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Scope of Study: A teaching schedule for a one-year course of study in physical and historical geology is outlined by topics showing the approximate amount of time which can be spent to adequately cover each of the subjects, yet finish the course in the allowed time of two semesters. Following this is a brief description of the overall geology of the state of California; then, a detailed study of the geology of northern California in the vicinity of the college where the geology course is to be taught. This area of approximately 20,000 square miles is bounded by the Pacific Ocean to the west, Oregon to the north, Nevada to the east, and includes parts of Del Norte, Humboldt, Trinity, Siskiyou, Shasta, Modoc and Lassen counties.

Conclusions: The report will aid in the planning of effective field trips for students of geology at the College of the Siskiyous and others interested in the geology of northern California.

ADVISER'S APPROVAL ______________________

A SCHEDULE FOR TEACHING GEOLOGY AT THE COLLEGE OF THE SISKIYOUS AND A SKETCH OF THE GEOLOGY OF NORTHERN CALIFORNIA

By

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A SCHEDULE FOR TEACHING GEOLOGY AT THE COLLEGE OF THE SISKIYOUS AND A SKETCH OF THE GEOLOGY OF NORTHERN CALIFORNIA

Report Approved:

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CHAPTER I

INTRODUCTION

The purpose of this report is two-fold. First, to outline a teaching schedule for a one-year course of study in physical and historical geology to be offered for the first time at College of the Siskiyous, a new junior college at Weed, in northern California. The curriculum has been expanded to include geology which the writer will teach starting September, 1961.

The second portion of this report is a survey of the geology of northern California, in the vicinity of the college, which will be used by the writer to familiarize himself with the area in order to plan effective field trips for his classes. This section describes the geology of northern California, an area of approximately 20,000 square miles. It is bounded by the Pacific Ocean to the west, Oregon to the north, Nevada to the east, and includes parts of Del Norte, Humbolt, Trinity, Siskiyou, Shasta, Modoc and Lassen counties. All of this area is within one hundred miles distance of the College of the Siskiyous, yet embraces parts of six different geomorphic provinces which differ markedly from the standpoint of topography, geologic history and mineral deposits.

A brief description of each of the geomorphic provinces of California as shown on the accompanying map (Figure 1) are given to familiarize the reader with the over-all geology of the state. This is followed by a more detailed discussion of the report area which is outlined in red on the map.

Figure 1

Map showing the relation of the report area to the major geomorphic provinces of California

Underground Water	1-1/3 weeks
Glaciation.	1-2/3 weeks
Deserts and Wind.	1 week
Oceans and Shorelines	1-1/3 weeks
Lakes and Swamps.	1/3 week
Rock Deformation and Mountain Building. . .	1 week
Metamorphism and metamorphic rocks.	1/3 week
Earthquakes	1/3 week
Earth's Interior.	1/3 week
Economic geology.	1 week

Laboratory work during the first semester

Minerals and Rocks.	5 weeks
Field Trips	7 weeks
Maps.	5 weeks

Second Semester - Historical Geology

Text

"Historical Geology" by Carl O. Dunbar, Second Edition, 1960, John Wiley and Sons, New York.

Subject	Time
Selected subjects from physical geology . . .	2 weeks
Earthquakes	
Earth's Interior	
Elementary Structural geology	
Principles of Historic Geology.	2/3 week
Geologic Time Scale	2/3 week
Fossils	2/3 week
Evolution	2/3 week
Origin of the Earth	2/3 week
Pre-Cambrian History of the earth	1 week
Cambrian Period-beginning of Paleozoic era.	1 week
Ordovician Period	2/3 week
Devonian Period	2/3 week
Mississippian Period.	2/3 week
Pennsylvanian Period.	2/3 week
Permian Period-end of Paleozoic era	2/3 week
Triassic Period-beginning of Mesozoic era .	2/3 week
Jurassic Period	2/3 week
Cretaceous Period-end of Mesozoic era . . .	1 week
Cenozoic Period and Era	1-1/3 weeks
Ice Age	2/3 week
Mammals Inherit the Earth	1 week
The Coming of Man	2/3 week

Laboratory work during the second semester

Structural geology.	2 weeks
Fossils	3 weeks
Geologic maps	2 weeks
Sequence of events.	3 weeks
Field trips (including a museum visit).	7 weeks

The first two weeks of the second semester will be a continuation of physical geology. The topics of earthquakes, elementary structural geology and the interior of the earth which were only mentioned during the first semester will be discussed in more detail.

