwood & Pratten)			x	
Mesolobus mesolobus var. *decipiens* (Girty)		x		
Neospirifer dunbari King	x			
N. texanus (Meek)		x		
Nudirostra rockymontanum (Marcou)		x		
Pelecypoda				
Astartella concentrica Conrad		x	x	
Aviculopinna americana Meek				x
Nuculana bellistriata (Stevens)		x	x	
Nuculopsis ventricosa (Hall)		x	x	
Parallelodon tenuistriata (Meek & Worthen)		x		
Yoldia glabra Beede & Rogers		x		

TABLE VIII--Continued

	Localities: 3047	3048	3049	3059
Gastropoda				
<u>Amphiscapha</u> <u>catilloides</u> (Conrad)		x		
<u>Cymatospira</u> <u>montfortianum</u> (Norwood & Pratten)		x		
<u>Glabrocingulum</u> <u>grayvillense</u> (Norwood & Pratten)		x	x	
<u>Phymatopleura</u> <u>nodosa</u> Girty			x	
<u>Trepospira</u> <u>depressa</u> (Cox)		x	x	
<u>Worthenia</u> <u>tabulata</u> (Conrad)		x	x	
Cephalopoda				
<u>Pseudorthoceras</u> <u>knoxense</u> (McChesney)		x	x	
Crinoidea				
Columnals	x		x	

nole County (southwest quarter, sec. 35, T. 8 N., R. 7 E.).

Original description: Boone Jones (1922) described the Belle City from its outcrops west and southwest of Wewoka:

> Belle City limestone is quite prominent throughout most of the area forming a high ridge along the line of its outcrop. In the southern part of the area it is very hard and weathers out into large irregular blocks sometimes twenty feet across the top which break away from the main outcrop and are found scattered along the east side of the ridge. It is twenty feet thick at the southern border of the area and maintains this thickness to the north line of sec. 22, T. 7 N., R. 7 E., where it begins to decrease in thickness. At the southwest corner of sec. 17, T. 7 N., R. 7 E., it is 16½ feet thick, the upper 2½ feet being quite sandy. At the middle of the south line of sec. 11, T. 7 N., R. 7 E., it is 12 feet thick and continues with this thickness northward. In

secs. 26 and 27, T. 8 N., R. 7 E., it begins to get shaly in character and in sec. 22, T. 8 N., R. 7 E., large lumps of shale appear interbedded with the limestone. At about this point it ceases to form a ridge and is no longer a factor in determining the topography. At the north line of sec. 22, T. 8 N., R. 7 E., only occasional limestone lumps are found in the shale. Nothing can be found of it north of this line.

This limestone where typically developed has a very peculiar appearance when weathered. Material seems to have been dissolved out along the lines of stratification leaving distinct layers of a usual thickness of 2 or 3 inches. In addition to this there seems to have been dissolving out of material at intervals along each layer giving the entire rock a lumpy appearance. These rounded lumps vary from three inches to over a foot in size and may be found scattered around over the top of the bed rock in places.

In certain places the limestone is given a speckled appearance by irregular particles which vary in size from a fraction of a millimeter to a centimeter in diameter and are apparently composed of calcium carbonate which has been given a reddish or brownish color due to the intermixed ferruginous matter.

Other descriptions: Morgan (1924) described the Belle City outcrops of southern Seminole and northern Pontotoc counties as follows:

The formation has an average thickness of 30 feet. It is composed of two limestones of varying thickness with an intervening shale. The upper lime is generally thicker and much more massive than the lower. Its range in thickness is from one foot, as just south of Byng, to as much as 15 feet near Canadian River. The bed is white or light gray in color and is often characterized by well developed stylolites. Pronounced weathering along joint cracks is common and in the eastern part of sec. 24, T. 6 N., R. 6 E., results in the formation of small sinkholes at the intersection of a few of the prominent joints.

The lower limestone bed is buff colored. Its range in thickness is from one foot, as in the vicinity of Byng, to as much as five feet near Canadian River and northward. At variance with the massive character of the upper member of the formation the bedding of this stratum is relatively thin.

The interval between the upper and lower limestones is composed of shale that ranges in color through shades of green, blue and black. Its average thickness is 12 feet.

Green (1936) summarized previous work on the Belle City:

The areal extent of the outcrop of the Belle City limestone is accurately shown on the Geologic Map of Oklahoma. In the Stonewall Quadrangle Morgan included two limestone beds and an intervening shale in the Belle City. The lower limestone grades rapidly into sandstone in Seminole County. At the southernmost exposure, Morgan describes the upper Belle City limestone as being only one foot thick. Northward the bed thickens, reaching the maximum of 20 feet at the south line of T. 7 N., R. 7 E. North from here it begins to thin again, being 5-7 feet thick west of Wewoka and less than one foot thick where it finally grades into sandstone in the south part of T. 10 N., R. 8 E. The bed is known to extend westward underground for many miles and it is probable that it extends around the west side of the central sandstone phases in Okfuskee and Creek counties and is represented by the Dewey or Avant limestone west of Sapulpa. This suggested correlation probably could never be checked by either surface or subsurface study.

Distribution: The northernmost exposure of Belle City in Seminole County occurs in the southwest quarter of sec. 17, T. 10 N., R. 8 E. From there south to Wewoka Creek, the formation is only a few inches to a foot thick, and hence has no real map width. Between Wewoka Creek and Canadian River the outcrop varies in width to a maximum of approximately three miles. South of Canadian River the formation extends to where it is truncated by the Ada formation, about two miles north of the town of Ada.

Because of its extreme resistance to weathering, the Belle City caps a distinctive cuesta across much of central and southern Seminole County. Its good exposures and sharply-defined contacts with beds both above and below make it an excellent horizon for structural mapping.

Character and thickness: The Belle City formation in Seminole County consists of upper and lower limestones separated by a dark shale.

The upper limestone, at most places the thicker of the two, is commonly a blue-gray, dense, fossiliferous limestone, exhibiting a rubbly, wavy type of bedding (see Fig. 15), and weathering to a dull, chalky white. South of Wewoka Creek, it varies from a maximum thickness of about 11 feet to a minimum of about two feet. The middle shale, although generally black or dark gray, and highly fossiliferous, is at places light green or gray-green, and non-fossiliferous. It is commonly 10 to 20 feet thick. The lower limestone, only two or three feet thick, is buff to pale yellow, and locally fossiliferous.

North of Wewoka Creek, the entire formation is commonly a blue crystalline limestone, a few inches thick, which weathers yellow. The fossil suite changes northward, becoming first crinoidal, then fusulinid. Within a few miles thereafter, the formation thickens locally to two or three feet, and becomes a dark red limestone. It vanishes about two miles almost due west of Cromwell.

The Belle City has a maximum thickness of 36 feet,

Figure 15. The wavy or "lumpy" bedding of the upper Belle City limestone, in the south central part of sec. 19, T. 7 N., R. 7 E. The Brunton compass is included to provide a scale.

thinning northward.

The lower limestone member is not everywhere present. Over certain structures in the southern part of the county it is absent, probably by non-deposition. Such thinning in the Belle City is accompanied by a similar thinning in the upper beds of the Nellie Bly (i.e., T. 5 N., R. 6 E.).

North of the Belle City townsite, the lower limestone is missing, again apparently by non-deposition.

The upper limestone member is more variable than Morgan's description would indicate. Locally it is thick, evenly-bedded, and fossiliferous. Elsewhere it varies somewhat from the typical picture. In sec. 7 T. 6 N., R. 7 E., the upper member consists of two distinct varieties of limestone, each about six feet thick. The lower unit is a gray-blue, very hard crinoidal limestone, in beds one to 12 inches thick. Shell fragments are abundant, and small chert pebbles occur near the base. The upper unit is a thin-bedded (one to three inches thick), very hard blue crinoidal limestone.

Northward, the Upper Belle City limestone thins to a few inches and passes into a cross-bedded, contorted siltstone and fine sandstone here interpreted as an offshore bar or barrier island. The barrier crosses the southern part of T. 10 N., and the northern part of T. 9 N. Immediately north of the barrier, the Belle City horizon is occupied by a dark red fusulinid limestone, one or two feet thick. This phase is well developed in sec. 20, T. 10 N., R. 8 E.

In several places (i.e., sec. 1, T. 5 N., R. 6 E.) the typical Upper Belle City has a "sugar cube" appearance on the air photographs (see Fig. 16). Joint-controlled solution weathering in these areas has separated rectangular blocks five to 20 feet long. These blocks, of chalky white resistant limestone, contrast sharply on the photographs with the thick grasses which cover the limy adjacent soil. The "sugar cube" appearance occurs on the back slopes of cuestas, and is associated with potholes, and, on a small scale, various karst features such as those described by Morgan (above).

Perhaps the most typical aspects of the Upper Belle City, other than its position in the stratigraphic column, are the chalky white color on weathered surfaces, and the wavy bedding.

The middle shale member reaches a maximum thickness of 20 feet in sec. 19, T. 6 N., R. 7 E. Here it is green, in the lower part of the member, and black in the upper portion. Occasionally the middle shale is blue or even red.

Between the Belle City townsite and Wewoka Creek, the formation thins from 10 feet to about two feet, and loses the lower limestone member. In this area, and north of Wewoka Creek, other limestones are present in both the underlying Nellie Bly and the overlying Hilltop formations. The

Upper Belle City is here almost invariably fossiliferous, blue and yellow on fresh surfaces, and possesses characteristic wavy bedding. The most prominent limestone lens in the Upper Nellie Bly, on the other hand, is crinoidal, massive and blue, and lies about 40 feet stratigraphically below the Belle City; this lens outcrops in the north central part of sec. 23, T. 8 N., R. 7 E. Typical Belle City may be seen in the roadside ditches below the Hilltop school, on the west line of the same section.

Limestone beds near the base of the overlying Hilltop will be discussed with that formation.

Stratigraphic relations: In the northern part of Seminole County, the Belle City is missing due to non-deposition. In the central part, it lies conformably between the Nellie Bly and Hilltop formations. In the southern part, the Vamoosa formation rests, locally, unconformably on the Belle City, which in turn is conformable with the underlying Nellie Bly. Between the Belle City and Vamoosa formations are isolated outliers of red or blue shale which may belong to the Hilltop.

In Pontotoc County, to the south, the Belle City is truncated by the Ada formation, about two miles north of the town of Ada (Morgan, 1924).

Paleontology: Morgan (1924) identified 32 species from the Belle City formation in the Stonewall Quadrangle.

Figure 16. Belle City blocks look like sugar cubes when seen from the air. This picture, taken on the ground, shows remnants of potholes and other evidences of solution weathering. Blocks of this kind are found on the back slopes of Belle City cuestas. These blocks occur in the southwest part of sec. 1, T. 5 N., R. 6 E.

The Belle City of Seminole County yielded 12 species, not counting _Fusulina_ in which the calcium carbonate had been recrystallized.

At Station 3092, the Belle City limestone contains these two species:

Brachiopoda
  Composita subtilita (Hall)
  Neospirifer dunbari King

The limestone yielded the following species at Station 3088:

Brachiopoda
  Composita sp.
  C. subtilita (Hall)
  C. trilobata Dunbar & Condra
  Dictyoclostus americanus Dunbar & Condra
  Dielasma bovidens (Morton)
  Neospirifer dunbari King
  Phricodothyris perplexa (McChesney)

Gastropoda
  Euconospira turbiniformis (Meek & Worthen)

Crinoidea
  Columnals

At Station 3054, the following species were collected from the Middle Belle City shale:

Bryozoa
  Rhombopora lepidodendroides Meek

Brachiopoda
  Chonetinella flemingi var. _plebeia_ Dunbar & Condra
  Marginifera splendens (Norwood & Pratten)
  Meekella sp.
  Neospirifer dunbari King

Age and correlation: Ries (1951) reported that he had traced the Dewey formation, of Okfuskee County, across

North Canadian River into Seminole County, and found it equivalent to the Belle City formation. This correlation has been made by many geologists, and probably is as good as any other. However, this writer, after tracing the Belle City horizon northward into Okfuskee County, prefers to correlate the uppermost Nellie Bly ledge of Seminole County with Ries' Nellie Bly No. 12. Since the Belle City lies only 10 to 20 feet, at the most, above this ledge, and since Ries' Nellie Bly No. 13 (shale) is reportedly 60 to 90 feet thick, the Dewey would be 50 to 70 feet higher than Ries assigned it.

Complicating this problem are the following facts:

1. The gap between actual Dewey and Belle City outcrops is about 10 miles wide.

2. Occurring in and near this gap is the Nellie Bly facies change from the regular bedding in Okfuskee County to the channeling, cross-bedding and contortions of Seminole County. Stratigraphic horizons carried across the gap are not absolutely reliable.

3. Two-thirds to three-fourths of the gap is blanketed by thick alluvium and high terrace materials.

4. The fossils of the area are not known well enough to permit detailed correlation.

5. North Canadian River, at the extreme northeastern corner of Seminole County, flows through what appears to be a graben (see Fig. 17). Southwest of the graben (secs. 3, 10, 11, in T. 11 N., R. 8 E.) strata which Ries mapped as

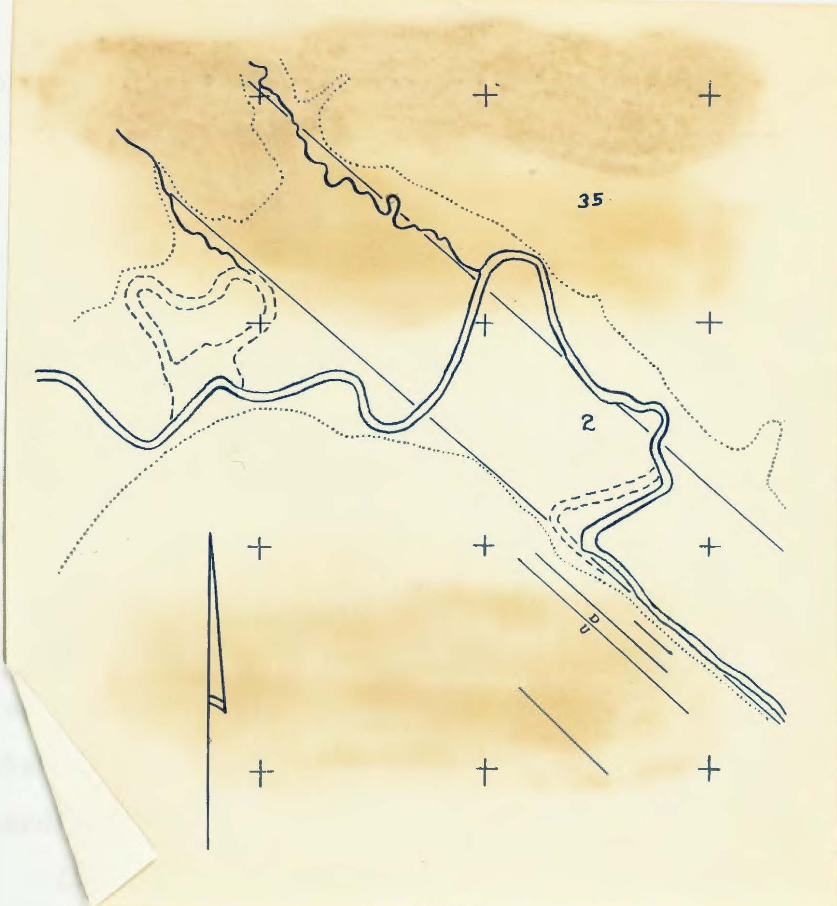

Figure 17. A graben inferred from aberrations in the behavior of the North Canadian River. Sec. 2 is in T. 11 N., R. 8 E. Among the faults southwest of, and parallel to, the supposed graben are several with sufficient displacement to be measured by reconnaissance methods. The presence of this fault system makes precise correlation of the Dewey and Belle City formations difficult.

upper Nellie Bly are cut by a closely-spaced sequence of northwest-southeast trending faults.

6. Immediately north of North Canadian River this writer measured 90 to 100 feet of Hilltop formation. Between the river and the northernmost appearance of Belle City, the Hilltop varies between 150 and 200 feet in thickness, and seems to be thickening northward.

7. In Okfuskee County (secs. 26, 27, in T. 12 N., R. 8 E.) one or more hard, dark limestones, showing evidences of solution weathering, may be found at least 30 feet below the base of the Dewey formation, and about 20 feet above the top of Ries' Nellie Bly No. 12 (sandstone).

8. The Dewey "limestone," as exposed in the southern part of Okfuskee County, is a fairly hard buff siltstone or fine sandstone, locally greenish, laminated, crumbly and not resistant. Ries described it as being, locally, a calcareous sandstone.

It is therefore concluded that the Belle City is not precisely a Dewey equivalent.

In Pontotoc County, to the south, the Belle City is truncated by the Ada formation, which also cuts out the Vamoosa formation in approximately the same area (Morgan, 1924).

The Belle City correlative in the Ardmore basin is the Anadarche member of the Hoxbar formation (Alexander, 1952).

Hilltop formation.

The Hilltop formation is here defined as a sequence of beds, in Seminole and Pontotoc counties, overlying the Belle City, and cut above by pre-Virgil erosion.

The name is taken from the Hilltop school (sec. 23, T. 8 N., R. 7 E.) which rests on the lower part of the formation. The type section was measured in and near the Wewoka Brick and Tile Company pit, north of Wewoka Creek (sec. 11, T. 8 N., R. 7 E.) (see Fig. 18). The formation varies in thickness, within Seminole County, from zero to 200 feet. Although the thickening is, in general, toward the north, it is not at all regular.

As here defined, the Hilltop formation contains specifically Barnsdall, probably Dewey, and perhaps Chanute and uppermost Nellie Bly beds. The new name was adopted only after it became evident that, with methods and time available, it was not possible to extend the Barnsdall-Chanute-Dewey sequence accurately into Seminole County.

Morgan (1924) described this interval as part of the overlying Vamoosa formation:

> At the base is about 30 feet of dark shale that might easily be mapped as a separate formation. No collections were made from this member. . . .

Green (1936) noted 225 feet of shales and sandstones between the Belle City and the Vamoosa formations, in central Seminole County (T. 9 N.), but gave them no name. Ries

Figure 18. The middle and upper parts of the Hilltop formation, exposed in the brick-shale pit in sec. 11, T. 8 N., R. 7 E. The picture was taken with a 5-factor red filter, to lighten the buff-colored silts and to darken the blue-gray shales.

(1951) described the Barnsdall, Chanute and Dewey formations of Okfuskee County.

Character and thickness: Lithologically, the Hilltop is a sequence of dark blue-gray shales grading upward into massive buff siltstones and fine sandstones, with many thin limestones near the base of the formation.

In the southern part of the county, isolated red shales, or typical blue shales up to 70 feet thick, appear between the Belle City and Vamoosa formations. Also in this part of the county the Hilltop contains, about 22 feet above the base, a single multi-colored conglomerate of limestone cobbles (up to seven inches in diameter), clay plates and chert and jasper pebbles. This bed is white, yellow and purple.

The continuous outcrop of the Hilltop is found only north of T. 6 N. It is in this area that the massive buff siltstones and fine sandstones occur. These, however, are not continuous, the longest known outcrop being about eight miles, and the average perhaps less than one mile.

In the type section, as measured with clinometer and tape, the following zones were observed:

4. At the top, about 44 feet of shale, covered heavily by conglomerate float from the overlying Vamoosa formation.

3. Seven to 20 feet of massive, tan to buff, silt-

stone or fine-grained sandstone. Fossil casts, poorly preserved in the siltstones, include brachiopods and pelecypods. Ripple-marks are common.

2. Twenty-two feet of shale, grading upward from blue to gray and then green; alternating with tan or buff siltstones and dense gray or blue limestones. The average limestone, siltstone or sandstone bed in this zone is two to six inches thick. Plant fossils occur near the top of the zone.

1. At the base, 41 feet, mostly blue shale, partings revealing plant fossils.

The blue-gray shales of the Hilltop do not seem to fit the descriptions of any Nellie Bly, Dewey, Chanute or Barnsdall shales examined by Ries (1951) in Okfuskee County to the north. The isolated red shales of the Hilltop (i.e., in secs. 7 and 30, T. 6 N., R. 7 E.) may be equivalent to the upper Barnsdall red shale, a unit which is truncated by the Vamoosa formation in the southern part of T. 13 N. Another possible correlation is with the Tallant red shale of northern Okfuskee County (Ries, 1951).

The electric log study of the Hilltop formation (see Plate IV) was most revealing. In the subsurface the Hilltop is divisible into two zones, the lower being a distinctive shale 50 to 100 feet thick in Seminole County, and thickening westward. Thin, discontinuous limestones are present.

This probably includes zones No. 1 and No. 2, given above. The upper subsurface zone, composed chiefly of sandstone, thickens both northward and westward. The section is similar to that in the Nellie Bly, where a more or less uniform plate of shale is overlain by a thick and complex sequence of coarser clastics.

Stratigraphic relations: The Hilltop rests conformably on the Belle City formation in the central and southern parts of Seminole County, and in the northern part of Pontotoc County. In northern Seminole County, it is apparently conformable on the uppermost Nellie Bly sandstone.

Five formations, exposed in Okfuskee County to the north, may be represented in the Hilltop interval: Nellie Bly, Dewey, Chanute, Barnsdall and Tallant. The Tallant is perhaps the least likely correlative of the five, the Barnsdall the most likely. It is possible that the Chanute is cut out completely by the overlying Barnsdall before it can emerge from underneath the wide belt of North Canadian River floodplain and high terrace deposits. The upper Dewey shales are probably included in the Hilltop. The possibility that the uppermost Nellie Bly shale unit is also included has been discussed on page 144.

At least one unconformity of major proportions seems to occur within the Hilltop interval: that at the base of the Barnsdall.

The unconformity which separates the Hilltop from the overlying Vamoosa formation also marks the Missouri-Virgil series boundary. The character of this erosion surface is depicted on Plate VIII. Measured along the strike, in the central part of the county, the angular relationship involved may be expressed as about seven feet per mile. The thickening and thinning is not regular, however; and, probably more important, the zero isopach crosses the outcrop more than once. For the 50-mile distance from the North Canadian River to the final point of truncation in Pontotoc County, the angle is perhaps less than three minutes. It is thought, therefore, that across Seminole County, pre-Virgil erosion left the thin edge of the Hilltop formation not far from the present north-northeast south-southwest outcrop.

In the subsurface beneath Seminole and Pottawatomie counties, the Hilltop thickens westward, by the addition of younger beds at the top of the section, in a ratio of 10 feet per mile. This is probably more nearly the true value for the pre-Virgil truncation. The maximum thickening should be obtained in the subsurface along a line running northwest or north-northwest from Seminole County.

Unlike the other unconformities discussed in some detail in this report, the truncation of the Hilltop is considered, for the reasons discussed above, to represent an uplift to the southeast.

Paleontology: Ries (1951) reported 40 species from the Dewey, plant remains only from the Chanute, a few crinoid stems only from the Barnsdall, and no fossils from the Tallant. This writer observed a rather prolific fauna in the Chanute formation in Okfuskee County (sec. 34, T. 12 N., R. 8 E.); nothing comparable to it was seen farther south.

In Seminole County, the upper Hilltop sandstones and siltstones yielded seven invertebrate species, and fragmentary plant remains were found to be common in many parts of the formation. The fossils collected at Station 3090 included:

Brachiopoda
- Hustedia sp.
- Other unidentified genera

Pelecypoda
- Acanthopecten carboniferus (Stevens)
- Nucula anodontoides (Meek)
- Nuculana sp.
- Tropidophorus sp.

At Station 3063, the following fossils were collected:

Gastropoda
- Worthenia tabulata (Conrad)

Cephalopoda
- Pseudorthoceras knoxense (McChesney)

Crinoidea
- Columnals

Age and correlation: The Hilltop is the youngest formation of the Missouri series in Seminole County. Its equivalents farther north include everything between the uppermost Nellie Bly sandstone and the top of the Barnsdall. Some of the Hoxbar beds above the Anadarche member are thought to be Hilltop correlatives in the Ardmore basin (Alexander, 1952).