The principles of historic geology, such as the natural laws of superposition and that life has continuously evolved leaving fossil records which succeed one another in a definite and determinable order, methods of correlating formations in separate outcrops and of determining the age of outcrops will be discussed during the introductory few weeks of historical geology. The history of the earth and of organisms will be discussed during the remainder of the term. The study of each geologic period will include consideration of the physical history of the world with emphasis on North America; climate, stratigraphic record, economic resources and life of the period.

CHAPTER III

SUMMARY OF THE GEOMORPHIC PROVINCES OF CALIFORNIA

The Great Valley

The Great Valley or central alluvial plain, about 50 miles wide by 430 miles long, lies between the Sierra Nevada and the Coast Ranges. The northern part, called the Sacramento Valley, is drained by the Sacramento River, while the southern part called the San Joaquin Valley is drained by the San Joaquin River. The two rivers join where they enter the San Francisco Bay. The eastern border of the Valley is formed by the west-sloping Sierran bedrock surface which continues westward beneath the alluvium and older sediments of the valley floor. The western border of the valley is underlain by east dipping Cretaceous and Cenozoic strata, which form a deeply buried synclinal trough. The axis of this syncline lies close to the western side of the valley. The valley contains a basin of interior drainage at its southern end. Great oil fields follow the anticlinal uplifts which mark the southwestern border of the San Joaquin Valley and its southern basin. The northern Sacramento Valley plain is interrupted only by Marysville Buttes which are eroded remnants of an isolated ancient volcano.[1]

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[1] Hinds, N. E. A., 1952, Evolution of the California landscape. California Div. Mines Bull. 158, 240 p.

Sierra Nevada

The Sierra Nevada is a singular, tilted fault-block nearly 400 miles long and 70 miles wide in middle-eastern California. It has a high steep fault-scarp face along the eastern front in contrast to a gentle two degree slope on the western flank which disappears under the sediments of the Great Valley. The western slope is carved by deep river-cut canyons. The upper portions of these canyons, which cut through the massive granite of the higher Sierra, have been modified by glacial sculpturing forming such scenic features as Yosemite Valley. The high continuous crest line of the Sierras culminates in Mount Whitney whose elevation is 14,496 feet above sea level, the highest point in the United States. Glacial moraines and alluvial fans spread across fault rifts and dropped blocks along the eastern base of the range. Metamorphic bedrock containing gold-bearing veins predominate the western slope of the Sierras. The southern Sierra boundary is determined by the Garlock fault which also forms the northern border of the Mojave Desert. The San Andreas fault forms the boundary between the southwestern tip of the Sierra and the Southern Coast Ranges.

Cascade Range

The Cascade Range is a chain of volcanic cones extending through Washington, Oregon and the northern part of California. In California the dominating feature of this range is Mt. Shasta, a glacier-mantled volcanic cone with an elevation of 14,162 feet above sea level. The range is terminated on the south by Lassen Peak, which is the only active volcano in the United States. The Cascade Range is transected by deep canyons of the Pit River which begins on the Modoc Plateau, and flows through the range between Mount Shasta and Lassen Peak on its way to the Sacramento River.

Modoc Plateau

The Modoc Plateau is a wide platform of land with an elevation ranging from 4,000 to 6,000 feet above sea level. It consists of thick accumulations of flat-lying lava flows, tuff beds and numerous small volcanic cones all of Cenozoic age. There are a few north-south faults in the plateau as well as occasional lakes and marshes, and sluggishly flowing tributaries of the Pit River. The province is a continuation of the vast Columbia Plateau lava region of eastern Oregon, Washington and southern Idaho. It is bounded indefinitely by the Cascade Range on the west and by Basin-Ranges on the east and south.

Klamath Mountains

The Klamath Mountains show a complex and rugged topography. The eastern part of the province is higher than the western. The prominent peaks and ridges are 6,000 to 8,500 feet above sea level. The entire mountain mass has been cut through by the Klamath River which follows a transverse and irregular drainage pattern, suggesting development on an uplifted plateau. The area has successive benches with gold-bearing gravels on the sides of the canyons. This province is more closely allied to the Sierra Nevada Range than to the Coast Ranges, as shown by the hard pre-Cretaceous rocks exposed by dissection. The province continues into Oregon. It is bounded by volcanic rocks of the Cascade Range on the east, Cretaceous sediments on the Great Valley on the southeast and by the younger Coast Ranges on the southwest.