Virgil Series

Three formations were laid down in Seminole County during Virgil time: the Vamoosa, Ada and Vanoss. These formations have a combined thickness varying from a minimum of about 700 feet, along Canadian River south of the county, to a maximum of over 1,100 feet in the northern part of the county. Thickening westward, into the subsurface, is more rapid.

The unconformity at the base of the series is one of the two best-developed erosion intervals in the Seminole County section. The other occurs well up in the Virgil, between the Vamoosa and the overlying Ada formation. Many other more or less local unconformities may be found, especially within the Vamoosa formation and at the base of the Vanoss. The top of the series is not marked by any pronounced erosion within the county.

The Virgil is distinguished as a whole by:

1. The coarsest chert conglomerates (in the Vamoosa).

2. The coarsest limestone conglomerates (in the Ada).

3. The first appearance of arkose in the surface

section (in the Vanoss).

4. The relatively large number of multiple-cycle brecciated chert pebbles and cobbles (in the Vamoosa).

5. The paucity of fossils.

The coarse chert conglomerates occur in lenses and as channel-fillings in the central and northern parts of the county. The coarse limestone conglomerates become even coarser southward into Pontotoc County, where limestone boulders are fairly common in the Ada formation. With one or two exceptions, the arkose is limited to the southern half of the county.

Virgil time in Seminole County must have been primarily a time of emergence, with repeated inundations of relatively short duration spreading southward across the area. Virgil time must also have been a time of repeated orogenic pulsations in the neighboring Hunton Arch-Arbuckle Mountain complex.

Vamoosa formation.

First reference: George Morgan, 1924.

Nomenclator: George Morgan, 1924.

Type locality: On the main road between Sasakwa and Konawa (i.e., in secs. 25 and 26, T. 6 N., R. 6 E.).

Original description: Morgan (1924) named the Vamoosa formation from outcrops in the south central part of

Seminole County:

A suitable geographic name was not available for this formation. The term finally selected is after the village of Vamoosa which is located in the northern part of the Stonewall quadrangle, about one-half mile west of the outcrop. The formation is typically developed on the main road between Sasakwa and Konawa.

In the Stonewall quadrangle the formation is exposed over an area of approximately 20 square miles. The lateral extent of its outcrop is similar to that of the underlying Belle City limestone. From the northern edge of the quadrangle, the principal outcrop trends in a southwesterly direction to an area about one-half mile east of Byng and is there covered by Guertie sand. South of Byng the formation is exposed on what is believed to be an outlier. The southern part of this exposure is covered in part by Guertie sand and is overlapped by the Ada formation.

Where all of the formation is exposed the entire section has an average thickness of 260 feet. At the base is about 30 feet of dark shale that might easily be mapped as a separate formation. No collections were made from this member, but it is very probably fossiliferous. The main mass of the formation is above this shale and has a maximum thickness of about 230 feet. It consists in large part of chert conglomerates, of massive, coarse, red and brown sandstones, and red shales. The clastic material is finer near the top and the red coloration is there also less pronounced.

The chert conglomerates of the Vamoosa formation closely resemble those of the Wewoka, Holdenville, Seminole, and Francis formations, but may be distinguished from somewhat similar beds in the Pontotoc terrane because of arkosic material contained in the latter. The Vamoosa formation contains a greater thickness of chert conglomerates than does any other formation of the area. . . . The chert fragments which make up the conglomerates are mostly angular and range in size from a fraction of an inch to as much as three inches in length. The average length, however, is less than an inch.

Overlap of the Vamoosa formation, by the succeeding Ada formation, is progressive southward. For this reason only the lower shale and about 30 feet of the clastic portion of the formation are exposed near Byng.

No fossils were found nor is it highly probable that any are present in the clastic beds of the Vamoosa.

Other descriptions: Boone Jones (1922), working in townships 6, 7 and 8 North, had previously used the name

"Little River conglomerate" for these beds:

> Little River conglomerate formation is found above the Belle City limestone and consists of alternating beds of shales, sandstones, and conglomerates. It is 500 feet thick at the north line of the area and thins greatly toward the south, having a thickness of 350 feet along the south line. The shales are all very bright red in color and make up at least half of the formation. So far they have not been found to contain any fossil remains. The sandstones are usually white and fine grained being quite free of large pebbles and seem to be more regular than the conglomerate layers.
>
> The conglomerate layers are very much like the Seminole conglomerate consisting of chert and quartzitic pebbles in sand cemented together with iron oxides. The chert pebbles are by far the more numerous, are subangular in shape, and range in size from small grains to three inches in diameter. The quartzitic pebbles are more rounded and range in size from one to three inches in diameter. . . .
>
> These conglomerate beds are very irregular and lenticular and are marked by cross-bedding.

Levorsen (1930), in summing up the geology of Seminole County, described the Vamoosa as follows:

> The Vamoosa formation occupies a belt two to eight miles wide through Rs. 6 and 7 E. It consists mainly of conglomerates, sandstones and variable amounts of shale and furnishes the most pronounced topographic expression of any of the formations. The conglomerates consist of rounded to sub-angular quartz pebbles, weathered chert pebbles, and sand grains, cemented by siliceous material. The size of the pebbles is generally less than one inch in diameter but locally pebbles up to six inches in diameter occur. Cross-bedding, lensing, and rapid lateral variations are common throughout the formation. It thins toward the south from 525 feet in T. 9 N. to 325 feet in the south part of T. 6 N. An interesting fact is the occurrence of the largest boulders in the conglomerate in T. 9 N., R. 7 E., where the formation is thickest.

Green (1936) summarized the features of the Vamoosa formation in Seminole County as follows:

> In the area extending 25 miles north from the Stonewall quadrangle the Vamoosa is a unit of lenticular sandstones, conglomerates, shales, calcareous sandstones, and

calcareous conglomerates. The coarsest conglomerates are in the basal 50 feet and the finer conglomerates are in the upper part of the formation. The upper limit of the conglomerates is irregular; in places they extend up to the Pawhuska limestone while short distances away there are no conglomerates in the first 50 feet below the Pawhuska. The formation shows definite effects of having been cut by cross currents during the time of its deposition, the best examples of which may be seen in T. 7 N., R. 6 E.

Ries (1951) mapped the Vamoosa formation in Okfuskee County:

The discovery of an unconformity at the base of the lowermost conglomerate of the Vamoosa formation necessitates redefinition of the formation. Heretofore, the Vamoosa formation as originally defined by Morgan has at its base a dark shale which was about 30 feet thick. . . . The presence of an unconformity at the base of the lowermost conglomerate is manifest in the strike-overlapping relations of the conglomerate with the underlying beds. In Okfuskee County alone, the entire Tallant formation and the upper two members of the Barnsdall formation have been strike-overlapped by the lowermost conglomerate of the Vamoosa formation. This unconformity makes it possible to have a natural boundary for the base of the Vamoosa formation and, therefore, also establishes a natural Missouri-Virgil series boundary. The author therefore redefines the Vamoosa formation (as used by Morgan) and restricts it, so that its lower boundary is extended upward and that the base of the Vamoosa formation is now placed above the unconformity at the base of the lowermost conglomerate (Boley conglomerate member) in the formation. . . .

The Vamoosa formation consists of a series of conglomerates, sandstones, conglomeratic sandstones, and red shales. At the base lies a conglomerate which is 50 to 60 feet thick. The base of this member can be clearly traced across the county. The upper limits of this member are not always as definite and sometimes grade into local sandstone lenses of the overlying undifferentiated beds, which appear to consist of a series of deltaic facies which are so erratic in distribution and thicknesses that the writer could not trace any of the individual sandstones for any great distance. This lowermost conglomerate of the Vamoosa formation is here named the Boley conglomerate member, after its type locality, the town of Boley, Oklahoma, which is situated on this member in Sec. 20, T. 12 N., R. 8 E. . . . This basal conglomerate member consists largely of sub-angular to well-rounded white chert fragments. Some of these fragments are as large as 6 inches in diameter. The fragments become progressively smaller toward the top of the member. Interspaced among these chert fragments are finer sands and fragments of fossiliferous limestone that have been replaced by silica. Delicate crinoid stems, Fenestrellinas, as well as other Bryozoans that are in these pebbles were entirely replaced by silica. Many of these pebbles were as large as 6 inches in diameter. Many pebbles of chalcedony, quartz, or quartzite were also observed. The largest of these, too, were about 6 inches in diameter. Rarer, but still present in numbers were exotic pebbles such as silicified tectonic breccias and second and even third generation conglomerates. . . .

Lying above the Boley conglomerate member of the Vamoosa formation are about 600 feet of undifferentiated sandstones, conglomeratic sandstones, and red shales. . . . .

The Vamoosa formation varies in thickness from 650 to 690 feet in Okfuskee County.

Distribution: The Vamoosa formation extends in a north-south direction across the middle of Seminole County. It widens northward from a minimum of about two miles to a maximum of perhaps seven miles along North Canadian River. This is a belt of considerable relief, excellent cuesta development (see Fig. 19), and high east-facing scarps. From the air it is a belt of maximum tree cover; on the county road map, it is a belt where roads in general do not coincide with section lines. It is also a belt of low population density.

In Pontotoc County, to the south, the Vamoosa extends to a point about three miles north of the town of Ada. Northward, the Vamoosa has been traced across Okfuskee County by Ries (1951); beyond there it is not known in detail.

Figure 19. The cuesta formed by the three lowest ledges in the Vamoosa formation. The picture was taken from above the highway in the south central part of sec. 23, T. 9 N., R. 7 E. The view is slightly east of north.

Character and thickness: The Vamoosa formation in Seminole County consists of a sequence of shales, sandstones and chert conglomerates, thinning southward as a result of numerous periods of erosion.

The coarsest conglomerates occur in the middle and lower portions of the formation. The chert cobbles in the lowest 100 feet coarsen from a maximum of about five inches in diameter, in T. 6 N., to a maximum of about seven inches in diameter, in T. 11 N.

Where not conglomeratic, the resistant ledges are buff to brown sandstones and siltstones, commonly cross-bedded and contorted. The shales are largely red, brown and orange.

The entire formation grades from a shale-sandstone ratio of 60:40, in the south to a ratio of about 80:20, in the north. The increasing coarseness of the pebbles occurs in the same direction as the increasing thickness, but in a direction opposite to that of the coarsening of the average particle size.

Three of the highest members of the formation have been mapped, frequently, across northern and central parts of the county as the Pawhuska, or Lecompton, limestone (Levorson, 1930; Green, 1936). This report does not so consider them. They are buff to yellow sandstones having a very high proportion of secondary calcite (about 40%), and occasional chert conglomerate lenses. Very hard, they reach thicknesses in excess of 10 feet, but are generally only a few feet thick. The three, like the overlying Pawhuska of Okfuskee County, are truncated by the Ada formation at more or less regular intervals (see Plate IX). Each of the three beds changes, southward, as it approaches the point of truncation: first, from a sandstone to a hard limy sandstone, then to a soft rotten sandstone probably deeply weathered in pre-Ada time.

The formation thickens from 125 feet, at Canadian River, to over 550 feet at North Canadian River. The northward component of thickening is about 10 feet per mile. In the subsurface to the west, the formation thickens to over 1,000 feet, with a westward component of thickening of nearly 12 feet per mile. Maximum thickening--18 feet per mile--is toward the northwest (see Plate X).

The Vamoosa has been subdivided in Seminole County into 12 members, each consisting of a basal coarse clastic ledge overlain by a shale section. The six uppermost members are colored distinctly on the accompanying map (see Plate I) to make clear the truncation by the Ada formation. The other six members are delineated on the map by solid lines drawn along the base of each ledge, but no distinctive colors have been assigned them.

Three of the twelve coarse clastic ledges cross the county completely: No. 1 (the basal Vamoosa conglomerate), No. 5 and No. 8. The latter is designated on Plate IX as

Figure 20. Conglomerate "pedestals" in the Vamoosa formation, in the northeast corner of sec. 21, T. 9 N., R. 7 E.

the "pink" ledge, a manuscript term not intended to be an addition to the stratigraphic nomenclature. (Pink was the crayon color used to identify this middle Vamoosa member on field maps.) The "pink" ledge is the best horizon within the formation.

Ledges No. 6 and No. 7 are found only in T. 10 N. Since Ries (1951) did not subdivide the Vamoosa in Okfuskee County, it is not now known whether or not they can be traced northward.

Ledges No. 9, No. 11 and No. 12 are locally hard and limy, and have been correlated by some geologists with the Pawhuska (see page 161).

Ledges No. 2, No. 3, No. 4 and No. 10 are apparently less significant, extending across one or two townships before being cut out by erosion or passing into shale.

The stratigraphic relationships among these ledges suggest that actually the Vamoosa is a group, with at least three formations represented in the county. Due to the lack of detailed knowledge northward, such a redefinition has not been attempted.

In northern Pontotoc County, the only coarse clastic material present in the Vamoosa is in the No. 1 (basal) conglomerate. The conglomeratic sandstone mapped by Morgan (1924) as uppermost Vamoosa is undoubtedly part of the overlying Ada formation (see Fig. 21).

Despite the fact that the formation is 60% to 80%

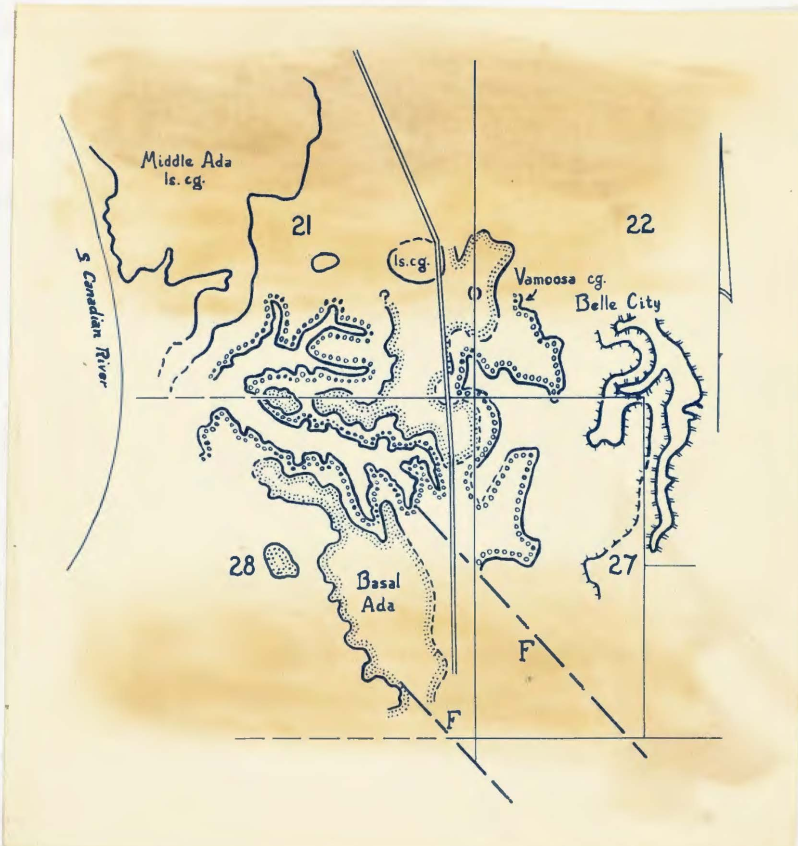

Figure 21. The Ada, Vamoosa and Belle City ledges in T. 5 N., R. 6 E., in Pontotoc County. Both limestone members of the Belle City are shown. The interval between the upper Belle City limestone and the Vamoosa conglomerate is mostly Hilltop shale. The Ada formation here consists of the basal (No. 1) sandstone, the middle Ada limestone conglomerate zone, and the intervening shale section. The upper Ada shale is missing locally due to erosion.

shale, and much of the rest is sandstone, the general appearance is that of a coarse conglomerate. This phase is well developed on the highway between Konawa and Sasakwa (as Morgan pointed out), on the highway between Wewoka and Seminole (T. 8 N.), and on State Highway 9, east of Seminole (T. 9 N.). The pebbles and cobbles found in these conglomerates fit into several distinctive groups:

1. Buff, in some instances faintly banded, subangular chert. These are most common.

2. Banded buff-and-green, or solid green, subangular chert.

3. Brecciated (tectonic) second or third generation chert pebbles.

4. Miscellaneous; including chalcedony, quartzite, quartz granules, clay plates and other forms.

Hugh Miser examined an extensive chert pebble collection in the writer's possession, and noted that cherts similar to types 1 and 2, above, are found in the Arkansas novaculite in the Ouachita Mountains. A dark green brecciated chert was also identified as being found near the base of the Woodford equivalent within the Arkansas novaculite. Miser did not recognize, as Ouachita Mountain varieties, any of the other cherts in the collection.

William Ham examined the same chert pebbles. A brown siliceous chert breccia (type 3, above) was recognized as being much the same as certain tectonic breccias found in

Boggy (?) formation beds in the Mill Creek syncline (sec. 8, T. 2 S., R. 5 E.). This writer agrees with such an identification. The outcrop mentioned by Ham is 40 to 70 miles, south-southwest, from the Vamoosa beds carrying the brecciated chert pebbles. Of course, the possibility remains that the actual source could have been other similar beds, located to the southeast, and now covered by the Cretaceous overlap of southern Oklahoma. For pebble type 2, Ham listed the Arkansas novaculite as a possible source, but eliminated the Woodford formation of the Arbuckle Mountains.

Thin-section study of pebbles of type 1 reveals evidence that they are formed by chert replacement in limestone (see van Tuyl, 1918). Crinoid plates and shell fragments are fairly common. Despite a careful search involving hundreds of pebbles, no macrofossils were found. In addition to the fossil evidence, rhombs similar to those of calcite were found on the thin sections.

Buff to tan replacement cherts occur frequently in the Arbuckle Mountains in various limestones. Some of these cherts are banded, and a few are darkly colored. The Royer, Viola and Woodford formations contain dark cherts; pale cherts are found in the Ordovician part of the Arbuckle group and in the Simpson, Viola and Woodford; and clearly banded specimens may be obtained from the Ordovician part of the Arbuckle group and the Viola formation.

In addition to field work on the chert-bearing limestones of the Arbuckle Mountains, detailed field examination of chert conglomerates in the Ardmore basin was undertaken. There, the Devil's Kitchen, Jolliff, Bostwick, Pumpkin Creek, Daube and other coarse clastics were found to contain chert much like that of the formations of Seminole County. Culp (1950) and Schacht (1947) postulate an eastern source (i.e., the Ouachita Mountains) for some of the Ardmore basin cherts. It is true that the conglomerates appear, in places, to coarsen eastward or southeastward, along the present strike of the beds. Modern outcrops, however, often do not give a true two-dimensional picture; in this case, a northeastern or even northern source can account for the same coarsening. Further, the coarsening does not necessarily occur in the direction toward the source, but may reflect, instead, the trend of the nearby shoreline, and the direction toward the mouth of the pebble-carrying stream. The sands of certain northeastern Florida beaches are being moved from north to south, yet had their source, in part, to the northwest (Longwell, Flint and Knopf, 1948). A northeast-southwest striking exposure, at some future date, would indicate a source to the northeast--an error of 90 degrees. The Ardmore basin cherts, therefore, might well have had an Arbuckle Mountain origin.

The evidence may be summed as follows:

1. It is not necessary to go to the Ouachita Mountains for a source terrane; in fact, much of the chert is

not identifiable with any known Ouachita Mountain variety.

2. Similar or identical cherts are found in depositional basins on both sides of the Arbuckle Mountain-Hunton Arch complex.

3. Such cherts are actually found in either Ordovician, Siluro-Devonian or Pennsylvanian sediments in the Arbuckle Mountains.

4. Tectonic chert breccias are known from the Pennsylvanian of the Mill Creek syncline.

5. Perhaps more than 90% of the Seminole County cherts are of organic origin (i.e., derived from a limestone terrane).

6. The angularity of many of the Seminole County chert cobbles indicates a short-haul rather than a long-haul history.

7. Structural considerations suggest that the source of most coarse clastics in Seminole County be located to the south rather than to the southeast (see Chapter VI).

8. The sand grains (garnetiferous) and the chert pebbles do not necessarily have the same provenance.

The conclusion drawn from these items is opposed to that of Taff (1901), Morgan (1924) and Oakes (1948), according to whom the source lay in the Ouachita mountain area or at least to the southeast. Llanoria, as a source land, is thought to be an unnecessary expedient.

Opposed to the conclusion reached above is the observation, made by Levorsen (1930), that the coarsest cobbles are found in the thickest part of the formation, i.e., in the northern part of Seminole County. This has undoubtedly influenced many geologists to think of the conglomerate as a channel or lens, crossing the present strike at some large angle, such as 70 or 80 degrees, and hence indicating a northwest trend and a southeast source.

Likewise opposed is the evidence adduced for an uplift to the southeast in post-Missouri pre-Virgil time (see page 152).

The latter is thought, however, to be relatively minor and distant compared with the known Arbuckle Mountain pulsations during early Virgil time; and for the former, the changes in the shale-sandstone ratio are thought to be more significant than the distribution of the coarsest cobbles. The northward thickening, by itself, is evidence in favor of a southern source.

Among the chert pebbles in the Vamoosa formation may be found many which are soft enough to be mashed easily by a single hammer blow, or in some instances by squeezing between thumb and fore-finger. The sticky, flaky material so formed is similar to that logged in well samples as "tripoli" or "tripolitic" sandstone. The Vamoosa, on the surface in Seminole County, is "tripolitic" more than any other formation described herein. The "tripoli" is obviously derived from chert, and is inferred to be the product of long weathering after deposition, but prior to burial, in an open and oxygen-rich environment such as might be found along a sandy beach or off-shore bar (Tarr, 1926). The cross-bedding and contortions in the Vamoosa support such a concept, as do the fossil plant fragments.

In the subsurface, the "tripoli" zone descends in the section to the west. This makes correlation by well samples difficult, but not impossible, and the problem vanishes on electric log correlations. The "tripoli" is taken to mean a specific environment, rather than a time horizon or rock unit. The paleogeography of the area is such that the Des Moines shore zone would have been west of the Virgil shore zone, and hence shore indicators would be expected lower in the section to the west.

Vamoosa sandstones are light buff to brown, thin-bedded to massive, cross-bedded and contorted. The grains are sub-rounded to sub-angular, and commonly in the 1/16 to 1/2 mm. size range. Sorting coefficients (Pettijohn, 1949) (and median diameters) are listed for six typical samples:

1.350	(.305)
1.330	(.200)
1.210	(.185)
1.205	(.230)
1.200	(.165)
1.175	(.250)

Beach sands commonly have sorting coefficients in the range 1.2 to 1.6 (less commonly, to 2.4) (Emery and Stevenson, 1950). A study of Recent Oklahoma river sands, however, revealed sorting coefficients ranging from 1.15 to 1.60 (Tanner and Mallams, 1950). Sorting of dune sands is usually in the same general range (Sidwell and Tanner, 1939). The character of the cross-bedding and the presence of contortions militates against the possibility that wind was the chief depositing agency.

Bagnold curves (Bagnold, 1941) indicate that the degree of sorting has been impaired, in some instances, by the later addition of significant proportions of fines, and hence that the original sorting was even better than given above.

Rounding curves (Tanner, 1940) suggest that some of the sand was wind-handled through at least part of its history.

Sandstone ledges No. 9, No. 11 and No. 12 are locally hard and very calcareous. Laboratory analysis showed a minimum insoluble residue content of 60%, so these are calcareous sandstones rather than arenaceous limestones. Each of these ledges is weathered and soft within the immediate vicinity of the point of truncation, limy and hard for some distance north of the leached phase, and beyond that a typical brown to buff sandstone. Where indurated with a high proportion of secondary calcite, the ledge is pale yellow or almost white. Sharp hammer blows on the hard surface result in a fine powder or "smoke" which may be obtained from almost any of the highly calcareous lenses in the county. Chert pebble conglomerates occur within these uppermost sandstone ledges;

an excellent example of what is probably a conglomerate-filled channel, crops out in secs. 12 and 13, T. 8 N., R. 6 E.

Stratigraphic relations: The Vamoosa formation, in Seminole County, overlies the Hilltop formation unconformably. The coarse cobble conglomerate which makes up the basal Vamoosa ledge is in sharp contrast with the shales and other fine clastics of the Hilltop. Small-scale irregularities along the contact, such as one would expect to find associated with a major unconformity where no peneplanation had taken place, are common. These include outliers of Hilltop shale in the southern part of the county, where the Vamoosa rests locally on the Belle City formation. In addition, the angle of truncation by which the Vamoosa cuts out the Hilltop is measurable. This unconformity has been traced southward from the Kansas line by Oakes (1949).

The top of the Vamoosa is likewise an unconformity. The basal sandstone of the overlying Ada formation cuts out, in order from north to south, the following Vamoosa ledges: No. 12, No. 11, No. 9, No. 8 or No. 5 (the critical point is hidden under Quaternary alluvium and terrace deposits) and, in Pontotoc County, No. 1. In each of the first three instances, the Vamoosa ledge presents two character-changes as the point of truncation is approached (see page 172).

The angles of truncation have been measured; two representative cases are discussed in Chapter VI. (For a stratigraphic diagram showing these relations, see Plate IX.)

Paleontology: The Vamoosa formation has long been considered barren (i.e., Morgan, 1924). Ries (1951) reported _Calamites_ and crinoid stems from Okfuskee County. Vamoosa beds in Seminole County yielded four fossil assemblages:

1. Internal gastropod molds preserved in hard, calcareous sandstone (upper Vamoosa).

2. Pelecypod suites preserved in local soft dark brown siltstone lenses (upper Vamoosa; basal Vamoosa).

3. Plant fragments (basal Vamoosa).

4. Crinoid columnals (lower to middle Vamoosa).

The following identifications were made:

Pelecypoda
  Acanthopecten carboniferus (Stevens). Stations 3089, 3099.
  Aviculopecten basilicus (Newell). Station 3099.

Flora
  Lepidodendron. Station 3084.
  Calamites. Station 3084.

Age and correlation: The Vamoosa formation has not been mapped northward from Okfuskee County; northern Oklahoma equivalents are not precisely known, but probably include parts of the Nelagoney and Elgin formations.

In the Ardmore basin, the Vamoosa horizon may occur within the erosion interval between the strongly folded and faulted Hoxbar beds and the gently dipping arkosic "red beds" which skirt the southern flank of the Arbuckle Mountains.

The Vamoosa is early Virgil in age. With its associated unconformities, both above and below, it may well represent as much as two-thirds of Virgil time.

Pawhuska formation.

The Pawhuska formation does not crop out in Seminole County. It is mentioned here because it has been mapped or traced across much of the county by several geologists. The beds so mapped are ledges No. 9, No. 11 and No. 12 in the upper part of the Vamoosa formation. They bear no lithologic similarity to the Pawhuska, which, in Okfuskee County, includes two thin red-coated dolomites separated by a few feet of shale (Ries, 1951).

The latter formation is truncated, in or near sec. 20, T. 11 N., R. 7 E., in western Okfuskee County, by the overlying Ada formation.

Ada formation.

First reference: George Morgan, 1924.

Nomenclator: George Morgan, 1924.

Type locality: In and west of the town of Ada.

Original description: Morgan (1924) described the Ada from outcrops in the northern part of the Stonewall quadrangle:

The average thickness of the Ada formation is about

100 feet. Limestone conglomerates and coarse sandstones are very prominent along the greater portion of the outcrop. Clastic material becomes less toward the north, however, and in the vicinity of Vamoosa is very scarce. With the decrease in the amount of clastic material northward the formation becomes thinner and at the northern edge of the sheet has a total thickness of only about 60 feet.

One very characteristic feature of the formation is the asphalt which it contains. This is always associated with the conglomerates or coarse sandstones many of which are often highly saturated. One mile west of Ada, asphalt-bearing sandstones and conglomerates are quarried for paving purposes.

North of Canadian River exposures of asphaltic strata are less numerous than they are to the south, but such strata are often encountered in water wells. . . .

Within the conglomerates of the Ada formation there are many fragments which contain Hunton and Viola fossils, while the sand which composes the sandstone strata is very similar to that in the Simpson. This evidence shows clearly that the Arbuckle Mountains were the source of at least a great part of the sediments that make up the Ada formation. . . .

Although fossils are very scarce in the Ada formation a few species were found which indicate that the sediments are of marine origin. . . .

Near the base of the formation is a thin black limestone that is very persistent in the vicinity of Ada.

North of Canadian River the Ada formation appears to rest conformably upon the Vamoosa, but toward the south it overlaps several of the underlying formations.

About one mile south of Byng the Vamoosa formation is overlapped, and in the vicinity of Fitzhugh the Ada formation extends across the Francis and Seminole formations to an unconformable contact with the Viola limestone.

Distribution: The Ada formation extends across the west central part of Seminole County, in a north-south belt one to four miles wide. The town of Seminole is located largely on the Ada.

Character and thickness: The Ada formation in Seminole County consists of variegated pastel shales, sandstones and siltstones, and occasional limestones and limestone conglomerates. The pastel shales are distinctive, except in the northern part of the county where they are easily confused with similar shales in the overlying Vanoss formation.

The basal member of the Ada is a buff, cross-bedded and contorted sandstone (see Figs. 10 and 11) 10 to 20 feet thick. Locally it is a chert conglomerate and therefore hard to distinguish from the underlying Vamoosa formation; Morgan (1924) failed to make this distinction.

The middle Ada limestone conglomerates are well-developed in the central and southern parts of the county. They are cross-bedded, and contain limestone cobbles as large as 4½ inches in diameter. Northward they grade into chert conglomerates in a sandstone matrix, and then into shale. Southward the limestone cobbles are accompanied by pebbles of red, tan and gray chert. Biotite flakes are also fairly common.

The Snomac limestone member, in the central part of the county, consists of an irregular sequence of thin, dull white, finely crystalline limestone beds in the lowest third of the formation. They are useful, where present, for structural control.

The Ada is 150 to 250 feet thick, thickening and thinning in no regular manner. This is due in part to less deposition northward, to channeling at the base of the overlying Vanoss, and probably in part to structural factors.

Like so many other Seminole County formations which give an erroneous impression of coarseness, the Ada is primarily shale. Even in the southern part of the county, where cobbles are relatively common in the conglomerate beds, shales still predominate. An excellent exposure of Ada shales may be seen in the roadcut immediately north of the Canadian River bridge (sec. 4, T. 5 N., R. 6 E.)(see Figs. 22, 23). In Pontotoc County (i.e., in the highway cut associated with the railroad underpass southwest of Ada) limestone boulders occur.

No single ledge other than the basal member, can be traced continuously for any great distance. The basal member, a distinctive beach-type sandstone, greatly resembles the underlying Vamoosa formation, which was being eroded and reworked during the Ada sea transgression. Only careful field work will show that this key bed belongs to the overlying shale rather than to the formidable-looking jumble of Vamoosa clastics below. Morgan's failure to make this distinction accounts in part for thickness differences noted above.

In the northern and central parts of the county, the basal Ada sandstone is commonly a chert puddingstone; there, the then-exposed portions of the Vamoosa were largely shale and sandstone. In the southern part of the county, the basal Ada is generally conglomeratic; here, coarse Vamoosa pebble-beds must have been exposed during early Ada time.

Fig. 22. Ada pastel shales, exposed in the roadcut in sec. 4 T. 5 N., R. 6 E., north of the Canadian River bridge.

Fig. 23. The same Ada shales, photographed from a different angle. The car was not moved between the two exposures.

With the transfer of the Ada beach zone southward into what is now Pontotoc County, and the submarine burial of the entire Vamoosa outcrop, the Ada sea bottom became an environment, primarily, of clays and other very fine clastics, with an occasional introduction of limestone pebbles from the Arbuckle Mountains.

The Snomac member, a sequence of thin limestones, is named after the Snomac townsite in secs. 10, 11 and 14, T. 7 N., R. 6 E. The member extends from the center of sec. 26, T. 8 N., R. 6 E., north of Little River, to secs. 14 and 15, T. 7 N., R. 6 E., south of Little River. Commonly only a single limestone is exposed at any one locality. The shale interval in which the Snomac member is found is about 45 feet thick, and overlies the basal Ada sandstone. The Snomac occurs rather high in this shale section. Generally a chalky white but hard limestone a few inches to a foot thick, the Snomac member has the wavy or rubbly bedding found in the upper Belle City limestone.

Overlying the Snomac member and its associated shales is the zone of the Middle Ada limestone conglomerates. These have their northernmost exposure in sec. 34, T. 8 N., R. 6 E. In the Snomac townsite area, the middle Ada limestone conglomerates occur 40 to 45 feet above the basal sandstone. Gray and rough-surfaced, the conglomerates are made up largely of limestone pebbles in beds a few inches to a few feet thick. These beds do not occur at a single precise horizon; in the southern part of the county they may be found 45 to 65 feet above the basal sandstone. At places they are torrent-bedded, with individual layers sloping westward. The outcrops are not continuous southward. The lack of continuity and the westward-sloping torrent-bedding might be construed as evidence for an eastern or southeastern source. Never-the-less, this writer agrees with the suggestion by Morgan (1924) that the source must be sought in the limestone terrane to the south.

The basal member, the Snomac member, and the middle conglomerates are all typically developed near the Snomac townsite.

Ada shales are brown, gray, black, red, maroon, purple, or green. Shale units 40 or more feet thick are not rare.

In addition to the lithologies given above, the Ada contains discontinuous beds of soft brown sandstone, varicolored siltstone, chert conglomerate, erratic lenses of limestone, green claystone, and biotite flake sandstone.

Two examples of arkose were noted in the Ada. One consists of several extremely rare and tiny grains of pink feldspar in an asphaltic limestone pebble conglomerate, in sec. 10, T. 6 N., R. 6 E. The other is a thick channel deposit of coarse conglomerate containing many pebbles of feldspar or granite, in the east half of sec. 36, T. 11 N., R. 6 E. Whether or not the latter was a channel of Vanoss lithology, cut deeply into the Ada formation, could not be determined.

Stratigraphic relations: Morgan (1924) observed that the Ada formation truncates the Vamoosa, Francis and Seminole formations, resting in its southernmost outcrops on the Viola limestone. His map shows that the Belle City is likewise truncated. Never-the-less, he failed to distinguish the basal Ada member, north of where the Vamoosa is cut out, from the underlying Vamoosa formation. As a result, he was led to the conclusion that, north of Canadian River, the two formations are conformable.

Field work across Okfuskee, Seminole and Pontotoc counties, coupled with data taken from Morgan's map near and south of Ada, shows that the Ada formation truncates, in succession, the following units:

Pawhuska formation
Vamoosa No. 12 member
Vamoosa No. 11 member
Vamoosa No. 9 member
Vamoosa No. 8 or No. 5 or perhaps both
Vamoosa No. 1 member
Hilltop formation
Belle City formation
Nellie Bly formation
Coffeyville formation
Seminole formation

This is a total of seven formations, or, measured in Okfuskee County, about 2,100 feet of section. This unconformity marks the last important orogenic activity in the Hunton Arch. The unconformity trace, as shown on the map is only slightly curved, representing one or more later but much lesser pulsations (i.e., between Ada and Vanoss times).

The unconformity at the top of the Ada is neither so distinct nor so important. The Ada formation is completely cut out by the overlying Vanoss formation, which then rests on Arbuckle group (i.e., Cambro-Ordovician) rocks in eastern Murray County (Morgan, 1924). In southern Seminole County, the contact between the two is marked by channeling and other irregularities. In northern Seminole County the contact is extremely difficult to follow, and beyond North Canadian River the two formations have not been separated.

Paleontology: Morgan (1924) listed fossils which may have come from the Ada formation, but also stated that they could have been derived from the underlying Francis. Ries (1951) named no fossils from Ada equivalents in Okfuskee County. Not a single fossil was found in the Ada in Seminole County.

Age and correlation: The Ada continues northward into the lower part of the Buck Creek formation. Southward the Ada is truncated as indicated above. The horizon of the Ada should occur, in the Ardmore basin, between greatly folded Hoxbar sediments and gently dipping arkosic "red beds" of latest Pennsylvanian age. The Ada is perhaps upper Virgil in age.

Vanoss formation.

First reference: George Morgan, 1924.

Nomenclator: George Morgan, 1924.

Type locality: The town of Vanoss (T. 3 N., R. 4 E.).

Original description: Morgan (1924) described the Vanoss from the northwestern part of the Stonewall quadrangle:

> The Vanoss formation consists of alternating sandstones, conglomerates, shales and a few thin limestones. All of the strata are arkosic, some of the sandstones so much so that at first glance a few of them might be mistaken for true granites.
>
> The base of the Vanoss rests on the Ada formation, the contact between the two being the plane dividing the arkosic and non-arkosic materials. Due to the lenticular nature of strata along the contact and to the fact that the Vanoss is progressively overlapping southward no one stratum can be selected to mark the adjacent limits of the formation. The base of the arkosic zone, however, is relatively contemporaneous. The resistant sandstones of the lower part of the formation form Lightning Ridge east and south of Vanoss.
>
> Near the center of the formation there are several thin limestone beds. These were not observed north of Canadian River, but appear intermittently along the outcrop to the south of that stream. They are generally argillaceous and are subject to rapid gradation into shale. Where freshly exposed the limestones are light gray in color and relatively soft, but on weathering become hard and white. Several of these beds are well exposed at the eastern edge of the town of Center. Good exposures are also common in the region about one mile east of Vanoss. The limestones are less arkosic than the associated sandstones, but some of them carry an appreciable amount of feldspathic fragments.
>
> In the upper part of the Vanoss formation sandstones are less prominent than they are near the base. The shales which constitute the greater part of this upper portion are generally of light color, ranging through shades of green and gray. Occasional red shales are also present. With the decrease in sandstone there is also a decrease in the quantity of arkose. Locally, however,

there are beds that are almost entirely composed of this material.

The upper limit of the Vanoss formation is marked by the base of the Hart limestone member of the Stratford formation. The thickness of the Vanoss formation increases southward. The exposed portion east of Konawa totals only about 250 feet, while near the southwest corner of the quadrangle there are about 650 feet of strata within the formation.

Other descriptions: Levorsen (1930) described the Vanoss formation in Seminole County as follows:

> The Vanoss formation occupies an area covering approximately the west half of Seminole County. It ranges in thickness from 250 feet to 520 feet and consists of shales, arkosic sands, conglomerates, and a few thin limestones.

Dott (1930) described the Vanoss formation in Garvin County:

> Only the uppermost part of this formation is exposed in Garvin County. . . .
>
> Near the top of the Vanoss formation occurs a 10 to 20 foot, persistent bed of gray, coarse-grained, arkosic sandstone, which can be traced with considerable certainty from the vicinity of Vanoss to and across T. 2 N., R. 3 E. This and a small thickness of underlying shales and sandstones comprise all of the formation exposed in Garvin County.

Distribution: The Vanoss formation crosses the western part of Seminole County in a north-south strip two to seven miles wide. It has not been traced beyond North Canadian River. Southward it extends through Pontotoc County and eventually around the west end of the Arbuckle Mountains (Birk, 1925).

Character and thickness: In Seminole County the Vanoss formation is composed of shales and sandstones, with arkosic sandstones and conglomerates prominent in the southern part. The base of the arkose, instead of marking the base of the Vanoss, climbs in the section northward; feldspar is also found in lower formations (see page 181).

Several limestones and limestone conglomerates occur in the Vanoss: (1) a yellow, crinoidal limestone, one foot thick, 20 feet below the top, in the north (north line, sec. 4, T. 10 N., R. 6 E.); (2) a crumbly, fossiliferous limestone lens in a sandstone, about 60 feet down from the top, west of the town of Seminole (northwest corner, sec. 19, T. 8 N., R. 6 E.); (3) a limestone, chert and quartz conglomerate, six inches thick, about 70 feet below the top, in the central part of the county (northwest corner, sec. 26, T. 7 N., R. 5 E.); and (4) a crinoidal limestone conglomerate, about 70 feet down from the top, northeast of Konawa (sec. 26, T. 6 N., R. 5 E.). Green (1936, 1937) has correlated at least one--and perhaps all--of these with the "Prague" (Grayhorse) limestone or the Brownville limestone.

The basal Vanoss sandstone, where sandy and buff but not arkosic, shows penecontemporaneous contortion.

The Vanoss is 140 to 500 or more feet thick, thickening southward.

The base of the Vanoss has been picked on criteria other than arkose. As far north as Little River, the basal member is the first, persistent, non-limestone conglomerate bed above the base of the Ada; here and there this ledge has pockets of arkose in it, and is locally hardened by secondary calcite. North of Little River, the arkose line climbs in the section, and the contact between the two formations, although drawn along what appears to be a continuous sandstone horizon, is still open to some doubt.

Locally, Vanoss sandstone ledges are marked by lenses or channels containing chert pebble conglomerate; an example may be found at Varnum church (sec. 33, T. 10 N., R. 6 E.). Otherwise, these sandstones, where not arkosic, are white, buff or brown; soft, thin and flaggy; and at places cross-bedded or contorted. These sandstones and siltstones have been tentatively interpreted as beach or near shore deposits.

The shales are multicolored and resemble those in the Ada formation.

During the course of field work, the writer undertook a detailed program of measuring sections in an effort to determine accurately the behavior of the Vanoss formation. Some of the thicknesses recorded, from south to north, were: 435, 415, 450 ?, 440 ?, 324, 264, 202, 180, 140, 147 feet. Two of these values--indicated by question marks--were obtained in areas of structural disturbance (including locally flattened dips) and may not be reliable. Several possibilities are entertained:

1. These figures are correct, and the Vanoss thins northward regularly at about 10 feet per mile. An angle of this order of magnitude is not at all out of line in Seminole

County where lower angles have been encountered. The direction of thinning, however, was disturbing.

2. These figures are in error, due to jumping of beds. Such an explanation requires that many beds were jumped, in a rather methodical fashion, going northward; such a large supply of ledges, so closely spaced, was not available. Later, more careful work showed that the thinning is continuous, rather than discontinuous.

3. These figures are misleading, because the Vanoss grades out to the north via facies change to soft, poorly-consolidated, relatively uniform sediments. This is a possibility for or against which no adequate field evidence was uncovered.

4. The northern outcrops represent rocks which were deposited farther up the initial dip (i.e., nearer shore), and are thinner; hence the measurements may well be reasonably accurate.

This problem is not confined to the Vanoss; in the Konawa and other post-Vanoss formations, the same situation is encountered.

Stratigraphic relations: In the northern part of the county, the Ada and Vanoss are extremely similar. No completely satisfactory contact was located. In the light of this, the two are considered to be conformable. In the southern part of the county, however, definite evidences of unconformity have been found. Arkosic sandstones and conglomerates fill channels cut into the underlying Ada formation (see Fig. 24), and local irregularities may be seen along the contact at many locations.

The best known channel (sec. 3, T. 6 N., R. 6 E.) trends southeast-northwest, is about 1,800 feet wide, and is cut 30 feet or more into the Ada. Feldspar fragments here have a maximum diameter of about one inch. This square mile (sec. 3) is cut by at least seven faults, along all of which measurable movement has taken place. Offsetting this difficulty, however, is the presence of easily recognizable basal Ada sandstone, middle Ada limestone conglomerate and basal Vanoss arkose, in such a pattern as to permit relatively accurate stratigraphic measurements.

Farther south, in Murray County, the Vanoss truncates the entire Ada formation (Morgan, 1924). Hence there is little doubt as to the unconformable relationships south of Little River. This is perhaps the last regional unconformity, in this area, due to an orogenic movement in the Arbuckle Mountains. The last previous line of erosion--that at the base of the Ada formation--has a faintly curved map trace, indicating that one or more weak Arbuckle movements have since taken place. If there was more than one of these, then the most important one is marked by the Ada-Vanoss unconformity.

Paleontology: Morgan (1924) listed six plant species

Figure 24. A channel at the base of the Vanoss formation, in sec. 3, T. 6 N., R. 6 E. The basal Ada sandstone is outlined by a double row of dots; two units within the middle Ada limestone conglomerate zone are indicated by two distinct hachure patterns; and arkose outcrops in the basal Vanoss member are shown by small triangles. Section-corner crosses provide a scale. The channel is at least 1,800 feet wide, and about 30 feet deep; the current probably flowed from the southeast to the northwest.

and nine invertebrate species among the fossils in the Vanoss formation. Four species, all invertebrates, were collected in Seminole County:

Bryozoa
Polypora sp.
Rhombopora lepidodendroides Meek

Pelecypoda
Edmondia sp.

Crinoidea
Columnals and other fragments

Age and correlation: The Vanoss is probably equivalent to the upper Buck Creek formation (Ries, 1951) of Okfuskee County. Southward, the Vanoss extends through Murray County (Morgan, 1924) and around the west end of the Arbuckle Mountains (Birk, 1925).

In the northeastern part of T. 2 S., R. 2 W., is a gently-dipping red shale underlying the Hart limestone (basal Permian) and overlying the steeply-dipping beds of the folded Arbuckle Mountains; this shale is here interpreted as Vanoss. In the Ardmore basin, gently-dipping red shales and arkosic limestone conglomerates spread across the strongly-folded late Pennsylvanian rocks are considered Vanoss correlatives (Pietschker, 1952).

The Vanoss is, by definition, uppermost Virgil in age (Morgan, 1924).

Permian System

Only one Permian formation is known definitely from

Seminole County: the Konawa formation. It is possible that, because of facies change, or for some other reason, one more Permian formation may be present in the northwestern corner of the county. Satisfactory solution of this problem must wait, however, until detailed mapping has been undertaken in Pottawatomie County.

Konawa formation.

First reference: George Morgan, 1924.

Nomenclator: George Morgan, 1924.

Type locality: The town of Konawa which is located on the extreme eastern edge of the outcrop.

Original description: Morgan (1924) originally described the Konawa formation from the southwestern corner of Seminole County and the northwestern corner of Pontotoc County.

> The base of this formation is drawn at the base of the typical red beds of the area. It was impossible to map any one stratum as the base of the formation so that the lower contact is only roughly established. In fact it is not definitely known but that the greater part of the Konawa formation is merely a northern gradational facies made up of parts of the Vanoss and Stratford formations. The general evidence of structure and lithology, however, favors the conclusion that it is higher than either the Vanoss or Stratford and that it is an overlapping formation. The Konawa formation is largely composed of typical red beds such as cover a large part of western Oklahoma. Red shales constitute the greatest thickness of strata in the formation, but coarse red sandstones are often prominent and sometimes outcrop over large areas. No limestones were observed in the formation.
> On the Konawa road, three miles east of Asher, is an

outcrop of heavy chert conglomerate that resembles beds of the same type contained by formations below the Ada. The only observable difference between this stratum, and those which occur at lower horizons, is afforded by the arkosic material which it contains, and which is absent from the lower strata.

A series of coarse, red and brownish-red sandstones, approximately 30 feet thick, caps the north bluff of Canadian River at the bridge south of Asher. Beds comparable to these were not observed in the Stonewall quadrangle to the south of Canadian River, and it is thought that their outcrop passes westward beyond the limit of the area before crossing and emerging from the sand-filled river bed.

From the bridge northward the outcrop of these strata forms a prominent eastward-facing escarpment that extends to the west of Asher and beyond the limits of the quadrangle about one mile northwest of that town.

The upward diminishing arkosic material common to Pontotoc strata, disappears near the base of these sandstones. In view of this fact and since the sandstones represent a rather definite zone their basal portion is here considered as the top of the Konawa formation and of the Pontotoc terrane. The sandstones above the Konawa formation constitute the basal part of the Asher.

The thickness of the Konawa is about 500 feet.

Other descriptions: Dott (1930) discussed the Stratford-Konawa problem under the heading, "Konawa formation":

> Morgan applied this name to a series of red shales and sandstones cropping out just north of the Garvin County line, in McClain, northwest Pontotoc and southern Pottawatomie counties, which he regarded as younger than, and overlapping upon the Stratford formation, though he could never find the two in contact.
>
> Such an interpretation has some merit, because of the lithologic difference between the Stratford and Konawa formations, and the similarity between the Konawa and the overlying Enid beds. It is not impossible that the Konawa formation represents the basal Enid of this region, older than the Enid group of Garvin County. The writer, however, is inclined to look upon the Konawa formation as merely a lateral phase of the Stratford formation, due to depositional factors. . . .
>
> The Pontotoc and Enid sediments were deposited under peculiar conditions. Conglomerates and fossils suggest marine or fresh water deposition for part of the Pontotoc beds, and red beds suggest terrestrial deposition for others. The red color, prevalence of cross-bedding

in the sandstones and the presence of bones suggest a terrestrial origin for the Enid beds.

In the Pontotoc terrane, the water-lain deposits occur nearest the mountains, where conglomerates and limestones are found in contact with the lower Paleozoic formations. They grade northward into synchronous red beds away from the mountains.

The writer has suggested in another paper that the Arbuckle uplift formed a narrow, deeply down-folded and faulted syncline (known in the outcrops of lower Pennsylvanian and lower Paleozoic formations, as the Mill Creek syncline), with relative uplifts north and south of this trough. That this was deep is indicated by the fact that Pennsylvanian formations have been brought in contact with the Arbuckle limestone and it is conceivable that it was invaded by a shallow arm of the Pontotoc sea or contained fresh or brackish water lakes which received part of the Vanoss and Stratford deposits.

In a recent publication the writer referred to finding of some undetermined gastropods in the Hart limestone in sec. 31, T. 3 N., R. 4 E. These forms were shown to D. K. Greger, who suggested that they might be fresh water forms. Later Raymond R. Moore expressed a similar opinion.

In Vanoss time, the streams were tapping the newly exposed Tishomingo granite. During this time and to a greater extent in Stratford time, large quantities of calcium carbonate were being dissolved from exposures of Arbuckle, Simpson, Viola and Hunton limestone, carried by streams and precipitated with muds and sands after the manner suggested by Clarke.

Of such probable origin were the lime nodules in the shales, the cementing material in the arkosic sandstones and the Hart and other limestones, though the presence of fossils in the Hart limestone indicates that it was formed in part, under normal conditions of limestone deposition. Algae may also have precipitated the calcium carbonate to form limestones. . . . Birk found algae in some of the Pontotoc limestone.

The above interpretation would account for the presence of the water-lain deposits of Vanoss and Stratford age so close to the mountains, and the localization of the limestones in a belt not far distant from the outcrops of lower Paleozoic limestones, and the change, away from the mountains in so short a distance, to contemporaneous continental deposits like the Konawa formation in northern Pontotoc and southern Pottawatomie counties.

That at least a minor unconformity occurs between the Stratford formation and the base of the Enid group is shown by the writer's interpretation of areal geology on the south side of Wildhorse Creek, where successively younger units of the Enid group rest upon Stratford shales, conglomerates, and limestones.

Green (1936) further discussed the probable facies changes involved:

> The exposure of Stratford shale at Wanette makes a radical change in the interpretation of the Pontotoc and moves the contact 8 miles west of that established at Asher. It causes the Asher sandstone to be included in the Pontotoc terrane and makes the Konawa and Asher formations gradational equivalents of the Stratford shale. Close examinations of the Asher sandstone along the highway between Asher and Wanette and of the sediments mapped as Konawa by Morgan south of the Canadian river and northwest from Chism have shown that the sections are identical in characteristics. This gradation from dark calcareous shales to red sandstones in a direction away from the Arbuckle Mountains is quite in accord with the northward gradations of the Belle City, DeNay, and Sasakwa limestones which occur lower in the section. The evidence is rather conclusive that the sandstones of Pontotoc age in Seminole, Pottawatomie, and Lincoln counties were derived from a source other than the Arbuckle Mountains. Both toward the north and toward the south these sandstones grade into calcareous shales.

Morgan (1924) described the Hart limestone member as follows:

> At the base of the Stratford formation is a series of limestone which constitute the Hart limestone member. Above this member is an undetermined thickness largely composed of dark colored shales. . . .
>
> The Hart limestone member is typically developed near the village of that name in the western part of T. 3 N., R. 4 E. This member is composed of alternating limestones, shales, and sandstones. In the vicinity of Hart the limestone beds are very prominent, but toward the north and south some of them thin out while others grade into shale. . . . Northeast of Stratford the Hart limestone is covered by a large area of Guertie sand.

Distribution: The Konawa formation was located on Morgan's map, near Konawa, and from there traced northward across Seminole County. As far north as Little River, the outcrop extends eastward into the county about one mile. North of Little River, the bottom contact is dubious, and the upper contact completely unknown; never-the-less, an area of probable Konawa equivalents, two to five miles wide within the county, has been mapped as far north as North Canadian River.

Reconnaissance work in Pottawatomie County, to the west, has permitted extension of the upper contact as far north as Little River (T. 9 N.); here faulting, a wide alluvial blanket, and changes in the lithology of the critical beds made additional work unprofitable within the time available. The regional strike as determined up to that point, if extended northward, would ensure that no beds younger than a Konawa formation of constant thickness might crop out in Seminole County. This strike, for both the lower and upper contacts, is about N. 10° E., the most northerly strike encountered in the area.

No effort was made to check the westward relocation of the upper contact, as suggested by Green (above).

The lower contact seems to swing markedly eastward, north of Little River, in Seminole County. Rather than having a structural or stratigraphic significance, this apparent shift in the strike direction is thought to be due to a combination of geomorphic circumstances, including the fact that the northwestern part of the county stands topographically high.

Character and thickness: The Konawa formation in the southwestern part of Seminole County and the southeastern part of Pottawatomie County is composed of shales, sandstones and conglomerates. The shales are thick and varied in color, with reds predominating. The sandstones are commonly soft and buff in color. The coarser clastics include buff chert conglomerates, dark chert conglomerates, and multicolored chert conglomerates. Parts of the sandstone ledges are arkosic, although the feldspar is neither so coarse nor so plentiful as in the underlying Vanoss formation.

The "Prague" (Grayhorse) limestone occurs in the northern part of the county, about 150 feet above what is here considered the base of the Konawa.

The basal Konawa is a sandstone with occasional penecontemporaneous contortion, cross-bedding, and chert pebble or mica flake lenses; it is at places limy; and is generally buff to light dirty brown or reddish purple. The basal contact is commonly undulatory.

The Konawa is 800 to 900 feet thick in southern Seminole and Pottawatomie counties. The formation apparently thickens down-dip; surface measurements indicate a dip at the base of about 90 feet per mile, at the top of about 60 or 70 feet per mile. The thickness figure obtained in the field was based on an assumed uniform dip of about 90 feet per mile, and is therefore probably somewhat high.

Two distinctively-colored chert assemblages are found within the Konawa: the Dripping Springs dark chert conglomerates, and the Jarvis Church multicolored chert conglomerates. The Dripping Springs beds are well exposed near the school of that name, in Pottawatomie County, northwest of Maude (sec. 29, T. 8 N., R. 5 E.). Here the blue, green, red and gray pebbles outnumber the white or buff pebbles five, or more, to one (based on actual counts). The cobbles and pebbles become smaller both to the north and to the south, but are found along the outcrop for a distance of nearly 20 miles, from south of Salt Creek to north of State Highway 9, between Earlsboro and Tecumseh. The dark pebbles are found in the upper three fourths of the Konawa formation (as defined by Morgan), and extend even into the lower part of the Asher formation (along State Highway 9). The occurrence and lateral extent of the dark pebbles in the Konawa are similar to those features of the pale pebbles in the Vamoosa formation. In each case, the coarsest cobbles are found some tens of miles north of the southernmost exposure of the formation.

The Jarvis Church member is a single bed typically developed near the church of that name in sec. 23, T. 10 N., R. 5 E. Here it is about 10 feet thick. Cross-bedding and torrent-bedding are common; locally sandstones and conglomerates occur in alternate beds. Subangular to subrounded buff chert pebbles up to 1½ inches are found. Green, red, gray and a few banded cherts are present in lesser amounts. Rare are pebbles, about three-quarters of an inch in diameter, of pink orthoclase micropegmatite containing small quartz crystals. The uppermost horizon within the member is a clay pebble conglomerate which grades upward into a thin cross-bedded sandstone, thin limy sandstone, or marl-like shale. Occasional cobbles of brown sandstone, three to four inches in diameter, are found. This thin member is about 250 feet above the base of the Konawa, and perhaps 100 feet above the horizon of the "Prague."

The latter, in Seminole County, is two to four inches thick, and is composed of soft lenses of white limestone in a red shale underlying a soft buff to brown sandstone. Crinoid columnals and fragments of other fossils are common. The outcrop is not continuous, however, and therefore difficult to follow southward.

In the upper Konawa, in southern Pottawatomie County, there is a return to the pale cherts so common in older formations. These continue upward in the section to a point a few miles west of Tecumseh, where they are last seen.

Lithologies found here and there in the Konawa include mica-flake sandstones, clay-ball conglomerates, siltstones and sandstones hardened by secondary calcite, red-and-white chert puddingstones, and lenses of purple hematitic sandstone.

From the above, it might be concluded that the stratigraphy of the Vanoss-Konawa interval is not now in a satisfactory state. Such is indeed the case. Morgan (1924) described and mapped three formations in what he termed the "Pontotoc terrane": the Vanoss, of late Pennsylvanian age, and the Stratford and Konawa of early Permian age. (Green, 1936, added the Asher.) The systemic boundary was defined as being at the base of the Hart limestone, itself the lowest member of the Stratford formation. The Vanoss has already been treated in this chapter. The Stratford was defined by Morgan as several hundred feet of dark shales, with no known upper limit in the Stonewall quadrangle, but confined to an area south of the Canadian River. The Konawa is described as a "red bed" interval, largely north of the river, but appearing in several locations on the south side. The contact between the two formations, on Morgan's map, is rather erratic.

Dott (1930) noted that, above the Vanoss formation, the Stratford and Konawa occupy about the same position. Morgan had explained this in terms of overlap, setting the Konawa higher in the column, and invoking truncation northward to account for the disappearance of the Stratford. Such an explanation seems inharmonious with the overall structural and stratigraphic pattern in the area. Dott, therefore, felt inclined toward the idea that the Stratford and Konawa are facies of the same formation. Green (1936) later adopted a similar position, but included the Asher as equivalent to part of the Stratford formation.

This writer, in the company of Malcolm Oakes, started northward from the Hart townsite with the purpose of extending the base of the Permian, if possible, into Seminole County. For this particular bit of reconnaissance, an effort was made to stay on the same stratigraphic horizon, regardless of the lithologic variations. The Hart was, at first, typical. Northward, however, it graded by easy stages into a sandstone, and the horizon of the Hart dropped steadily below the line drawn by Morgan. Such a behavior was not surprising; many Seminole County limestones grade into sandstone northward. The Hart horizon passes between one and two miles west of the town of Vanoss (sec. 3, T. 3 N., R. 4 E.), and trends northward through the middle of T. 4 N., R. 4 E. In sec. 10 of that township, the trace swings northeastward, and then passes under high terrace deposits in sec. 1. The terrace is approximately four miles wide, and sufficiently thick to prevent physiographic development of any resistant ledges. In order to jump this gap, the writer projected an average-strike line northward across the terrace. This line emerged on bedrock in Sec. 19, T. 5 N., R. 5 E., approximately at the bottom of a well-developed sandstone ledge correlated with the base of the Konawa formation in the type locality of the latter. Stratigraphic work of this nature is, of course, hazardous, but seemed the best expedient. Oakes concurred fully in the correlation, and showed to the writer an unpublished map by Robert Dott, on which the same general contact had been sketched.

Dott's facies hypothesis is, then, at least tentatively supported, and the Stratford is removed from formation rank. If the Konawa-Vanoss contact sketched, during this work, across northern Seminole County is accepted, the following facies are found in the Konawa formation:

1. In the south, the thick, dark shales of the Stratford facies, with the lagoonal Hart limestone at the base.

2. Between Canadian River and Little River, a well-bedded sequence of alternate shales and coarse clastics, cut by conglomerate-filled channels or lenses. Some of these conglomerates are dark.

3. Between Little River and North Canadian River, a continuation of the above facies, and a gradation to poorly consolidated shales with occasional siltstones, sandstones and soft limestones.

4. Beyond North Canadian River, alternating shales and limestones.

These four facies may represent, in the same order as given above, the following environments:

1. Lagoon or tidal flat.

2. Barrier island and beach; channels.

3. Shallow near shore.

4. Open shelf-sea.

Similar facies changes seem to hold for older formations already discussed.

This interpretation, reached from field observations prior to consultation of any of the literature cited here, is in many respects in agreement with the observations of Dott (1930) and Green (1936). This writer does not, however, follow Green in his ideas concerning the source of the sediment; instead, a contrary view is held (see page 169), based on the concept that, along a more-or-less lagoonal shore, the coarsest clastics will not normally accumulate in the lagoons.

Stratigraphic relations: The Konawa rests with only local unconformity on the underlying Vanoss (uppermost Pennsylvanian) formation. In northern Seminole County this contact is known imperfectly, and beyond North Canadian River not at all. South of the county, this contact is found at the base of the Hart limestone, a horizon which extends along the north flank of and around the west end of the Arbuckle Mountains, disappearing, as far as this writer knows, in T. 2 S., R. 2 W. Since the Hart, and immediately adjacent beds both above and below, parallel the northern and western flanks of the mountains, it is thought that Arbuckle orogeny was complete before Hart deposition.

The contact at the top of the formation (Asher-Konawa; following Morgan) appears to be marked by local unconformity. Conditions of this type seem to have continued in central Oklahoma well into Permian time, but the reasons for sea-level fluctuations must be sought in areas other than the Arbuckle Mountains.

Paleontology: No fossils were found in the Konawa other than in the "Prague" member and other limestone lenses. The "Prague" yielded identifiable species at two sites. At Station 3081, the following collection was made:

Bryozoa
  Rhombopora lepidodendroides Meek

Crinoidea
  Fragments

At Station 3098, the following species were collected:

Bryozoa
  Rhombopora lepidodendroides Meek

Brachiopoda
  Marginifera cf. muricatina Dunbar & Condra

Pelecypoda
  Allorisma terminale Hall

Age and correlation: On the basis of incomplete work in Pottawatomie County, the Konawa is thought to correlate, northward, with the Sand Creek formation, the Elmdale shales (including the Cushing limestone), the Neva limestone, and the Eskridge shales.

Beds of Konawa age extend around the western end of the Arbuckle Mountains and into Carter County where they have not been mapped separately.

The Konawa is lowermost Permian in age.

Quaternary System

Pleistocene and Recent deposits in the Seminole County area include modern floodplain and older terrace materials. These are unconsolidated clays, silts, sands and gravels. The floodplains are now being alluviated, as is shown by construction of a fan on the Salt Creek valley flat, in sec. 13, T. 7 N., R. 5 E. (see Fig. 6). This is not entirely a short-term flood-time deposit, but the result of a general program of aggradation throughout much of the Canadian River system (Evans, 1951; Fisk, 1947).

Other workers in the area profess to be able to identify certain terrace levels on a lithologic basis. Taff (1901), Morgan (1924), Hendricks (1937) and Weaver (1952) have so outlined the Gerty sand. Taff named the formation for the town of Gerty in the south-central part of Hughes County. He described it as follows:

> Generally the sand becomes coarse downward, ending in gravel at the base. In many places the finer sediments have been washed away, leaving beds of coarse gravel and thin mantles of pebbles. In places the deposit is of even texture; in other places it grades gradually from fine to coarse materials; and in still other places, especially noted in well sections, there are alternate strata of bluish, red and yellow clay, silt and sand, usually ending at the base in quicksand or gravel.
>
> The sand is composed of fine white quartz which is usually more or less mixed with yellow silt. The pebbles of the gravel are well rounded and smooth, varying in size from that of a hen's egg to a sand grain. They are composed of quartz, quartzite, jasper and chert, and vary

in color from white, yellow, red, and black. Very little material from the country rocks such as limestone, shale, and sandstone was found mixed with the gravel.

This writer worked with Weaver in an area in Hughes County which included deposits he had identified as Gerty. They fit Taff's description very well. Hendricks' work on the Gerty, especially in Hughes, Coal, and Pittsburg counties, is convincing. Never-the-less, the same lithologic description also fits terrace material both lower and higher than the level of the Gerty. In fact, this writer would expect to find identical gravels at the bottom of the alluvial fill in most major stream valleys in Oklahoma. Evans (1952) has indicated that such is indeed the case (see also Chapter VII). The validity of the Gerty, as anything more than a terrace-level in Seminole County, is therefore questioned.

Farther to the southeast, geomorphic evidence lends considerable support to the Gerty concept; this is, indeed, its strongest point.

Weaver (1952), describing the stratigraphy of Hughes County, wrote:

> The Gerty averages 35 feet thick across Hughes County. Typically, it reaches a maximum of about 40 feet in the central parts of its outcrop and thins rapidly toward its edges. The top of this deposit slopes eastward at about 7 feet per mile across the county though this is but an estimate.

This, also, could be said of many, if not all, of the well-developed terraces in the area. The modern valley-fill is about 35 to 50 feet thick.

(For a discussion of terrace levels in the area, see Chapter III.)

CHAPTER V

SUBSURFACE STRATIGRAPHY

Introduction

Subsurface data for the Seminole County area were obtained largely from electric well logs. For this purpose several hundreds of logs were examined. Over 400 logs were correlated in some detail, and of these 62 are included in two subsurface stratigraphic sections which accompany this report.

The subsurface work was undertaken in order to determine:

1. Thicknesses.
2. Dips.
3. Regional stratigraphic relationships.
4. Regional variations in thickness.
5. Correlations between surface and subsurface units.
6. Facies changes in the down-dip direction.

Several tentative lines of logs were laid out. Two of these were selected for final drafting; the others permitted constant checks on the accuracy of correlation, inasmuch as the several lines crossed in many places. Of the two lines finally adopted, one--consisting of 26 wells--starts from the surface in the southeastern part of the county, runs westward (downdip) into the subsurface to a point in the southwestern part of the county, turns northward and continues approximately along the west county line into southeastern Lincoln County, turning again and running eastward until it ties in with (1) the surface again, and (2) an electric log section prepared by Ries (1951).

The other--of 36 wells--starts at the surface east of Wewoka, where it can also be tied in with an electric log section prepared by Weaver (1952), extends westward across the county to a point where it crosses the first section, and continues from thence westward into R. 4 W.

Four other electric log sections were assembled and drafted, but not included in this report. One extends north and south through Pottawatomie County; a second runs east and west through southern Seminole and Pottawatomie counties; and the third and fourth cross Seminole County in northeast-southwest and northwest-southeast directions. In addition, other electric log cross sections, both short and long, were laid out to facilitate checking of subsurface correlations.

With so many electric logs available for study, poor logs could be rejected, in many cases, without seriously impairing the continuity of section. Over the routes chosen, logs were available every quarter or half mile. Never-the-less, some correlations were necessary across gaps of two or more miles. In and close to Seminole County, multiple lines of section tended to overcome this difficulty. The western one-third of section B-B', however, was constructed without benefit of adjacent sections, and is therefore not thought to be as reliable as the other parts of the subsurface work. Correlations between the surface and the subsurface were possible in nearly all parts of the county. Since surface work was not extended to include any strata below the upper Wewoka, subsurface correlations of lower beds were started, largely, from the electric log sections of Ries and Weaver, mentioned above.

The strata correlated on the electric logs lie between the Senora limestones and the base of the Permian. Where this sequence of beds lay at or close to the surface, generalized topographic profiles were constructed and transferred to the electric log sections. The cuestas which show on the former made surface-subsurface correlations relatively easy.

The results of the subsurface investigation are summarized below.

Thicknesses

In no case did the subsurface work yield thicknesses which differed greatly from figures obtained from surface measurements. Where apparent discrepancies exist, they are accounted for by demonstrable changes in thickness. The tabulated values are shown in Table IX.

Dips

Throughout most of the county, dips near the surface average close to one degree (about 90 feet per mile). Variations from that figure, except for local anomalies associated with certain structures, are both slight and systematic. All of the beds studied now have northwestward dips, with values decreasing in the lower part of the section.

Regional Stratigraphic Relations

The only unconformities shown on the two sections are those at the bases of the Ada and Vamoosa formations, respectively. Both of these are well established by surface mapping. In each instance, the surface evidence is quite convincing, the subsurface evidence less so.

Other, lesser, surface unconformities were not extended into the subsurface.

The zigzag route taken by the southern leg of section A-A' reveals the influence of the Hunton Arch on middle-to-late Pennsylvanian sedimentation. Deviations southward (toward the mountains) result in thinning; northward (away from the mountains), in thickening. (See Plate III.)

The active or effective part of the arch was shifting eastward during that time. During the deposition of the upper Des Moines formations, the highest part of the arch was located farther west; throughout Missouri and during

TABLE IX

THICKNESSES OF CERTAIN PENNSYLVANIAN AND PERMIAN FORMATIONS IN THE SEMINOLE COUNTY, OKLAHOMA, AREA

Formation	Surface (South)	Surface (North)	Subsurface (South)	Subsurface (Central)	Subsurface (North)	Morgan	Surface Ries	Weaver
Konawa	800-900					500		
Vanoss	550 ?	140	350				200 ? (Vanoss and Ada)	
Ada	150-250		190-220	150-200		100		
Vamoosa	150	550	230-420	420-550	570	230	680	
Hilltop	0-200		0-200	100-420	260-450	30	355-470	140
Belle City	0- 30		20- 30	0- 25		30		
Nellie Bly	300-400		320-440	270-520	500	500 (Nellie Bly and Coffeyville)	450-500	340
Coffeyville	150-200		200-220	190-260	220-250		230-280	300
Seminole	170[a]		200-220	220-285	270-300	150	250-350	270-310
Holdenville	250		130-250	135-170	150-170	100-235	150-210[b]	185-200[c]
Wewoka	600-700		400-520	440-670	680	400	550-750	600-700

[a]Thickening or thinning of the Seminole and Coffeyville from the surface into the subsurface is complicated by the fact that the surface and subsurface intervals do not contain the same beds. On the surface, the contact is at the base of the DeNay member, a limestone commonly only a few inches thick. Since this member does not appear distinctly on electric logs, a substitute contact must be chosen. The shifting of the contact may result in the addition or subtraction of as much as 70 feet.

[b]In the subsurface, 200-280.

[c]In the subsurface, 250.

All thicknesses are given in feet.

much of Virgil time, it was east of the present position.

Regional Variations

Isopach sketch maps, compiled from data collected during the course of the investigation, reveal the following:

1. The upper Des Moines series (Calvin-Wetumka-Wewoka-Holdenville) thickens to both the east and west from a point in eastern Cleveland County. Thickening to the west was not studied in detail. Thickening to the east averages 17 feet per mile; that is, the interval increases from about 500 feet in eastern Cleveland County, to about 1,400 feet in Hughes County, 55 miles away. This increase becomes progressively more rapid to the east, varying between five and 25 feet per mile. In Seminole and Hughes counties, isopach lines are rather clearly concave eastward.

2. The Missouri series thickens, from a minimum of about 700 feet in the southern part of Seminole County, northwestward to about 1,200 feet in 25 miles. The change averages about 20 feet per mile, but there are several sharp exceptions, especially in west central Seminole County. Across central Pottawatomie County, the thickness varies less than 100 feet. From here thickness increases again, steeply to the west, much less steeply to the north. In Cleveland County, westward thickening averages about 25 feet per mile.

3. The lower Virgil series (Vamoosa formation) thickens northwestward from zero to about 700 feet in 40

miles (about 17 feet per mile). Thickening continues westward to more than 1,000 feet, but the direction of maximum thickening is not clearly indicated. (See Plate X.)

Correlations

Many subsurface names in current usage have been included on the electric log cross-sections. With a few exceptions, these have been set off by quotation marks. The use of quotation marks indicates neither approval nor disapproval as far as correlation goes. It will be observed that current usage varies rather widely, and, of course, all of these correlations cannot be right.

The following points were noted during the compilation of the sections:

1. The subsurface "Checkerboard" (as distinct from the surface Checkerboard) is actually the equivalent of the middle Seminole sandstone. This correlation was previously made by Ries (1951), and has been verified in the course of this study. Where "First" and "Second" "Checkerboards" are identified, the former (higher) is commonly the equivalent of the middle or lower member of the Coffeyville formation, and the latter (lower) is the correlative of the middle Seminole sandstone.

2. The subsurface "Hogshooter" varies in the section by as much as 600 feet. It is often called at the correct position of the surface Hogshooter (i.e., between the

Nellie Bly and Coffeyville formations). It has also been called as high as the Belle City formation, and as low as the "First Checkerboard." The correct location is 300 to 400 feet below the Belle City, and 300 to 400 feet above the "Checkerboard."

3. The various subsurface limestones identified as "Pawhuska" occur, chiefly, in the upper part of the Ada formation, or the lower part of the Vanoss formation. Since these two formations are often not separable, the precise location is not too important. The surface Pawhuska, however, is truncated by the Ada and hence 200 to 600 feet below the subsurface "Pawhuska."

4. Subsurface names such as "Oread," "Dewey," and "Avant" are applied to various horizons which, for any one name, may be as much as 1,000 feet apart.

5. Some of the best horizons, for correlation purposes, are the "Henryetta coal" (Upper Senora limestone), "Checkerboard," Belle City, and various shales in the Senora, Coffeyville, Nellie Bly and Hilltop formations.

<u>Facies Changes</u>

One of the two most obvious down-dip changes is the transition from coarse clastics--many of which, at the surface, are conglomeratic--to shales. The Calvin-Wetumka-Wewoka-Holdenville sequence, for example, becomes so shaly down dip that correlations are extremely difficult if not impossible. The Vamoosa has been reported, on the basis of sample logging (Patterson, 1932), to grade downdip to a red shale, but the electric log data do not bear out such a change.

The other obvious downdip facies change involves the appearance and disappearance of relatively thick sequences of thin limestone beds. Such a sequence occurs, although poorly developed, on the surface in the upper Nellie Bly formation in the southern part of Seminole County. In the subsurface, these sequences have lateral extents up to 20 or 30 miles, and vary in thickness up to 500 or more feet. Examples may be found in the lower Coffeyville ("Hogshooter"; "First Checkerboard"); in the Nellie Bly ("Upper Hogshooter"; "Belle City"; "Dewey"); in the Hilltop and Vamoosa ("Avant"; "Oread"; "Belle City"). (See Plate IV, section B-B'.)

Northward, the Wewoka-Holdenville-Seminole sequence grades to a thick, almost uniform shale. Other northward facies changes are essentially those discussed in the chapter on surface stratigraphy.

CHAPTER VI

STRUCTURE

Introduction

The structure of Seminole County strata is deceptively simple. At first glance the sequence seems to consist of gently westward dipping beds which have suffered little or no deformation other than the tilting which elevated them to their present position. Closer examination, however, reveals that a rather complex structural history may be read from these low dip beds. The structures of the county fall into four general groups:

1. Linears.

2. Surface and subsurface structures, including faults and warps.

3. Unconformities and truncations.

4. Penecontemporaneous contortion.

Group No. 4, formed prior to lithification, is discussed on page 94. The three other groups are treated in this chapter.

Linears

Most of the features described as linears are not observed in the course of casual field work. Detailed plane table mapping would bring out some--but not all--of them. They show up clearly, though, on the air photographs. These are, in part, faults with measurable movement. The precise line between faults and other linears is hard to draw, especially in Seminole County, where many of the faults have movement of the order of one to ten feet and therefore have not been measured.

Wilson (1948) has used the term "linear" to include faults, fractures, foliation and bedding. Some of the linears of Seminole County have proven to be faults with measurable displacement at the surface. Others have given no surface indications, but develop in the subsurface into definite structure. Still others are largely without either surface or subsurface evidence of displacement. These may be joints, as Melton (1951) has suggested.

No effort has been made to map all of the linears within the county. The more pronounced have been drawn on the field map, especially those which showed offset or definite control over the drainage.

The bedding in Seminole County is so distinct, in most places where it shows at all, that the term linear has been used with this meaning excluded; in other words, the usage in this report is strictly tectonic. Linears have been observed where drainage lines (not drainage channels) cross, or where several drainage lines are definitely parallel.

In the Cromwell oil field area, in the northeastern corner of the county, subsurface data were used[9] to determine the behavior of linears at depth. The Cromwell sand, a local producing horizon at 2,500 to 3,000 feet below sea level, was the control. Displacements ranging up to about 200 feet were indicated. On the surface, movement was negligible, and these linears could not be evaluated as to the degree of movement in the subsurface (see Fig. 25).

Many of the linears are followed by stream courses, and therefore obscured by alluvium. The very characteristic which makes them easy to recognize on the photographs--the straight and parallel stream channels--also makes them practically impossible to study in the field. The alluviated condition of most Seminole County streams means that valley-floor exposures are rare.

It would be futile to guess how many linears occur in the area. Throughout the course of the field work, the author has found that each re-examination of photographs previously studied has brought out additional linears. At least one set of linears--including a fault--was located on the basis of subsurface work. The fault, with a surface displacement of about 130 feet, lies along the valley of Little River, crossing sec. 30, T. 6 N., R. 8 E. The wide alluvial

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[9]Douglas Cummings, at that time a senior in the school of geology at the University of Oklahoma, carried out this subsurface project under the author's supervision.

valley and the large areas of upland terrace deposits prevented an accurate location of the fault zone. It is likely that additional subsurface work would reveal other zones of linears within the county.

For many years Seminole County has been known for its belts of en echelon faults (Nevin, 1949; Willis, 1934). These belts parallel the strike, more or less, although the individual faults are mapped as lying chiefly northwest-southeast. Many of the features which have been mapped as faults, in the course of earlier work, probably have insignificant displacement and therefore should more properly be called linears.

It has been observed that these belts seem to coincide with the outcrop areas of the most resistant beds in the county. This observation is perhaps more apparent than real. It is true that the Vamoosa, which caps the highest cuesta scarp in the county, is crossed by faults or other linears; on the other hand, a relatively large proportion of the linears appears in the shale belts of the Coffeyville and Nellie Bly formations.

A more likely possibility is that the location of the linears is determined in the subsurface.

Faults

Many of the linears within the county are undoubtedly fractures or joints. Some of those which are faults have in-

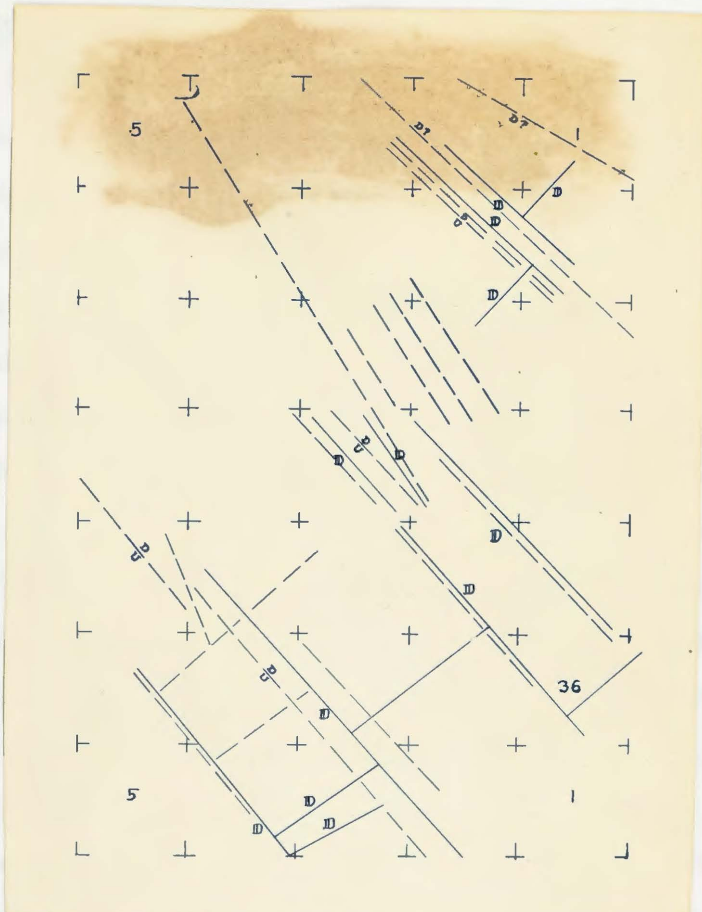

Fig. 25. Relationships between air photograph and subsurface structural data, in the Cromwell oil field area (T. 10 N., R. 8 E.; T. 11 N., R. 8 E.). The solid lines were drawn by Cummings (see page 219) on the basis of subsurface work; the dashed lines were drawn by the author, from air photograph data.

significant or almost imperceptible movement. Many which do not appear as faults may actually be such. In any case, measurable movement or offsetting is not a common characteristic of the linears.

No effort was made to determine the movement, if any, along many of the linears. On the more obvious ones, direction of movement was indicated. In some cases this suggested a "scissors" type of mechanism: up at one end along one side of the fault plane, and down at the other end along the same side. These are, on a small scale, rotational faults.

So far as was measured, none of the surface faults exhibits any great amount of movement. Measurements were obtained up to a maximum of about 130 feet. All values higher than this were derived from subsurface information. In a few instances local dips were obtained adjacent to faults. These ranged up to a maximum of 11 degrees, in sec. 11, T. 11 N., R. 8 E.

Levorsen (1930) reported that structural erratics in Seminole County in some instances reveal subsurface displacement of as much as 600 feet, with the average being between 100 and 300 feet. These were reported from the Searight, Seminole, Bowlegs, Little River and Earlsboro fields. The erratics represent downward movement, perhaps grabens; photographic analysis tends to support the graben hypothesis. Where the grabens are arbitrarily eliminated, simple domed structures are left. That is, the grabens seem to be tensional gravity features across what would otherwise be ordinary structural highs. Not all of the block movements are of the graben type, if photograph evidence is dependable; a few seem to be horsts.

The maximum figure of 600 feet, obtained by Levorsen, has been confirmed, tentatively through construction of an electric log cross-section across central Seminole County.[10]

Movement of this order does not show on the surface, however. In the Seminole City field it is usually a matter of a few tens of feet.

When this author first saw Levorsen's structure map (Levorsen, 1930) of the Seminole City field, he had already completed his own field work in Seminole County. A comparison of Levorsen's map with field data resulted in Fig. 26. The author's faults and linears (shown by dashed lines) were obtained chiefly from air photographs, and adjusted as a result of field work.

Several other areas, highly faulted, are shown on the areal map (Plate I), but were not studied in the subsurface.

Other Local Structures

Faults and other linears commonly indicate subsurface structure in Seminole County. Other structures have been

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[10] Mrs. Paula Mallams Highfill, at that time a geology senior at Oklahoma Baptist University, made this subsurface study under the author's supervision.

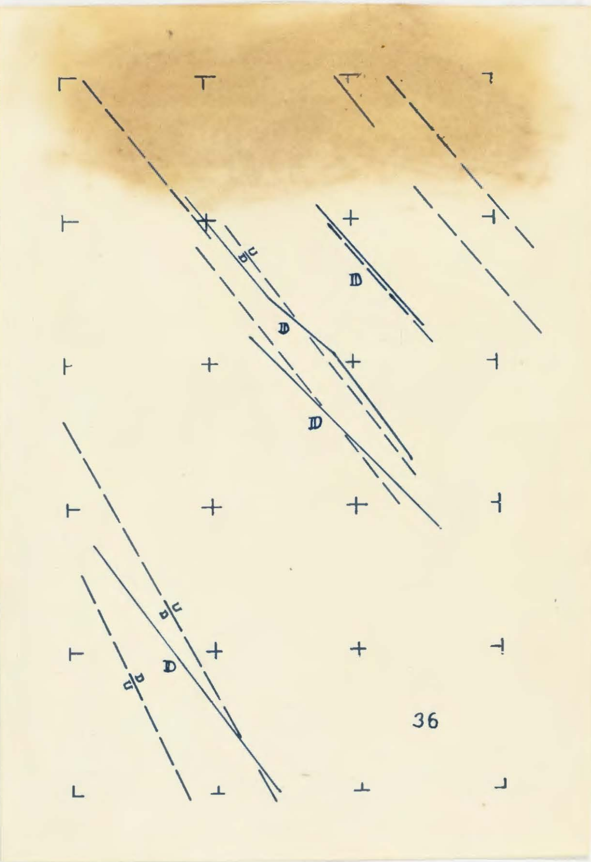

Fig. 26. Surface faults in part of the Seminole City field, in T. 9 N., R. 6 E. The solid lines indicate surface faults drawn by Levorsen (see page 223); the dotted lines, surface faults drawn by the author from air photograph data.

picked up on the basis of minor changes in the degree or direction of dip. Since the regional dip is approximately one degree (i.e., about 90 feet per mile), local aberrations in the strike or dip may not be obvious to the field geologist who is working with Brunton compass, hand level, altimeter, or some other reconnaissance instrument. Plane table and alidade would suffice for the delineation of structures of this type, but plane table mapping was not undertaken for this study. In a few cases, however, photographic evidence was sufficiently clear to permit the location of gentle structures. These are more or less symmetrical domes. In some instances they are reflected in outcrop patterns which curve across two or three or more sections; in others, by local deflection of otherwise regular stream channels.

Two such structures may be seen on the areal map: one is located in T. 9 N., R. 7 E.; the other, the controlling factor in an anchored stream meander, is located in T. 5 N., R. 5 E. and T. 5 N., R. 6 E.

Origin of Linears

Melton (1951) has suggested--as have many others--strike slip in the basement complex to account for the en echelon arrangement of the linears in east central Oklahoma. This is adequate to explain the pattern, but does not seem to account for the combination of tensional and gravity features (i.e., grabens) across many of the domes of the area.

Sherrill (1929) postulated torsion caused by depression of the northeast and southwest corners of the area. The resulting tension, realized in a northeast-southwest direction, would be localized along anticlinal flexures which trend north and south and therefore determine the fault zones. This concept can be demonstrated by putting a piece of moist tissue paper on an ordinary diamond-shaped soft-rubber eraser, and subjecting it to the torsion described above. One or both of two features will result, depending on the wet strength of the tissue paper: (1) en echelon tension faults, of the Oklahoma type, properly oriented, or (2) northeast-southwest trending parallel folds. If a north-south set of lenses or flexures already existed, the first set of results would be indicated.

Sherill's concept may be connected with the Permian sinking of the Anadarko basin (since only one corner of the eraser needs to be depressed to achieve the same result). If this explanation is correct, the en echelon faults are Permian in age. Sherrill's mechanism has the merit of explaining the dome-top grabens.

Billings (1947) discusses en echelon faulting, specifically that of eastern Oklahoma, in terms of the strain ellipse. He makes the tension effective in a northeast-southwest direction (as did Sherrill), but draws the strain ellipse to show a couple composed of a north force moving eastward and a south force moving westward. Such a couple is thought to be more or less incompatible with the known structural outlines of Oklahoma.

Using the same strain ellipse suggested by Billings, and keeping the tension axis in the same position, one might draw a couple composed of a west force moving southward and an east force moving northward. This likewise seems incompatible.

In gravel pits in Seminole County, where bedrock has been exposed by recent operations, a network of closely-spaced fractures may be observed. One such gravel pit is located in a dark chert conglomerate in the southwest corner of sec. 22, T. 7 N., R. 5 E. Here the fractures show up as ridges of grass, the primary or most pronounced set trending about N. 35° E., and the secondary set trending almost east-west. Similar fracture nets may be observed elsewhere in the county. Melton (1930) has advanced the concept that high-angle thrust faulting in the Ouachita mountains, in early Permian time, may have provided a force adequate to account for the fracture nets.

The trend of the primary fractures is paralleled by a small but nevertheless significant fraction of the faults and other linears in the county. These northeast-southwest faults usually do not show on maps of the Oklahoma en echelon fault belts, but they exist in sufficient numbers to be more than mere accident.

In his field notebooks the author has a sketch showing the down-warping of the Anadarko basin to the west-southwest, and the development of the en echelon faults localized over subsurface highs. At a later date, following compilation of subsurface data on the Cromwell sand in the northeastern part of the county, a similar sketch was drawn, with some of the faulting taking place over areas of locally thickened sandstones or conglomerates which might not qualify as domes.

These ideas are essentially those expressed by Sherrill more than 20 years earlier, with the exceptions that no downward movement to the northeast is envisaged, and depositional lenses as well as domes might be the loci for surface faulting.

Unconformities and Truncations

The earliest--and by far the most obscure--surface structure features in Seminole County are the truncations. These are difficult to unravel, not because of high relief and sharp angles, but because of extremely low relief and almost imperceptible angles. Most of them represent angles on the order of a fraction of a degree, and involve beds which have been mapped by previous workers as parallel.

The truncations can be dated with some precision, because they necessarily are restricted to the interval between the two confining beds.

A correct interpretation of the truncations rests on an understanding of the map relationships between positive areas (i.e., mountains) on one hand, and the patterns of unconformity traces on the other. For the purposes of this discussion, these relationships are two: (1) unconformities which approach and in some fashion disappear against the edge of a positive area were formed by a pulsation of that area; and (2) unconformities which tend to skirt the periphery of a positive area were formed at a time when that area was not active.

The unconformities which may be traced across Seminole County to the north skirt the Ouachita-Ozark uplifts; these areas, then were inactive and perhaps very low during late Pennsylvanian time (as defined by the beds described here-in). At some post-Pennsylvanian date, both of these areas have been actively positive. Only the Ouachitas are of concern here; they were probably thrust and uplifted early in Permian time. Such a movement, coupled with the more prolonged Permian sinking of the Anadarko basin, tilted the Seminole County section, thereby exposing the unconformities contained in that section.

These unconformities may be traced across the county to the south, where they merge and pass into a more general erosional interval which marks the periphery of the Hunton Arch-Arbuckle Mountain core. Because each unconformity disappears, in some fashion, against the Hunton Arch complex, it represents a pulsation of the Hunton Arch-Arbuckle Mountain positive area.

These concepts can be clarified by viewing the areal map of east central Oklahoma "down dip." In this fashion it becomes a stratigraphic and structural cross-section extending south-and-north, with the west edge representing "up" and the east edge "down." The unconformities now rise and merge toward the Hunton Arch to the south, much as they do in the actual strata.

The two generalizations made above may be repeated as follows:

1. Each unconformity exposed in the area represents a pulsation in the Pennsylvanian history of the Hunton Arch-Arbuckle Mountain complex.

2. The present attitude of the unconformities in the area represents a post-Pennsylvanian movement in the Ouachita Mountains.

Generalization No. 2 is not subject to very much elaboration; it may be interpreted trigonometrically as about 3,650 feet of Ouachita uplift, measured near Atoka, Okla., in post-Pennsylvanian time. A cursory examination of unconformities south and east of the Ouachitas indicates that perhaps only half of this movement occurred in the Permian, with the rest delayed until later, but the details of that interpretation are not properly a part of this study.

If the point of uplift is taken deeper in the Ouachita Mountain area, the amount of post-Pennsylvanian uplift may be increased to a figure above 10,000 feet.

The smaller figure given above is based on careful measurements of five truncating unconformities in Seminole County. Two of these involve the Ada and the Vamoosa formations, two are entirely within the Vamoosa, and one is within the Seminole formation. The values obtained for Ouachita uplift at or near the edge of the thrust area ranged from 3,620 feet to 3,685 feet; the mean was 3,657. A sixth measurement, involving the base of the Vamoosa and the underlying shales, yielded precisely 3,650 feet; this is thought to be the base of the Virgil, and the most important unconformity in the county.

Generalization No. 1 may be studied in detail with some profit. From this standpoint, each unconformity represents a separate pulsation of the Hunton Arch-Arbuckle Mountain complex. The truncations were measured in the field, and the results were extended trigonometrically to a point selected, arbitrarily, near Ada, Okla. At that point, the six measured truncations yield the following figures (uplift in feet):

Within Seminole formation--300

Base of Vamoosa--422

Within Vamoosa--760

Higher in Vamoosa--235

Ada, over next-to-highest Vamoosa--180

Ada, over highest Vamoosa--560.

An average of these six figures would be pointless, since they stand for different, though sequential, events. More appropriate would be a total, in this case 2,457 feet for only six of the truncations in Seminole County alone.

It is not implied here that each pulsation is thought of as taking place in precisely the same spot. What is implied is that each pulsation, regardless of where it took place within the Hunton Arch-Arbuckle Mountain area, resulted in an uplift approximately as calculated above, at the point designated.

The Ada formation is stated, above, to truncate the uppermost Vamoosa at one angle, and the next-to-highest Vamoosa at another. Two different amounts of uplift are indicated: 180 feet, and 560 feet. The basal Ada is an overlapping beach or near-shore sandstone which is not a true time horizon. Although there seems to be no method of determining how much time elapsed, on the average, during each mile of southward sea advance, that time was sufficient to span at least two distinct uplifts: the first of 560 feet, as the Ada beach approached the uppermost Vamoosa, and the second, of 180 feet, by the time the Ada shoreline had moved three miles farther south.

Since many of the truncations in the county were not measured and studied in detail, it is likely that the Virgil alone may represent 3,000 or more feet of Hunton Arch-Arbuckle Mountain uplift, and that a study of all Pennsylvanian beds in eastern Oklahoma would yield a figure higher than

5,000 feet.

One corollary of these figures is a picture of slow, long-term movements in the Hunton Arch-Arbuckle Mountain area, rather than one or two sharp, short pronounced orogenies. Another is that the close of the Pennsylvanian coincided more or less with the termination of active uplift in the Hunton Arch-Arbuckle Mountain area, and that deposition of coarse boulder conglomerates along the flanks reflects primarily high altitudes achieved in earlier uplifts.

That the active orogeny was distributed throughout an appreciable time rather than sharply limited is also indicated by the occurrence of many beds of limestone conglomerate at various horizons within the Missouri and Virgil series. These have been described in Chapter IV.

Each truncation referred to above is a structure in which a single bed cuts out completely--that is, cuts both top and bottom contacts--of an older, underlying bed. In the case of the truncating unconformity at the base of the Vamoosa (base of the Virgil), perhaps two or three or more formations are cut out over a distance of several miles. These are, locally, indistinguishable, and field work has not revealed precisely how many formations may be present between the Vamoosa and the Belle City, within the county. Never-the-less an interval 200 feet thick is truncated or cut out by the basal Vamoosa unconformity, within a measured distance.

The result is an altitude (thickness in feet) in relation to a horizontal distance, or base (distance in miles). Such a relationship may be expressed as an angle, or, more conveniently, the sine or tangent of an angle. Accurate usage requires the tangent or its reciprocal, but at the low angles obtained in Seminole County, tangent and sine are interchangeable. In this sense, it may be said that the truncations in the area may be represented by ratios (angles) ranging from as little as about four feet per mile (less than two minutes) up to something less than 92 feet per mile (one degree).

These are very small angles, indeed, for determination in the field by reconnaissance methods. In the case of the smallest, the field geologist might be confronted with two seemingly parallel beds, eight feet from base to base, including an intervening shale, with the younger bed cutting out both the shale and the entire older bed, all in exactly two miles.

As far as this author knows, no previous worker in Seminole County has recognized the truncating relationships present. The discrepancies in the section, taken from north to south or vice versa, have been explained variously as the result of faulting, warping or channeling; and in perhaps a few cases, beds have been jumped in order that a constant stratigraphic sequence might be maintained.

Despite the low angles involved, the truncating relationships are reasonably clear as a result of careful interpretation of the air photographs. Their existence was made doubly sure through a practice of taking measured sections, in the field, at intervals of one mile or (as was often the case) less. These sections, compiled as a stratigraphic cross-section extending north and south, show the truncations in clear detail (see Plate IX).

Morgan (1924), working in the Stonewall quadrangle, noted that the Ada formation truncated the Francis southward (although he failed to state thicknesses or angles of truncation). Field examination of the Vamoosa reveals that it is truncated by the Ada in precisely the same manner. It should be noted that, in both instances, the Ada cuts out the underlying beds one at a time, working down in the section from north to south; that is, this is a clear case of overstep. The beds within the Vamoosa and Francis formations do not pinch out against older units.

The equations used to obtain magnitude of uplift, in feet, were:

$$h_1 = T_1 d_1 = \frac{d_1 \theta}{M} \qquad (1)$$

$$h_2 = T_2 d_2 = d_2 \sin s \tan \delta \qquad (2)$$

where:

h is the magnitude of uplift in feet

d is the map distance, in miles, to the arbitrarily chosen "center" of uplift

T is the angle of truncation, as described above

θ is the thickness, in feet, of the bed truncated

M is the map width, in miles, of the bed truncated

s is an angle obtained by subtracting from 90° the following:

1. The map angle between the unconformity and an underlying horizon (such as the top or base of the truncated bed);
2. The map angle, if any, between the unconformity and an overlying horizon; if these are parallel, this factor may be disregarded.

δ is the dip of the truncated bed

and where the subscripts identify the two uplift areas, the Hunton Arch-Arbuckle Mountain complex being first, and the Ouachita area being second.

Utilization of these equations required map measurement of d, M, and s, and field determination of θ and δ. The values for d were read from the Geologic Map of Oklahoma (1926); the values for M and s were read from the field map prepared in the course of this study.

The magnitude of uplift derived from equations (1) and (2) is thought to be accurate to thousands and hundreds of feet; tens and units of feet are included in the results to indicate the precise product of calculation rather than a precise value for uplift.

An examination of the geologic map of Oklahoma shows clearly enough that truncating relationships exist throughout the Pennsylvanian above the base of the Boggy formation. Each of these truncating unconformities exhibits a characteristic trace: the older ones are sharply curved (concave westward), the younger ones are essentially straight, and those in between pass in proper order from one extreme to the other. Since the curvature of each such unconformity trace reflects the total movement involved in all of the later unconformities in the same area, the oldest should show the sharpest arc, and the youngest the least. The straightness of the late Pennsylvanian unconformity traces is here adduced as additional evidence that Hunton Arch uplifting was largely complete by the close of Pennsylvanian time; if there had been significant orogeny in that area during the Permian, even the latest Pennsylvanian unconformities should have been warped more than they were.

The highest, youngest, and straightest unconformity trace identified and studied in detail was that at the base of the Ada formation, which is probably upper Virgil in Age.

CHAPTER VII

ECONOMIC GEOLOGY

Structural Materials

Gould (1911) listed the structural materials available in Seminole County as limestone, sandstone, conglomerate and shale. No particular change has been made in this list in more recent years.

Several limestone quarries may be found in the county in different places; they are now used for local purposes only. The largest, south of Sasakwa, has not been in use for several years. Another quarry, utilizing Belle City limestone, was in operation near the Limestone school (sec. 17, T. 7 N., R. 7 E.) in 1951. Gould reported that both crushers and kilns were located in the county in 1911. The limestones of the area are, however, too thin and commonly of too poor a quality to permit utilization on a large scale.

Sandstone has been used occasionally, especially in the early days of the county's development, as a construction stone. Most buildings and houses erected in more recent years have used other materials.

Conglomerates are plentiful in nearly all parts of the county, and are widely used for gravelling roads and in concrete work. The Vamoosa and Konawa formations have furnished large quantities of road gravel. In recent construction, such as the extension of State Highway 9 across the county, Vamoosa outcrops were used to provide material for about 18 inches of sub-base.

Loose sand is available in many of the river and creek bottoms of the county, but no single large operation has been active in the last few years.

The shales of the area are suitable for manufacture of tile and brick. The Wewoka Brick and Tile company plant, northwest of Wewoka, uses dark calcareous shales of the Hilltop formation. Francis formation shales are being used in a brick plant near Ada, in Pontotoc County. In addition to Francis (i.e., Coffeyville and Nellie Bly) and Hilltop shales, other formations in the county are shaly, and offer prospects of development by the brick-making industry. Among these are the Wewoka, Holdenville, Seminole and especially Ada formation shales.

Water

Only two large lakes exist in Seminole County, and both of these are artificial. One is Lake Wewoka, in secs. 1 and 12, T. 8 N., R. 7 E. The other is a privately-owned lake in sec. 27, T. 8 N., R. 7 E. The former is the larger of the two, with 4,800 acre-feet of storage capacity.[11]

[11] Much of the water-supply information in this chapter was furnished by the Tri-City Area Council, Wewoka, Okla.

Over the two-year period during which field investigations were being made in Seminole County, both lakes were full or nearly so.

In addition, many ponds and stock-tanks may be found in the county.

The topography is especially suitable for the ponding of lakes. Structurally controlled streams on the back slopes of Vamoosa cuestas have commonly cut deeply enough to provide good dam sites. Other formations also are crossed by streams suitable for ponding, but the sites are not so numerous as on the Vamoosa.

Rainfall in the county averages 35 or more inches annually.[12] Evaporation from Class "A" pans in the county averages about 70 inches annually (Horton, 1943). Since Class "A" pans have a coefficient of about 0.7 (Linsley, Kohler and Paulhus, 1949), effective evaporation from lake surfaces is probably close to 49 inches annually. Hence the ratio of catchment-basin-area to lake-surface-area does not have to be large.

Few of the streams in the area are permanent. Canadian River, North Canadian River, Little River, Wewoka Creek

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[12] Figures presented on page 10 show an annual average of 43.26 inches. This may indicate, however, that the rain-gauges on which these data are based are not well located, since rainfall averages to the north and west are seven or eight inches lower. For the purposes of county-wide calculations, it is thought wise to use the lower figure. (Data from Linsley, Kohler and Paulhus, 1949.)

and Salt Creek definitely come in that category. Other smaller streams, such as Turkey, Gar, Coon and Sand creeks are permanent except during dry spells. To serve as year-round water sources, these streams would have to be dammed. Since they appear to be alluviating, the problem of siltation is paramount in any dam-construction project.

Sub-alluvial flow, however, is important in the rivers and larger creeks. The city of Oklahoma City recently put down 200 test wells (Johnson, 1953a) in the North Canadian River bed in Oklahoma County. The results led to a prediction by M. B. Cunningham, city water superintendent, that the coarse sand and gravel in the bed will produce about 1,500,000,000 gallons of water per linear mile. In March and April, 1940, 15 wells in the alluvium there produced 4,258,000 gallons of water daily. The river bed is close to the surface, being no deeper than 50 to 70 feet in Oklahoma County (Johnson, 1953b). Since the fill is only 70 feet thick at Ft. Smith, Ark. (Fisk, 1947), the figures obtained in Oklahoma County should be at least indicative of possibilities in Seminole County.

Ground water also seems to be plentiful in the area. The city of Seminole now operates 16 deep wells which produce from the sandstone and conglomerate members of the Vamoosa formation. Farther west, in a lower-rainfall area, the city of Norman obtains its municipal water supply from sandstones within the Garber formation (Bretz, 1952). Since many other sandstones in Seminole County are apparently aquifers comparable to the Vamoosa and Garber, and since even the Vamoosa is not being used to maximum capacity, the supply of subsurface water seems to be bountiful. (For an analysis of Vamoosa formation water, see page 14.)

Oil and Gas

The Wewoka field, near the town of that name, was discovered in 1923 by R. H. Smith (Levorsen, 1930). Gas had been discovered earlier in the Cromwell field, but no commercial oil had been obtained there at the time of the Wewoka discovery. Both of these early pools produced from the Cromwell sand (lower Morrow series). For two years thereafter, wildcats testing the Simpson group (Ordovician) beneath surface structures found it dry.

In 1925 a 4,000 barrel well was completed in the Seminole sand member of the Simpson, south of the Wewoka high. Within two years, the Seminole City, Searight, Earlsboro, Bowlegs and Little River fields were producing from the same horizon. (For location of fields, see Plate XI.)

By 1950, production had reached a total of more than one billion barrels.[13] About 80% of the sections within the county have been drilled, and every township produces oil. Most of the surface structures have probably been mapped and

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[13]Tri-City Area Council, Wewoka, Okla., furnished most of the information on oil production.

tested, and in some parts of the county (i.e., west central), strikes have resulted from geophysical work. In the last few years, the major companies have been cutting down on operations, and most of the development has been extension of known pools or semi-wildcatting by small independents.

Miscellaneous

Neither volcanic ash, nor coal, reported from various counties to the east, has been found in Seminole County.

CHAPTER VIII

CONCLUSIONS

1. One new formation has been named in Seminole County: the Hilltop. It is equivalent to the Barnsdall formation of Okfuskee County, plus the Dewey formation, and probably the Chanute and the uppermost part of the Nellie Bly.

2. Three new members have been named: the Snomac limestone member of the Ada formation; and the Dripping Springs dark chert member and the Jarvis Church multicolored chert member of the Konawa formation.

3. The correlation of the Belle City with the Dewey must be recognized as strictly tentative. At least as good a case can be made for correlating the Belle City with a limestone lens in the upper part of the Nellie Bly formation of Okfuskee County.

4. The Pawhuska formation does not crop out in Seminole County. Instead, it is truncated by the Ada formation in the western part of Okfuskee County.

5. The Francis formation is subdivided into the Coffeyville (lower) and Nellie Bly (upper) formations.

6. The most important unconformity in the Seminole

County section is that at the top of the Hilltop (Missouri series) and at the base of the Vamoosa (Virgil series).

7. Convincing evidence for the unconformity between the Holdenville (Des Moines series) and the Seminole (Missouri series) must be sought in Hughes County, Pontotoc County and other parts of Oklahoma.

8. The best example of truncation may be found at the base of the Ada, which rests, in Okfuskee County, on the Pawhuska formation (Virgil series), and, in Murray County, on the Simpson group (Ordovician system).

9. The best example of a beach or near-shore sand is the basal Ada sandstone, a member which has hitherto been mapped, erroneously, with the Vamoosa formation.

10. The environment of deposition in Seminole County, during late Pennsylvanian and early Permian time, was that of a fluctuating shoreline. Widespread, calcareous gray shales rich in marine invertebrate fossils indicate transgressions. Channeled, contorted, cross-bedded and barren sandstones and conglomerates indicate beach or near-shore conditions. At least some of the limestones appear to be lagoonal. Fossil plant remains point to continental-type deposits, specifically in parts of the Vamoosa formation.

11. The facies indicated in Item 10, above, are commonly arranged in a regular north-south order: open shallow shelf sea; near-shore; beach or barrier; lagoon or tidal flat.

12. The source of the limestone conglomerates was the Arbuckle Mountain range, to the south.

13. The source of the chert conglomerates may well have been the Arbuckle Mountain range. No reason is known for requiring a Ouachita Mountain area provenance.

14. The "arkose line" is not considered satisfactory as the contact between the Ada and Vanoss formations. The advent of arkose does, however, indicate something of the history of the Arbuckle Mountain area.

15. Upper Des Moines rocks thicken eastward; Missouri and Virgil rocks thicken westward. A shift from the McAlester basin to the Anadarko basin is indicated.

16. The Stratford is removed from formation rank, and considered as a facies of the Konawa and perhaps Asher formations.

17. The base of the Konawa is retained as the base of the Permian.

18. The present state of paleontology does not permit fossils to be used with any great degree of accuracy in dating or correlating Seminole County beds.

19. Stream patterns combine elements which can be traced to strike and dip of strata, and to fault and fracture systems.

20. A Permian date--perhaps early Permian--is indicated, within the county, for the Ouachita orogeny.

21. The Arbuckle Mountains-Hunton Arch complex was

active throughout Des Moines, Missouri and much of Virgil time. This is indicated by local unconformities, truncations and limestone conglomerate tongues within the section. The total uplift to the south, during that time interval, was of the order of 10,000 feet, but no single pulsation was much, if any, larger than 1,000 feet.

22. Virgil time was largely a period of exposure and erosion.

23. The Ada and Vanoss formations were not deposited until upper Virgil time.

24. The curvature of unconformity traces across the county furnishes a clue as to orogenic activity in the area. These indicate that Arbuckle Mountain diastrophism was largely complete by middle Virgil time.

25. Conglomerates in rocks higher than the middle of the Virgil series are concluded to be products of epeirogeny or normal geomorphic rejuvenation.

26. Surface and subsurface terminology do not match in all particulars. For example, the "Checkerboard" of the subsurface is actually equivalent to the middle part of the Seminole formation of the surface.

27. The outstanding undeveloped mineral resource of Seminole County is water.

28. Although many thousands of wells have been drilled in the county, and the boom days have long been over, there is still room for modest oil development.

APPENDIX A

REGISTRY OF FOSSIL-COLLECTING SITES

Station 3023. Wewoka No. 4. NW. corner, sec. 18, T. 5 N., R. 8 E.

Station 3024. DeNay limestone member of the Coffeyville formation. NW. quarter, SE. quarter, sec. 31, T. 7 N., R. 8 E.

Station 3025. Holdenville shale. NW. quarter, NE. quarter, sec. 12, T. 5 N., R. 7 E.

Station 3026. Middle Holdenville shale. SW. quarter, SE. quarter, sec. 12, T. 5 N., R. 7 E.

Station 3027. Sasakwa limestone member of the Holdenville. Center of the west line, SW. quarter, SW. quarter, sec. 8, T. 6 N., R. 8 E.

Station 3028. Sasakwa limestone member of the Holdenville. Center of the south line, SW. quarter, sec. 36, T. 6 N., R. 7 E.

Station 3029. Upper Nellie Bly. SE. quarter, NE. quarter, NE. quarter, sec. 33, T. 6 N., R. 7 E.

Station 3030. Belle City. SW. quarter, SW. quarter, SW. quarter, sec. 17, T. 7 N., R. 7 E.

Station 3031. Homer limestone member of the Holdenville. NE. quarter, SE. quarter, NE. quarter, sec. 8, T. 6 N., R. 8 E.

Station 3032. Lower Seminole shale. SE. quarter, SW. quarter, sec. 7, T. 6 N., R. 8 E.

Station 3035. Holdenville. About 0.75 mile east of the NW. corner, sec. 10, T. 6 N., R. 8 E.

Station 3036. Sasakwa limestone member of the Holdenville. SE. quarter, NW. quarter, sec. 17, T. 6 N., R. 8 E.

Station 3037. Lower Nellie Bly shale. On both sides of line between the NE. quarter of sec. 9 and the NW. quarter of sec. 10, T. 6 N., R. 7 E.

Station 3039. Sasakwa limestone member of the Holdenville. NE. quarter, SE. quarter, sec. 8, T. 6 N., R. 8 E.

Station 3040. Upper Holdenville shale. SE. quarter, SW. quarter, sec. 18, T. 6 N., R. 8 E.

Station 3041. Upper Holdenville shale. NE. quarter, SW. quarter, sec. 10, T. 6 N., R. 8 E.

Station 3042. Upper Wewoka shale. SW. quarter, SW. quarter, SW. quarter, sec. 7, T. 5 N., R. 8 E.

Station 3043. Upper Wewoka shale. West central part, NW. quarter, SW. quarter, sec. 18, T. 5 N., R. 8 E.

Station 3044. Upper Holdenville shale. NW. quarter, SW. quarter, sec. 25, T. 6 N., R. 7 E.

Station 3045. Upper Wewoka shale. NE. corner, sec. 31, T. 6 N., R. 8 E.

Station 3047. Lower Nellie Bly. NW. quarter, NW. quarter, sec. 9, T. 5 N., R. 7 E.

Station 3048. Lower Nellie Bly green shale. NW. quarter, NW. quarter, sec. 9, T. 5 N., R. 7 E.

Station 3049. Lower Nellie Bly black shale. NW. quarter, NW. quarter, sec. 9, T. 5 N., R. 7 E.

Station 3054. Middle Belle City shale. SE. quarter, sec. 19, T. 6 N., R. 7 E.

Station 3057. Limestone lens in middle Nellie Bly shale. SE. quarter, SE. quarter, SW. quarter, sec. 3, T. 6 N., R. 7 E.

Station 3059. Upper Coffeyville siltstone. Center of south line, sec. 24, T. 7 N., R. 7 E.

Station 3063. Lower Hilltop. NW. quarter, SW. quarter, sec. 11, T. 8 N., R. 7 E.

Station 3081. "Prague" limestone. East central part, SE. quarter, SE. quarter, sec. 30, T. 11 N., R. 6 E.

Station 3082. Limestone lens in the Upper Vanoss. About 0.2 mile east of the SW. corner, sec. 18, T. 9 N., R. 6 E.

Station 3083. Upper Coffeyville shale, beneath the limestone conglomerate underlying the former Seminole governor's mansion. NE. quarter, NE. quarter, NE. quarter, sec. 33, T. 6 N., R. 7 E.

Station 3084. Vamoosa conglomerate, in the highway cut. South central part, sec. 9, T. 8 N., R. 7 E.

Station 3085. Coffeyville shale above the DeNay limestone member. South central part of sec. 26, T. 6 N., R. 7 E.

Station 3086. Uppermost Vamoosa sandstone. NW. quarter, sec. 2, T. 8 N., R. 6 E.

Station 3087. Thin Coffeyville limestones below the limestone conglomerate underlying the former Seminole governor's mansion. NE. quarter, sec. 33, T. 6 N., R. 7 E.

Station 3088. Belle City limestone. SW. quarter, sec. 17, T. 7 N., R. 7 E.

Station 3089. Shale associated with uppermost Vamoosa sandstone. SE. quarter, sec. 30, T. 11 N., R. 7 E.

Station 3090. Hilltop siltstone lens. SE. quarter, sec. 1, T. 9 N., R. 7 E.

Station 3091. Sasakwa limestone member of the Holdenville. In the Sasakwa quarry, sec. 36, T. 6 N., R. 7 E.

Station 3092. Belle City limestone. Sec. 30, T. 6 N., R. 7 E.

Station 3093. Belle City limestone. Sec. 31, T. 6 N., R. 7 E.

Station 3094. DeNay limestone member of the Coffeyville. About 0.18 mile east of the center, sec. 31, T. 7 N., R. 8 E.

Station 3095. Sasakwa limestone member of the Holdenville. In the cut beside the road to the quarry, sec.

36, T. 6 N., R. 7 E.

Station 3096. Limestone conglomerate at the top of the Coffeyville. In the ditch beside the highway, and from thence northward; center of the east line, sec. 33, T. 6 N., R. 7 E.

Station 3097. DeNay limestone member of the Coffeyville. About 0.18 mile east of the center, sec. 31, T. 7 N., R. 8 E.

Station 3098. "Prague" limestone. SW. quarter, NW. quarter, sec. 5, T. 10 N., R. 6 E.

Station 3099. Uppermost Vamoosa sandstone. SE. corner, sec. 30, T. 11 N., R. 7 E.

Station 3100. DeNay limestone member of the Coffeyville. SE. quarter, sec. 23, T. 6 N., R. 7 E.

Station 3101. Sasakwa limestone member of the Holdenville. About 0.1 mile east of the center, sec. 36, T. 6 N., R. 7 E.

Station 3102. Seminole No. 1 sandstone. In highway cut, west of Sasakwa townsite, center of sec. 35, T. 6 N., R. 7 E.

Station 3103. Homer limestone member of the Holdenville. In creek bed south of road, NE. quarter, sec. 12, T. 5 N., R. 7 E.

Station 3104. Homer limestone member of the Holdenville. Center of east line, sec. 19, T. 6 N., R. 8 E.

APPENDIX B

MEASURED STRATIGRAPHIC SECTIONS

During the course of the field work, 260 sections were measured in Seminole and adjacent counties. Since it was the author's practice to work along the strike, rather than across it, each measured section is relatively short, and may cover only two or three formations, or even only part of one formation. Because of the necessity of determining the behavior of certain truncations in the county, some of the sections were measured close together; in exceptional cases, these were only a few hundred feet apart, along the strike. Therefore not all of the sections are necessary to present a representative picture of the stratigraphy of the county, and are not here included.

Directions, locations and distances used in computing these measured sections were obtained from air photographs. Relative elevations of more-or-less distant points were determined by use of a microaltimeter in a series of closed traverses. The Brunton pocket transit was used to measure detailed sections in terms of units about five feet thick or thicker. For units less than five feet in thickness, a steel tape was employed.

All thicknesses are given in feet and tenths of feet. Where two thickness columns are used, the first contains the separate thickness of each bed, and the second, the cumulated thickness from the base of the formation, including the bed there listed. Where only part of a formation is measured, the second column may not be used.

Township 5 North

13. North central part, sec. 1, T. 5 N., R. 6 E.

Hilltop		
Shale: red; about	15.0	83.7
Shale: dark, silty	44.0	68.7
Conglomerate: bluish-gray; limestone pebbles, maximum diameter 7 inches, average diameter between ½ and 1 inch; chert and jasper pebbles; coarsely or massively bedded; locally purple or yellow; pebbles and cobbles poorly rounded	2.7	24.7
Shale: mostly covered	22.0	

195. Measured along the north line of sec. 27, T. 5 N., R. 6 E., in Pontotoc County.

Ada (basal member only)		
Sandstone: reddish; chert flake sandstone; at least	3.0	
Vamoosa		
Shale:	5.0	72.0
Conglomerate: small chert pebbles in sandstone matrix	14.0	67.0
Shale: red	15.0	53.0
Sandstone: white, limy, laminated	3.0	38.0
Shale: covered	14.0	35.0
Shale: mostly red, some khaki color	11.0	21.0
Sandstone: soft, white to buff, limy but not a ledge-maker	10.0	10.0
Hilltop		
Shale:	4.0	4.0

Belle City		
Limestone: hard, light gray; sparingly fossiliferous	1.0	21.0
Shale: dark gray; fossiliferous	19.0	20.0
Limestone: hard, dark gray; fossiliferous	1.0	1.0

30. Measured in the southeast quarter of sec. 12, T. 5 N., R. 7 E.

(Continue upward with No. 33)

Holdenville (lower part)		
Shale: green	45.0	176.9
Limestone: (Homer member) black; <u>Chaetetes</u>	0.9	131.9
Shale: silty; partly covered	6.0	131.0
Siltstone: buff to brown; cross-bedded	25.0	125.0
Shale: green; partly covered	100.0	100.0
Wewoka (uppermost part)		
Sandstone: brown; limonite spots		

<u>Township 6 North</u>

33. Measured along the highway about one mile west of Sasakwa townsite, in sec. 35, T. 6 N., R. 7 E.

(Continue upward with No. 186)

Seminole		
Shale: gray-green	60.0	120.0
Sandstone: buff, thin-bedded to massive; contorted	5.0	60.0
Shale: gray-green	43.0	55.0
Sandstone: buff, conglomeratic locally; contorted	12.0	12.0
Holdenville		
Shale:	35.0	264.9
Limestone: (Sasakwa member) hard, light gray; thin-bedded; fossiliferous	7.0	229.9
Shale: gray-green	21.0	222.9
Sandstone: buff, conglomeratic locally	25.0	201.9
Shale: gray-green	45.0	176.9

Limestone: (Homer member)

(Continue downward with No. 30)

186. Measured in the southwest quarter of sec. 26, T. 6 N., R. 7 E.

(Continue upward with No. 71)

Coffeyville (lower and middle parts)		
Sandstone: soft, buff, friable; about	7.0	110.0
Shale: sandy; about	35.0	103.0
Sandstone: buff; ledge-maker; about	6.0	68.0
Shale: partly covered; about	60.0	62.0
Limestone: (DeNay member) hard, yellow to brown; sparingly fossiliferous	2.0	2.0

(Continue downward with No. 33)

71. Measured along the road, through the center of sec. 34, T. 6 N., R. 7 E.

(Continue upward with No. 68)

Nellie Bly (lower part)		
Shale: green or brown; occasional soft sandstone or siltstone	140.0	146.0
Sandstone: buff to brown, cross-bedded, thin-bedded siltstone or very fine grained sandstone	6.0	6.0
Coffeyville (upper part)		
Conglomerate: hard, gray or white, lenticular, cross-bedded; contains fragments of _Neospirifer dunbari_ King and other species; occasionally yellow on fresh surface; contains yellow or pale green clay pebbles; limestone cobbles have maximum diameter of five inches; soft, dark yellow siltstone cobbles also occur up to five inches in diameter	3.0	223.0
Shale: black or dark green, highly fossiliferous; near base, shales are dark and flaggy	110.0	220.0

(Continue downward with No. 186)

68. Measured in the southeast part of sec. 19, T. 6 N., R. 7 E.

(Continue upward with No. 192)

Belle City		
Limestone: hard, white, fossiliferous; about	11.0	33.0
Shale: green, grading upward to black; fossiliferous	20.0	22.0
Limestone: hard, buff, fossiliferous	2.0	2.0
Nellie Bly		
Siltstone: soft, buff to brown	2.0	317.1
Shale: very pale; clay shale	10.0	315.1
Siltstone: soft, buff, massive	26.0	305.1
Shale: covered	13.0	279.1
Conglomerate: limestone pebbles; lenticular	1.0	266.1
Limestone: very pale; silty	0.3	265.1
Conglomerate: limestone pebbles; lenticular	0.3	264.8
Shale: gray	3.0	264.5
Limestone: hard, gray, non-fossiliferous	0.5	261.5
Shale:	6.0	261.0
Conglomerate: limestone pebbles; lenticular	1.0	255.0
Shale: partly covered	22.0	254.0
Covered: (alluvium and terrace materials)	140.0	232.0
Sandstone: buff; about	10.0	92.0
Shale: mostly covered; about	70.0	82.0
Sandstone: soft, brown to buff, thin-bedded to massive; silty; about	12.0	12.0

(Continue downward with No. 71, which duplicates part of the section given above)

192. Measured along the highway between Sasakwa and Konawa; i.e., through secs. 35 and 36, T. 6 N., R. 6 E.

(Continue upward with No. 21)

Vamoosa

Shales: red; occasional lenses of

cross-bedded sandstones and chert conglomerates	20.0	173.0
Conglomerate: buff; chert pebbles and cobbles	22.0	153.0
Shale: covered with chert pebble "float"	22.0	131.0
Sandstone: locally conglomeratic; about	10.0	109.0
Shale:	14.0	99.0
Sandstone: locally conglomeratic; about	7.0	85.0
Shale:	17.0	78.0
Conglomerate: various pale shades, but mostly buff to white; chert pebbles and cobbles include brecciated (second generation) cherts; about	14.0	61.0
Shale: red; partly covered; about	35.0	47.0
Conglomerate: buff to white; chert and brecciated chert pebbles and cobbles	12.0	12.0
Hilltop		
Shale: red; about	18.0	18.0

(Continue downward with No. 68)

21. Measured along the east-west line between secs. 28 and 33, T. 6 N., R. 6 E.

(Continue upward with No. 214)

Ada		
Shale: pastel shades of green and purple; contains lenses of cross-bedded sandstone near top and bottom; in the center of the unit are layers of very hard limestone, 2 to 15 inches thick each	16.0	167.5
Siltstone: very hard, buff, limy, laminated	2.0	151.5
Shale: pastel shades of green and purple	5.0	149.5
Siltstone: perhaps very fine sandstone; biotite flakes	1.5	144.5
Shale: brown; partly covered	33.0	143.0
Siltstone: pale to medium green; contains soft limy nodules, up to 1 inch in diameter, near top	10.0	110.0
Shale: mostly covered	12.0	100.0

Shale: green	3.0	88.0
Conglomerate: blue-gray; chert pebbles up to ½ inch in diameter	0.5	85.0
Shale: green	1.0	84.5
Sandstone: soft, brown, broken	4.0	83.5
Shale: green, silty	3.5	79.5
Claystone: gray-green	11.0	76.0
Sandstone: hard, gray, limy laminated; biotite flakes; ledge-maker	2.0	65.0
Claystone: brown and green	7.0	63.0
Conglomerate: gray, torrent-bedded; chert pebbles up to ½ inch in diameter	2.0	56.0
Shale: red; partly covered	21.0	54.0
Shale: pale green, occasionally purple; contains very hard silty layers up to 2 inches thick; cross-laminated	22.0	33.0
Sandstone: very hard, dark brown, calcareous; contains chert flakes and clay pellets; about	11.0	11.0

(Continue downward with No. 192)

214. Measured westward from the northeast corner of sec. 35, T. 6 N., R. 6 E.

Konawa		810.0
Vanoss		
Shales and sandstones	70.0	433.0
Crinoidal limestone conglomerate	3.0	363.0
Shales and sandstones; arkose near base	360.0	360.0
Ada	160.0	160.0

(Continue downward with No. 21)

22. Measured along the road in the southern part of sec. 7, T. 6 N., R. 7 E.

Hilltop		
Shale: red; partly covered or deeply weathered; covered locally by chert conglomerate from overlying Vamoosa formation	41.0	48.0
Siltstone: reddish, thinly-to-mas-		

sively-bedded	3.0	7.0
Siltstone: reddish; partly covered	4.0	4.0
Belle City		
Limestone: very hard, blue, thin-bedded, crinoidal; layers one to three inches thick	6.0	
Limestone: very hard, gray-blue, crinoidal; layers one to 12 inches thick; small chert pebbles near base	6.0	
Shale: mostly covered	9.0	
Sandstone: buff, massive, cross-bedded; fractured; many calcite "veins"	10.0	
Base unknown: (Covered by alluvium)		

66. Southeast part of sec. 30, T. 6 N., R. 7 E.

Belle City		
Limestone: upper	5.0	18.9
Shale: green	13.0	13.9
Limestone: lower	0.9	0.9
Nellie Bly (uppermost part)		
Sandstone: soft, brown; contains lenses of green shale	18.0	
Sandstone: soft, buff-to-brown, thin-bedded, very fine grained; weathers dark brown or red; contains fine chert flakes	24.0	
Shale: mostly covered	6.5	
Limestone: buff, silty, thin-bedded	8.0	
Limestone: hard, light to medium gray, fine-grained, thin-bedded to massive; non-fossiliferous; weathers yellowish-gray to almost black; locally green, red, dark brown or dark blue; occasionally cross-bedding shows on weathered surface; outcrop is often marked by presence of limestone plates in the soil	1.5	
Shale: green	33.0	
Siltstone: green; occasionally purple	5.0	
Conglomerate: limestone pebbles, pink, red, yellow, buff, purple or black on weathered surface; maximum pebble size, under two		

inches; weathers with rough surface	1.0	
Siltstone: pale green, shaly	21.0	
Conglomerate: white to pink limestone and chert pebbles; up to 3/4 inch in diameter; thinly bedded; weathers to give a "grainy" appearance because of the chert flakes present; fresh surface is occasionally pale green; grades laterally into fine-grained silty limestone two to three feet thick	1.0	
Shale: mostly covered	9.0	
Siltstone: fairly hard, brown; contains chert flakes	1.5	
Shale: mostly covered	12.5	

117. Measured in secs. 26 and 27, T. 6 N., R. 7 E.

Coffeyville		
Shale:	25.0	185.1
Conglomerate: cross-bedded, limestone pebble and clay ball conglomerate; fossil fragments	10.0	160.1
Shale: mostly covered	24.0	150.1
Shale: soft, brown, silty	16.0	126.1
Sandstone: soft, brown, cross-bedded or massive; ledge-maker; thins southward	10.0	110.1
Shale: mostly covered; sandy or silty; about	35.0	100.1
Sandstone: soft, buff, friable; about	5.0	65.1
Shale:	60.0	60.1
Limestone: (DeNay member) hard, faintly yellow, crinoidal; occurs as small blocks or plates in the soil; at least	0.1	0.1
Seminole		
Shale: gray-green	36.0	

31. Measured in the southeast quarter of sec. 8, T. 6 N., R. 8 E.

(Continue upward with No. 16)

Holdenville		
Shale: green	32.0	199.5
Limestone: (Sasakwa member) hard, gray, fossiliferous	0.5	167.5
Shale: green	44.0	167.0
Conglomerate: buff chert pebbles; about	22.0	123.0
Siltstone: buff, calcareous	3.0	101.0
Shale: covered	5.0	98.0
Siltstone: buff, calcareous	3.0	93.0
Shale: covered	14.0	90.0
Limestone: (Homer member) hard, nearly black	6.0	76.0
Shale: green; about	70.0	70.0

16. Measured along the north line of secs. 7 and 8, T. 6 N., R. 8 E.

(Continue upward with No. 76)

Seminole		
Shale:	11.0	172.0
Sandstone: soft, buff, flaggy; fine-grained	7.0	161.0
Shale: mostly covered	27.0	154.0
Sandstone: soft, buff, thin-bedded	20.0	127.0
Shale: mostly covered	80.0	107.0
Sandstone: soft, buff; grades into a local channel which extends into the underlying Holdenville formation to below the horizon of the Sasakwa limestone member; channel filling is coarse chert conglomerate; sandstone is about	27.0	27.0

(Continue downward with No. 31)

76. Measured along a line extending westward from the southwest part of sec. 4, T. 6 N., R. 7 E.

(Continue upward with No. 34 or No. 36)

Nellie Bly		
Shale: mostly covered	50.0	402.5
Conglomerate: hard, yellowish, cross-bedded; limy and silty; contains rounded limestone		

nodules; manganese stained locally; contorted; locally dark brown to black siltstone	12.0	352.5
Shale: mostly covered	33.0	340.5
Limestone: coarsely crystalline, pale; contains clay balls	5.0	307.5
Shale: mostly covered	33.0	302.5
Siltstone: soft, buff	16.0	269.5
Shale:	5.0	253.5
Siltstone: soft, buff	11.0	248.5
Shale: mostly covered	27.0	237.5
Siltstone: buff; siltstone or very fine grained sandstone; ledge-maker	8.0	210.5
Shale: silty	19.0	202.5
Siltstone: soft, buff	4.0	183.5
Shale: mostly covered	30.0	179.5
Conglomerate: chert pebbles in soft, buff, fine grained sandstone	15.0	149.5
Covered: (alluvium and terrace materials)	70.0	134.5
Limestone: hard, medium-gray, thin-bedded, fossiliferous	1.5	64.5
Shale: black	53.0	63.0
Conglomerate: chert pebbles in soft, buff, fine grained sandstone	10.0	10.0
Coffeyville		
Shale: mostly covered	35.0	155.0
Sandstone: buff, occasionally siltstone or fine chert conglomerate; ledge-maker	15.0	120.0
Shale: contains local yellow limestone lenses which might be mistaken for the DeNay limestone member, below; about	29.0	105.0
Sandstone: buff, occasionally siltstone or fine chert conglomerate; ledge-maker	11.0	76.0
Shale: mostly covered	62.0	65.0
Limestone: (DeNay member) hard, yellow to brown, thin-bedded; fossiliferous; vuggy	3.0	3.0

(Continue downward with No. 16)

34. Measured in the southeast quarter of sec. 30, T. 6 N., R. 7 E.

(Continue upward with No. 218)

Belle City			
	Limestone: hard, white, fossiliferous	6.0	20.0
	Shale: green	13.0	14.0
	Limestone: hard, gray	1.0	1.0

(Continue downward with No. 76)

218. Measured along the east-west county road through secs. 12 and 14, T. 6 N., R. 6 E.

(Continue upward with No. 216 or No. 217)

Vamoosa			
	Shale:	15.0	159.0
	Conglomerate: buff chert pebbles in sandstone	12.0	144.0
	Shale:	35.0	132.0
	Sandstone: grades westward into conglomerate	6.0	97.0
	Shale:	36.0	91.0
	Conglomerate: chert pebble pudding-stone	3.0	55.0
	Shale:	12.0	52.0
	Conglomerate: buff chert pebbles in sandstone	12.0	40.0
	Shale:	18.0	28.0
	Conglomerate: grades upward to buff sandstone	10.0	10.0
Hilltop			
	Shale: red, silty	48.0	48.0

(Continue downward with No. 34 or No. 36)

217. Measured in the northeast quarter of sec. 3, T. 6 N., R. 6 E.

Ada			
	Shale: about	20.0	102.0
	Conglomerate: small limestone pebbles	1.0	82.0
	Shale: about	50.0	81.0
	Conglomerate: small limestone pebbles	1.0	31.0
	Shale: about	20.0	30.0
	Sandstone: buff; occasional chert pebbles	10.0	10.0

(Continue downward with No. 218)

216. Measured along the north lines of secs. 2 and 3, T. 6 N., R. 6 E.

Vanoss (not detailed)	450.0 to 550.0	
Ada		
Shale: mostly covered	35.0	160.0
Conglomerate: limestone pebbles in buff sandstone	6.0	125.0
Shale: mostly covered; dark	105.0	119.0
Sandstone: buff, contorted; scattered chert pebbles	14.0	14.0

(Continue downward with No. 218)

Township 7 North

77, 78. No. 77, Coffeyville and lower part of Nellie Bly; measured between secs. 24 and 25, T. 7 N., R. 7 E. No. 78, middle and upper part of Nellie Bly and Belle City; measured between secs. 27 and 34, T. 7 N., R. 7 E.

(Continue upward with No. 36)

Belle City		
Limestone: partly covered; at least	11.0	
Nellie Bly		
Shale:	3.0	352.0
Siltstone: soft, buff	6.0	349.0
Shale: mostly covered	27.0	343.0
Siltstone: hard, buff, cross-bedded; non-fossiliferous; weathers dark; limy in spots; conglomeratic locally	10.0	316.0
Shale: mostly covered	49.0	306.0
Siltstone: or very fine grained sandstone; buff	25.0	257.0
Covered:	88.0	232.0
Siltstone: or very fine grained sandstone; buff	11.0	144.0
Shale: green; mostly covered	27.0	133.0
Sandstone: soft, buff; locally limy, silty or conglomeratic	35.0	106.0

Shale: mostly covered	55.0	71.0
Sandstone: soft, buff to brown, very fine grained; contains hard limy "pockets"; alternating with thin green shales; occasionally laminated or cross-bedded siltstone	16.0	16.0
Coffeyville		
Shale: dark green to almost black	115.0	158.0
Sandstone: soft, yellow, friable, very fine grained	6.0	43.0
Shale: covered)		
Sandstone: covered) Total	35.0	37.0
Shale:)		
Limestone: (DeNay member) hard, yellow to brown	2.0	2.0

36. Measured in the northwest quarter of sec. 31, T. 7 N., R. 7 E.

(Continue upward with No. 218)

Hilltop		
Siltstone: reddish; may be very fine grained sandstone	2.0	51.5
Shale: covered with "float" from Vamoosa	27.0	49.5
Shale: sandy; perhaps covered with "float"	17.0	22.5
Shale: red	5.5	5.5
Belle City		
Limestone: partly covered; at least	26.0	26.0

(Continue downward with No. 77 and No. 78)

165. Measured along the south line of secs. 33, 34, 35, in T. 8 N., R. 8 E.

(Continue upward with No. 79)

Seminole		
Shale: gray-green; partly covered	80.0	339.0
Sandstone: soft, yellow to buff, locally contorted; very fine grained; makes only a weak ledge at cuesta front; about	10.0	259.0
Shale: mostly covered	49.0	249.0

Siltstone: or very fine grained sandstone; soft, buff	6.0	200.0
Shale: silty	5.0	194.0
Shale: covered	123.0	189.0
*Sandstone: soft, buff, friable; very fine grained; silty	10.0	66.0
Shale: (4,000' to the west, only 35')	48.0	56.0
*Sandstone: soft, yellow to brown siltstone and sandstone; makes weak ledge; grades westward into chert flake conglomerate or very fine chert flake sandstone; about	8.0	8.0

79. Measured westward along the highway and then along the section line road, from the south line of sec. 8, T. 7 N., R. 8 E.

(Continue upward with No. 37)

Nellie Bly		
Shale:	17.0	338.0
Limestone: gray, silty, cross-bedded	2.0	321.0
Shale: blue, calcareous	9.0	319.0
Sandstone: buff, thin to massive; alternating with laminae of bright red siltstone or very fine sandstone	11.0	310.0
Shale: blue, calcareous; occasionally green or silty	12.0	299.0
Siltstone: buff	6.0	287.0
Shale: green	82.0	281.0
Sandstone: buff, friable	13.0	199.0
Sandstone: cross-bedded; contains layers of green and red shale; locally buff siltstone	18.0	186.0
Sandstone: buff; cross-bedded	12.0	168.0
Shale: mostly covered	93.0	156.0
Sandstone: soft, limy, buff; very fine grained; silty; thin-bedded	9.0	63.0
Shale: includes stringers of siltstone and limestone	42.0	54.0
Sandstone: hard, buff, cross-bedded, very fine grained; interbedded with green to purple shales	12.0	12.0

*Farther south, these two sandstones merge to form a single ledge (the Seminole No. 1 sandstone).

Coffeyville		
Shale:	37.0	131.0
Sandstone: hard, buff, considerable secondary calcite; silty	4.0	94.0
Shale: mostly covered	60.0	90.0
Sandstone: soft, buff, friable; very fine grained; about	5.0	30.0
Shale: about	25.0	25.0
(DeNay limestone member is missing)		

(Continue downward with No. 165)

37. Measured along the road which follows, roughly, the south line of sec. 18, T. 7 N., R. 7 E.

(Continue upward with No. 24)

Vamoosa		
Shale: red and brown; about	40.0	224.0
Conglomerate: ("pink" member) chert pebbles in buff sandstone; locally	43.0	184.0
Shale: red and gray; sandy near base	16.0	141.0
Shale: maroon	22.0	125.0
Sandstone: buff	1.0	103.0
Shale: maroon; occasional sandstone lenses	32.0	102.0
Sandstone: gray, silty, cross-bedded	4.0	70.0
Sandstone: buff	1.3	66.0
Shale: silty; partly covered	4.5	64.7
Shale: red and green	7.0	60.2
Siltstone: buff	1.2	53.2
Shale: red	7.0	52.0
Sandstone: buff; chert flakes abundant	1.0	45.0
Shale: red; partly covered	34.0	44.0
Conglomerate: chert cobbles; green shale lenses locally	10.0	10.0
Hilltop (thins eastward to between 5 and 40 feet)		
Shale: red	3.5	81.5
Sandstone: buff, cross-bedded, fine grained	3.5	78.0
Shale: maroon and brown	13.0	74.5
Siltstone: cross-bedded; many calcite veins	16.0	61.5
Sandstone: chert flakes common	4.0	45.5
Shale: brown to green; silty	1.5	41.5
Siltstone: buff	2.3	40.0

Shale: silty; partly covered	2.5	37.3
Shale: gray	5.5	34.8
Siltstone: hard, yellow	0.8	29.3
Claystone: gray	2.0	28.5
Siltstone: hard, limy	2.2	26.5
Shale: maroon	1.0	24.3
Limestone: green, silty	1.0	23.3
Shale: green, silty; with limestone stringers	3.5	22.3
Shale: maroon	2.6	18.8
Claystone: red and gray; contains clay pellets	1.5	16.2
Siltstone: white, shaly	1.2	14.7
Siltstone: green to tan	2.5	13.5
Siltstone: gray, shaly	11.0	11.0
Belle City		
Limestone: hard, gray, fossiliferous; middle member not well exposed	19.0	19.0

(Continue downward with No. 79)

24. Measured along section-line road south of secs. 10, 11, 12, T. 7 N., R. 6 E. (Snomac townsite.)

Vanoss (lower part)		
Shale: green and maroon	16.0	60.3
Sandstone: soft, brown, chert-flake bearing; contains pale secondary limestones, very hard, two inches to two feet thick	9.0	44.3
Shale: green and maroon	11.0	35.3
Limestone: light gray to bluish gray, finely crystalline; biotite flakes are common	0.2	24.3
Shale: pale green	2.5	24.1
Limestone: light gray to bluish gray, finely crystalline; biotite flakes are common	0.1	21.6
Shale: green and maroon	13.5	21.5
Conglomerate: blue, limy, silty, arkosic; feldspar pebbles ¼ inch in diameter	8.0	8.0
Ada		
Shale: covered	5.0	210.8
Shale: green and maroon	10.0	205.8
Sandstone: hard, buff; contains abundant secondary calcite; chert flakes; clay balls up to three		

inches in diameter	8.0	195.8
Shale: green and maroon	10.0	187.8
Sandstone: hard, buff to brown; contains thin limestone fingers	2.5	177.8
Shale: green near top, maroon near base	27.0	175.3
Siltstone: buff to pale green	3.5	148.3
Shale: maroon	19.0	144.8
Shale: green and maroon; silty	6.0	125.8
Sandstone: pale; silty	9.0	119.8
Limestone: gray to dark brown; silty; finely crystalline	0.5	110.8
Sandstone: buff	4.5	110.3
Shale: gray	2.5	106.8
Conglomerate: gray; contains limestone pebbles	0.9	104.3
Shale: gray and red	3.7	103.4
Shale: green	0.4	99.7
Shale: gray and red	9.0	99.3
Sandstone: buff, silty; shaly near base	8.0	90.3
Conglomerate: buff, silty, chert puddingstone; contains clay pebbles	0.1	82.3
Approximate horizon of the Snomac limestone member (locally absent)		
Shale: maroon, brown and green	52.0	82.2
Limestone: hard, gray to tan, finely crystalline; contains chert flakes	0.5	30.2
Shale: maroon	10.0	29.7
Siltstone: pale green	2.7	19.7
Conglomerate: buff to brown chert pebble puddingstone	17.0	17.0

(Continue downward with No. 37

221. Measured from the west line of sec. 10, T. 7 N., R. 6 E., to 0.25 miles west of the northeast corner of sec. 10, T. 7 N., R. 5 E. This section was measured exclusively with the microaltimeter and, with the exception of the single ledge given below, was not detailed.

Vanoss

Shale: silty, sandy	40.0	440.5
Conglomerate: limestone pebbles; not fossiliferous	0.5	400.5
Interval to base: about	400.0	400.0

(Continue downward with No. 24)

6. Measured in the northwest quarter of sec. 31, T. 7 N., R. 7 E.

Vamoosa (lowest part)		
Conglomerate: chert pebbles, maximum diameter 2.5 inches	5.5	50.2
Sandstone: red; chert flakes common; partly covered	1.7	44.7
Shale: mostly covered; much conglomerate "float"	27.0	43.0
Conglomerate: chert pebbles having maximum diameter up to 3.5 inches, plus brown siltstone cobbles having maximum diameter up to 6 inches, in sandstone matrix; basal contact is conspicuously undulatory; about	16.0	16.0
Hilltop		
Shale: red	5.0	5.0
Belle City		
Limestone: hard, white, fossiliferous; partly covered; at least	26.0	26.0

7. Four different vertical or "stratigraphic" measurements, all made in the northeast quarter of sec. 19, T. 7 N., R. 7 E., south of the east-west road, and west of Little River.

Hilltop				
Shale: varies	5.0	17.0	37.0	40.0

80. Measured in the southwest part of sec. 2, T. 7 N., R. 7 E.

Hilltop		
Shale: dark, occasional thin siltstones	38.0	38.0
Belle City		
Limestone: (upper) hard, white, fossiliferous	5.0	8.0
Limestone: (lower) hard, buff, coarsely crystalline, crinoidal	3.0	3.0

Township 8 North

114. Measured along the south lines of secs. 30, 31, 32, in T. 8 N., R. 8 E.

Nellie Bly		
Shale:	3.0	378.5
Limestone: hard, gray, sandy	0.5	375.5
Shale:	16.0	375.0
Sandstone: soft, buff, massive	6.0	359.0
Shale: green	60.0	353.0
Sandstone: buff	10.0	293.0
Shale: red	6.0	283.0
Sandstone: buff	27.0	277.0
Shale: multicolored	13.0	250.0
Sandstone: buff; locally hard and calcareous	11.0	237.0
Shale:	3.0	226.0
Sandstone: locally cross-bedded; locally siltstone or shale	14.0	223.0
Shale:	10.0	209.0
Sandstone: very soft, buff	11.0	199.0
Shale: with siltstone lenses	25.0	188.0
Sandstone: buff, massive, cross-bedded, contorted	23.0	163.0
Shale: partly covered; local faulting; about	135.0	140.0
Sandstone: very fine grained; locally siltstone	5.0	5.0
Coffeyville		
Shale: partly covered; local faulting; about	53.0	143.0
Sandstone: lower part is soft; upper part is fine chert conglomerate	12.0	90.0
Sandstone: scattered chert flakes; clay pellets; blue, crystalline limestone lenses; about	2.0	78.0
Shale: estimated) (	21.0	76.0
Sandstone: soft, buff) locally (	3.0	55.0
Shale:) continuous (	14.0	52.0
Sandstone: soft, buff) shale (	3.0	38.0
Shale: mostly covered) (	24.0	35.0
Sandstone: buff, thin-bedded, flaggy, cross-bedded and contorted; interbedded with thin shales	11.0	11.0
Seminole		
Shale: gray-green	80.0	

122. Measured along the south lines of secs. 19, 20, 21, T. 8 N., R. 8 E.

Coffeyville		
Shale: covered (estimated)	40.0	189.0
Sandstone: soft; despite being a cuesta cap, does not make an obvious or well-exposed ledge; about	8.0	149.0
Shale: mostly covered; about	135.0	141.0
Sandstone: soft, buff, very fine grained	6.0	6.0
Seminole		
Shale:	14.0	189.0
Sandstone: soft, buff, thin-bedded or cross-bedded	21.0	175.0
Shale: gray-green	44.0	154.0
Sandstone: soft, buff, thin, silty, flaggy	10.0	110.0
Interval to base; about	100.0	100.0

126. Measured along the north line of sec. 27, T. 8 N., R. 7 E.

Hilltop		
Shale: silty	10.0	93.0
Siltstone: soft, buff, massive	8.0	83.0
Shale: partly covered	47.0	75.0
Siltstone: soft, buff, massive	8.0	26.0
Shale: blue-gray, calcareous; contains very thin limestones	18.0	18.0
Belle City		
Limestone: yellow to white, wavy-bedded, fossiliferous; lower portion rather soft	6.5	6.5

127. Measured along the south line of the Belle City townsite, in the southwest quarter of sec. 35, T. 8 N., R. 7 E.

Hilltop		
Shale: silty	3.0	65.0
Siltstone: soft, buff, massive ledge	5.0	62.0
Shale: gray-green	19.0	57.0
Siltstone: soft, buff, massive ledge	7.0	38.0

Shale: covered (alluvium)	31.0	31.0
Belle City		
Limestone: (upper) hard, white, fossiliferous	5.0	10.0
Shale: black; locally red	2.0	5.0
Limestone: (lower) yellow, wavy-bedded, fossiliferous	3.0	3.0

129. Measured in and near Wewoka Brick and Tile Company shale pit, about 1,200 feet north of U. S. Highway 270, sec. 11, T. 8 N., R. 7 E.

Vamoosa		
Conglomerate: chert pebbles up to four inches in diameter; bottom contact is undulatory, with about 12 feet of relief in 50 feet of distance		
Hilltop		
Shale: (locally 25 feet thick)	11.0	91.3
Sandstone: buff, laminated, cross-bedded, contorted and ripple-marked siltstone and very fine grained sandstone; local shale beds; leaf prints; (locally 17 feet thick); about	8.0	80.3
Shale: green	2.0	72.3
Siltstone: buff, laminated, gently cross-bedded	3.3	70.3
Shale: alternating with buff siltstones; shales are blue and calcareous; individual layers one to four inches thick	5.0	67.0
Shale: alternating with wavy-surfaced silty blue limestones; shales are blue and calcareous; layers about one inch thick each; about	5.0	62.0
Shale: blue; partly covered; thin, silty limestones occur in this interval in adjacent areas; about	57.0	57.0
Belle City		
(Locally covered; but "float" may be found)		

(Maximum thickness of Hilltop, in above area: about 112 feet.)

133. Measured along the north line of sec. 11, T. 8 N., R. 7 E.

Hilltop		
Shale: covered with conglomerate "float" from the overlying Vamoosa; about	44.0	130.0
Siltstone: soft, buff	11.0	86.0
Shale:	12.0	75.0
Shale: alternating with thin siltstone ledges	10.0	63.0
Shale:	33.0	53.0
Siltstone: white	3.0	20.0
Shale:	17.0	17.0
Belle City		
Limestone: hard, blue, crystalline, crinoidal; weathers yellow; about	0.1	0.1
Nellie Bly (upper part)		
Shale:	22.0	
Sandstone: buff, very fine grained, friable	3.0	
Shale:	33.0	
Sandstone: light-colored, massive, friable	14.0	

Township 9 North

138, 141. No. 138 covers the Hilltop and the uppermost Nellie Bly; measured along the north line of sec. 13, T. 9 N., R. 7 E. No. 141 covers the middle and lower Nellie Bly and the Coffeyville; measured along the south lines of secs. 8, 9, 10, in T. 9 N., R. 8 E.

(Continue upward with No. 81 or No. 83)

Hilltop		
Shale: silty	80.0	204.0
Sandstone: very fine grained; contains poorly preserved fossils	12.0	124.0
Shale: mostly covered	76.0	112.0
Siltstone: or very fine sandstone; about	3.0	36.0
Shale: silty	33.0	33.0

Belle City		
Limestone: blue crystalline limestone; weathers yellow to dark brown; contains crinoids, *Fusulina*, and fossil fragments; thickest exposure is found in field about 450 feet north of the line of section; about	0.4	0.4
Nellie Bly		
Shale: silty	16.0	247.0
Sandstone: soft, buff, friable; very fine grained	14.0	231.0
Shale:	10.0	217.0
Sandstone: buff; with chert flakes and clay pellets	11.0	207.0
Shale:	3.0	196.0
Sandstone: buff, friable, very fine grained	8.0	193.0
Shale: much of it red	66.0	185.0
Siltstone: soft, buff	3.0	119.0
Sandstone: brown to buff ledge	3.0	116.0
Shale:	15.0	113.0
Siltstone: buff	11.0	98.0
Shale:	17.0	87.0
Siltstone: buff	5.0	70.0
Shale: mostly covered	48.0	65.0
Sandstone: thin-bedded to massive; contorted; fine grained	17.0	17.0
Coffeyville		
Shale: mostly covered	77.0	242.0
Siltstone:	1.0	165.0
Shale:	27.0	164.0
Siltstone: or very fine grained sandstone	3.0	137.0
Shale: covered or deeply weathered	105.0	134.0
Siltstone: soft, brown; thickens to north and west	1.0	29.0
Shale:	14.0	28.0
Siltstone: or very fine sandstone	3.0	14.0
Shale:	9.0	11.0
Sandstone: buff, friable, very fine grained	2.0	2.0

81. Measured in the southeast quarter, sec. 1, T. 9 N., R. 7 E.

(Continue upward with No. 85)

Vamoosa (lower part)		
Sandstone: ("pink" member) buff, contorted, cross-bedded, locally massive; contains chert pebble stringers	10.0	272.0
Shale:	10.0	262.0
Sandstone: buff, friable	8.0	252.0
Shale: mostly covered	27.0	244.0
Sandstone: very soft	3.0	217.0
Shale: mostly covered	24.0	214.0
Sandstone: buff, contorted, cross-bedded	3.0	190.0
Shale: mostly covered	11.0	187.0
Conglomerate: buff, cross-bedded; chert cobbles up to six inches in diameter	15.0	176.0
Shale:	20.0	161.0
Sandstone: buff, cross-bedded, contorted; scattered chert pebbles; weathered surface is nodular	15.0	141.0
Shale: sandy	35.0	126.0
Conglomerate: chert pebbles larger than three inches in diameter	5.0	91.0
Sandstone: buff, contorted; locally shaly, locally conglomeratic, locally strongly cross-bedded	21.0	86.0
Sandstone: fine conglomerate lenses; massive or contorted	28.0	65.0
Shale:	27.0	37.0
Sandstone: hard, buff, cross-bedded and contorted; very fine grained, but grades laterally into conglomerate; occasional laminated limy "pockets"; weathered surface is nodular; silty lenses contain _Nuculana_, _Tropidophorus_, _Acanthopecten_, and _Hustedia_; at least	10.0	10.0

(Continue downward with No. 138)

83. Measured in the northwest quarter, sec. 12, T. 9 N., R. 7 E.

(Continue upward with No. 85)

Vamoosa (lower part)		
Sandstone: ("pink" member) buff; locally conglomeratic with pebbles as large as two inches in diameter; about	10.0	206.0

Shale:	15.0	196.0
Conglomerate: maximum pebble diameter, about 5½ inches	5.0	181.0
Sandstone: with occasional chert pebble lenses	11.0	176.0
Shale: sandy and silty	60.0	165.0
Conglomerate: three ledges, the lowest six feet thick, separated by thin shale or sandstone zones; maximum pebble diameter, 4½ inches; about	18.0	105.0
Conglomerate: chert pebbles in sandstone	8.0	87.0
Sandstone: very soft; shaly	75.0	79.0
Sandstone: ledge-maker; grades laterally into conglomerate	4.0	4.0

(Continue downward with No. 138)

85. Measured between secs. 4, 5, 6 and secs. 7, 8, 9, in T. 9 N., R. 7 E.

(Continue upward with No. 225)

Vamoosa (upper part)

Shale:	27.0	464.0
Sandstone: buff, friable; locally limy and hard	5.0	437.0
Shale: mostly covered	65.0	432.0
Sandstone: soft, buff, contorted, torrent-bedded; tripolized chert flakes, and chert pebbles up to ½ inch in diameter	15.0	372.0
Shale:	22.0	357.0
Conglomerate: buff, cross-bedded or massive; locally sandstone; chert pebbles up to two inches in diameter	10.0	335.0
Shale: mostly covered	53.0	325.0
Conglomerate: massive but no ledge-maker; chert pebbles up to two inches in diameter	16.0	272.0
Shale:	16.0	256.0
Sandstone: ("pink" member) buff; chert pebble stringers contain pebbles up to about ½ inch in diameter; about	10.0	240.0
Interval to base of formation; about	230.0	230.0

(Continue downward with No. 81 or No. 83)

225. Measured in an east-west direction, along State Highway 9, from the upper part of the Vamoosa formation in the southwest quarter of sec. 14, T. 8 N., R. 6 E., westward to the Pottawatomie County line.

Konawa				
	Interval to top of formation: about	315.0	653.0	
	Conglomerate: pale chert pebbles, coarsening upward to a maximum diameter of one inch; ledge thins westward in about 900 feet to 20 feet thick; ledge-maker; about	40.0	338.0	
	Sandstone: hard, buff, limy; basal contact is undulatory	5.0	298.0	
	Shale: mostly covered	75.0	293.0	
	Conglomerate: contorted chert pebble lenses in sandstone; about	11.0	218.0	
	Shale: includes intervals of soft, friable, thin-bedded sandstone; about	145.0	207.0	
	Sandstone: buff, friable	2.0	62.0	
	Shale: about	50.0	60.0	
	Sandstone: alternating thin-bedded sandstones and shales; contains lenses of chert pebble and clay pellet conglomerate; maximum pebble diameter, two inches; base is undulatory; varies from 5 to 15 feet thick	10.0	10.0	
Vanoss				
	Shale: red to purple; locally silty and pale colored	33.0	182.0	?
	Limestone: soft, white, fossiliferous	2.0	149.0	?
	Sandstone: soft, buff; locally hard and limy	13.0	147.0	?
	F A U L T	25.0	134.0	?
	Shale: about	43.0	109.0	?
	*Sandstone: nearly white; silty; locally limy	10.0	66.0	

*Details of the lower Vanoss formation obtained in the southeast quarter of sec. 30, T. 9 N., R. 6 E., and in the northeast quarter of sec. 31, T. 9 N., R. 6 E.

*Shale: red	9.0	56.0
*Sandstone: very soft, white	13.0	47.0
*Shale: red	22.0	34.0
*Sandstone: white, limy	12.0	12.0
Ada		
Shale: mostly covered	32.0	156.0 ?
Sandstone: soft, light tan, friable	5.0	124.0 ?
Shale: covered	34.0	119.0 ?
Sandstone: soft, buff, cross-bedded	10.0	85.0 ?
F A U L T	32.0	75.0 ?
Sandstone: soft, buff, about	9.0	43.0 ?
Shale:	16.0	34.0
Sandstone: buff, contorted, friable	18.0	18.0
Vamoosa		
Shale:	49.0	
Sandstone: hard, light-colored and speckled; limy	6.0	

(Continue downward with No. 84)

130. Measured westward from the northwest corner of sec. 11, T. 8 N., R. 8 E.

(Continue upward with No. 148)

Coffeyville		
Shale: black; forms wide valley; about	102.0	231.0
Sandstone: brown to gray, massive or cross-bedded, very fine grained; small lenses of hard gray limestone	23.0	129.0
Siltstone: soft, buff, flaggy; thickens and hardens northward; about	4.0	106.0
Shale:	87.0	102.0
Sandstone: very soft, shaly	5.0	15.0
Sandstone: soft, buff; about	10.0	10.0

148. Measured along the south line of sec. 36, T. 9 N., R. 7 E.

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*Ibid.

(Continue upward with No. 136)

Nellie Bly

Shale: mostly covered	75.0	299.0
Sandstone: buff, massive; occasional lenses of chert conglomerate with pebbles up to maximum diameter of three inches; thin beds of shale; about	26.0	224.0
Shale: mostly covered	15.0	198.0
Sandstone: buff, contorted, silty; about	12.0	183.0
Shale:	28.0	171.0
Sandstone: soft, friable; poorly exposed but caps cuesta	15.0	143.0
Shale: covered	15.0	128.0
Sandstone: very soft, faint ledge-maker	11.0	113.0
Sandstone: buff, massive)locally a	(7.0	102.0
Shale: green)single con-	(4.0	95.0
Sandstone: buff, massive)glomeratic)ledge	(5.0 (	91.0
Shale: black; forms wide valley; about	80.0	86.0
Sandstone: soft, buff, fine grained; about	6.0	6.0

(Continue downward with No. 130)

136. Measured along the west line of sec. 36, T. 9 N., R. 7 E.

(Continue upward with No. 84)

Hilltop

Shale: silty	16.0	120.0
Siltstone: or very fine sandstone; massive at the base, thin-bedded at the top; locally limy and hard	5.0	104.0
Shale: mostly covered	51.0	99.0
Siltstone: or very fine grained sandstone	4.0	48.0
Shale: dark blue and calcareous; contains thin ledges of hard, dark blue, finely crystalline limestone	44.0	44.0

Belle City

Limestone: hard, blue, coarsely

crystalline; crinoidal; weather yellow	0.4	0.4

(Continue downward with No. 148)

84. Measured between secs. 19, 20 and secs. 29, 30, in T. 9 N., R. 7 E.

(Continue upward with No. 225)

Vamoosa (upper and middle parts)		
Shale:	49.0	426.0
Sandstone: soft, thin-bedded, friable	10.0	377.0
Sandstone: thin-bedded, cross-bedded; chert flakes common	4.0	367.0
Shale: covered	65.0	363.0
Conglomerate: soft; pale chert pebbles up to two inches maximum diameter; harder and finer grained near top; thickens westward to 15 feet; ledge-maker	3.0	298.0
Shale:	21.0	295.0
Sandstone: very coarse, cross-bedded	18.0	274.0
Shale: multicolored	41.0	256.0
Sandstone: ("pink" member) buff; ledge-maker	16.0	215.0
Shale: silty	43.0	199.0
Sandstone: soft, buff	15.0	156.0
Shale:	21.0	141.0
Interval to base of formation; about	120.0	120.0

(Continue downward with No. 136)

132. Measured along the south line, sec. 25, T. 9 N., R. 7 E.

Hilltop		
Sandstone: buff, very fine grained	3.0	136.0
Shale:	14.0	133.0
Sandstone: buff, very fine grained	3.0	119.0
Shale: gray-green	44.0	116.0
Siltstone: white; may be very fine grained sandstone	5.0	72.0
Shale: silty	11.0	67.0
Siltstones: buff, friable, gently cross-bedded; alternating with light-colored shales; about	5.0	56.0

	Shales: light-colored	51.0	51.0
Belle City			
	Limestone: hard, blue, crinoidal; weathers yellow	0.4	2.7
	Shale: gray-green	2.0	2.3
	Limestone: pale gray, contorted, non-fossiliferous	0.3	0.3
Nellie Bly (upper part)			
	Shale: dark	38.0	
	Sandstone: dark brown, thin-bedded, fine grained; about	2.0	

213. Measured in the northeast quarter of sec. 31, T. 9 N., R. 6 E.

Vanoss			
	Interval to top; not detailed; about	170.0	236.0
	Sandstone: hard and white where limy; elsewhere buff	10.0	66.0
	Shale: red	9.0	56.0
	Sandstone: soft, buff	13.0	47.0
	Shale: red	22.0	34.0
	Sandstone: hard, white, limy	12.0	12.0

Township 10 North

153. Measured along the north line of secs. 14 through 18, T. 10 N., R. 8 E.

(Continue upward with Nos. 88, 94 and 98)

Hilltop			
	Shale:	15.0	162.0
	Sandstone: buff to red; very fine grained	5.0	147.0
	Shale: mostly covered	78.0	142.0
	Siltstone: buff	13.0	64.0
	Shale:	5.0	51.0
	Siltstone: buff	6.0	46.0
	Covered: (alluvium); about*	40.0	40.0
Nellie Bly			
	Covered: (alluvium); about*	34.0	389.0

*Sand Creek, which flows almost parallel with the

Sandstone: very fine grained; silty; poorly exposed but caps a pronounced cuesta; at least	5.0	355.0
Siltstone: very soft, shaly; locally white	95.0	350.0
Sandstone: buff	14.0	255.0
Shale: pale green; includes siltstone stringers	39.0	241.0
Sandstone: soft, buff, cross-bedded; oscillation ripple marks trend N. 40 E. to N. 50 E.; grades westward to 18 feet of sandstone over 20 feet of shale; about	38.0	202.0
Shale: blue gray; grades westward to 31 feet, so that this and above unit maintain relatively constant thickness; about	11.0	164.0
Sandstone: soft, buff to red; bar structure	38.0	153.0
Sandstone: very fine grained; thin-bedded; current ripple marks trend N. 10 W. to N. 15 W., with current from the northeast, and N. 60 E., with current from the southeast; grades westward to 10 feet of very coarse, unrippled sandstone; about	5.0	115.0
Shale: gray		
Interval to base of formation; about	110.0	110.0

88, 94, 98. No. 88, upper part of the Vamoosa formation, measured between secs. 8 and 17, T. 10 N., R. 7 E.
No. 94, middle Vamoosa, was measured between secs. 9, 10 and secs. 15, 16, in T. 10 N., R. 7 E.
No. 98, lower part of the Vamoosa formation, was measured along the south lines of secs. 10, 11 and 12, T. 10 N., R. 7 E.

(Continue upward with No. 234

Vamoosa

Shale: mostly covered	33.0	576.0

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strike, masks the contact at this point. The position of the contact has been calculated from adjacent measured sections; in adjacent areas, where exposed, much of the interval hidden here is siltstone or fine sandstone, buff, cross-bedded, contorted and relatively soft.

Sandstone: buff, very soft	4.0	543.0
Shale: mostly covered	33.0	539.0
Sandstone: hard, yellow to white, highly calcareous (40%); "Pawhuska"	2.0	506.0
Shale:	23.0	504.0
Sandstone: soft; contains few chert pebbles; faint ledge-maker	11.0	481.0
Shale: maroon	29.0	470.0
Sandstone: soft, brown to white, contorted	26.0	441.0
Conglomerate: soft; about	5.0	415.0
Shale: mostly covered	42.0	410.0
Sandstone: lens	8.0	368.0
Shale:	17.0	360.0
Sandstone: lens	9.0	343.0
Shale:	19.0	334.0
Sandstone: ("pink" member) buff; good ledge-maker	15.0	315.0
Shale: locally sandy	70.0	300.0
Sandstone: locally conglomeratic	23.0	230.0
Siltstone: and sandstone; soft, cross-bedded	31.0	207.0
Sandstone: soft, buff	3.0	176.0
Sandstone: very soft; locally shale	13.0	173.0
Shale: mostly covered	89.0	160.0
Conglomerate: buff; chert pebbles to two inches in diameter	7.0	71.0
Shale: includes sandstone and fine conglomerate lenses	10.0	64.0
Sandstone: cross-bedded; locally conglomeratic; some shale	5.0	54.0
Shale: covered	6.0	49.0
Conglomerate: chert cobbles in buff sandstone matrix	13.0	43.0
Interval to base of formation; about	30.0	30.0

(Continue downward with No. 153)

234. Measured along an east-west line, from the southwest quarter of sec. 8 T. 10 N., R. 6 E., to the southeast quarter of sec. 7, T. 10 N., R. 7 E.

Vanoss

Shale: mostly covered	65.0	147.0
Sandstone: almost white; silty	14.0	82.0
Shale: silty	55.0	68.0
Sandstone: pale; limy; locally conglomeratic (i.e., in the southeast		

quarter of sec. 14, T. 10 N., R. 6 E.); about	13.0	13.0
Ada		
Shale: pastel shales, multicolored	152.0	162.0
Sandstone: buff, massive, locally contorted; contains occasional lenses of chert pebble conglomerate; about	10.0	10.0

(Continue downward with No. 88)

144. Measured along the east-west line between T. 9 N., and T. 10 N., in R. 8 E.

Vamoosa (lower part)		
Conglomerate: buff; chert cobbles up to 3½ inches in diameter	6.0	99.0
Shale: mostly red; much of it covered	44.0	93.0
Siltstone: very soft	10.0	49.0
Sandstone: silty	3.0	39.0
Shale:	26.0	36.0
Conglomerate: buff; chert cobbles up to 5 inches in diameter; not conglomeratic to the west; about	10.0	10.0
Hilltop		
Shale: red	120.0	158.0
Sandstone: soft, buff, friable, fine grained	5.0	38.0
Siltstone: sandy; locally hard; includes Belle City horizon near the base; not separable, lithologically, from underlying siltstone in the Nellie Bly; contorted; about	33.0	33.0
Nellie Bly		
Siltstone: sandy; locally hard; not separable, lithologically, from overlying siltstone in the Hilltop; contorted; about	30.0	362.0
Conglomerate: soft, buff; chert cobbles up to four inches in diameter; good cuesta cap; about	15.0	332.0
Shale: red	50.0	317.0
Sandstone: buff, very fine grained	10.0	267.0
Shale: mostly covered	26.0	257.0

Siltstone: buff, massive	5.0	231.0
Shale:	28.0	226.0
Sandstone: cherry red, hard; hematite cement; caps hill; color varies, locally, to bright purple	10.0	198.0
Shale:	27.0	188.0
Sandstone: cherry red to purple; hematite cement	2.0	161.0
Shale:	22.0	159.0
Sandstone: soft, buff to light red	11.0	137.0
Shale: alternating with soft siltstones	33.0	126.0
Siltstone: soft, buff	10.0	93.0
Shale:	5.0	83.0
Sandstone: soft, buff	17.0	78.0
Shale: gray-green	60.0	61.0
Siltstone: soft, buff, thin-bedded	1.0	1.0

156. Measured westward from the northeast corner of sec. 5, T. 10 N., R. 8 E.

Hilltop

Shale:	16.0	208.0
Siltstone: soft, buff	12.0	192.0
Shale: mostly covered	65.0	180.0
Sandstone: soft, buff to almost white, very fine grained	12.0	115.0
Shale: very dark, calcareous	103.0	103.0

Township 12 North

209. Measured along the south line of secs. 26 and 27, T. 12 N., R. 8 E., in Okfuskee County.

Barnsdall

Shale: red; silty, especially in the middle	109.0	111.0
Sandstone: very fine grained; laminated	2.0	2.0

Chanute

Shale:	25.0	27.0
Limestone: hard, yellow, locally silty, crinoidal	2.0	2.0

Dewey

Shale:	6.0	21.0

Siltstone: or very fine sandstone; buff	1.0	15.0
Shale:	10.0	14.0
Limestone: sandy limestone or fairly hard buff siltstone	4.0	4.0
*Lowest Hilltop		
Shale:	26.0	
*Belle City equivalent ?		
Limestone: hard, silty; weathers yellow and brown	1.0	
Nellie Bly		
Shale:	18.0	
Sandstone: pale or buff; very fine grained; this is the No. 12 sandstone of Ries (1951); about	10.0	

*If the Dewey is considered the equivalent of the Belle City, these two intervals must be placed in the upper Nellie Bly formation.

Summary

Summary of measured intervals across the Vanoss and Ada formations:

Measured Section Number	Vanoss	Ada	
234	147	162	(North)
232	140	138	
225	180	154	
231	202	-?-	
230	264	219	
229	324	243	
221	440	---	
24	---	210	
216	450*	160	
215	415	155	
214	433	160	(South)

*This measurement can be interpreted as high as 550 feet, but 450 seems to be a more reliable figure.

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