Coast Ranges

The Coast Ranges province is a system of parallel ridges with a 30 to 40 degree northwesterly trend. The altitudes of the ranges are commonly 2,000 to 4,000 feet, but occasionally reach 6,000 feet with the highest peaks in the extreme south. The Coast Ranges province is divided by the partly below-sea-level San Francisco Bay area into two parts--northern and southern. Sedimentary rocks of Cenozoic and later Mesozoic ages predominate, but there are some volcanics. Still older plutonic and/or metasedimentary rocks occupy considerable areas in the southern Coast Ranges. Strong folding and much faulting characterize the whole province. The great San Andreas fault-zone cuts through the province diagonally at a low angle for hundreds of miles. Displacement during the 1906 earthquake was horizontal along this fault with the coast side moving northward. Two other important faults -- Hayward and Sunol -- in the San Francisco Bay area are branches of the San Andreas fault. The province is terminated on the east where the strata dip beneath the alluvium of the Great Valley; on the west by the Pacific Ocean; on the north by the Klamath Mountains, and on the South by the Transverse Ranges.

Transverse Ranges

This is a complex series of high mountain ranges and valleys distinguished by their dominant east-west trend in contrast to the northwest-southeast direction of the Coast Ranges and Peninsular Ranges which the Transverse Ranges separate. Subordinate structural trends (NW-SE and NE-SW) are significant in the formation of important oil fields in Santa Barbara, Ventura and Los Angeles counties. One of the thickest Cenozoic sedimentary sections in the world is found in this area. The western limit of the province includes the islands of San Miguel, Santa Rosa, and Santa Cruz, while the eastern limit extends within the Mojave Desert and includes the San Bernardino Mountains which lie to the east of the San Andreas fault, and are offset several miles from the western portion of the Transverse Ranges. The trend of the San Andreas fault as it passes through the Transverse Ranges is N60^{o}W, a change of more than 20^{o} in direction from its alignment in the Coast Ranges. The western part of the province consists mainly of Cenozoic and Mesozoic strata, together with some volcanics, all of which are much folded and faulted. The eastern, San Bernardino portion of the range consists largely of pre-Cretaceous igneous and metamorphic rocks.

Peninsular Ranges

This province is a series of ranges separated by longitudinal valleys trending NW-SE which have developed by erosion along the San Jacinto and Elsinore faults, representing active branches of the San Andreas system. The trend of the topography is like that of the Coast Ranges, but the geology is more like that of the Sierra Nevada. The dominating rocks being granitic, intruded into metasedimentaries of pre-Cretaceous age. Cenozoic strata, however, are well-represented on the seaward side of the province. This province includes the Los Angeles Basin and the off-shore islands of Santa Barbara, Santa Catalina and others. The Peninsular Ranges province continues into Lower California. It is bounded on the east by the Colorado Desert and on the west by the Pacific Ocean.

Colorado Desert

A large part of this wedge-shaped desert basin or depression, in southern California, lies below sea level. It is largely a sunken fault block, bounded by branches of the San Andreas fault system. Most of the basin floor is covered with thick allumium. The northern part is called the Coachella Valley, and the wider, southern part is the

Imperial Valley. Between these is the Salton Sea whose surface lies about 234 feet below sea level. The desert is characterized by ancient beach lines and silt deposits of extinct Lake Cahuilla.

Mojave Desert

This great, wedge-shaped, desert region of southern California is characterized by numerous hills, peaks, ridges, and short ranges separated by wide, arid basins. Altitudes vary from near sea level at the southwest to more than 7,000 feet in the northeast, most of the province being above 1,000 feet. Many of the basins contain playas or "dry lakes." Rocks of almost all kinds, ages and structures are well exposed. Faults are common and widespread. The San Andreas fault marks two long stretches of the southwestern boundary of the province, and the important Garlock fault bounds most of it on the northwestern side. These two faults meet at the western tip of the Mojave Desert wedge.

Basin-Ranges

There are three Basin-Ranges areas in eastern California -- a large one east of the Sierra Nevada, and two small ones in the northeast. These are western parts of the so-called Great Basin which extends eastward across Nevada and well into Utah. The Great Basin in characterized by a conspicuous series of nearly north-south fault-block mountain ranges separated by desert valleys or troughs which are mostly closed basins. Some of the basins contain lakes, but most of them have so-called "dry lakes" known as playas. No drainage from the Great Basin reaches the sea. Altitudes in the eastern California part of the province vary from 282 feet below sea level in Death Valley, lowest area in the United States, to 14,242 feet in the Inyo Mountains. Rocks of all important kinds and ages are found in the province.[2]

[2]Ibid., p. 7.

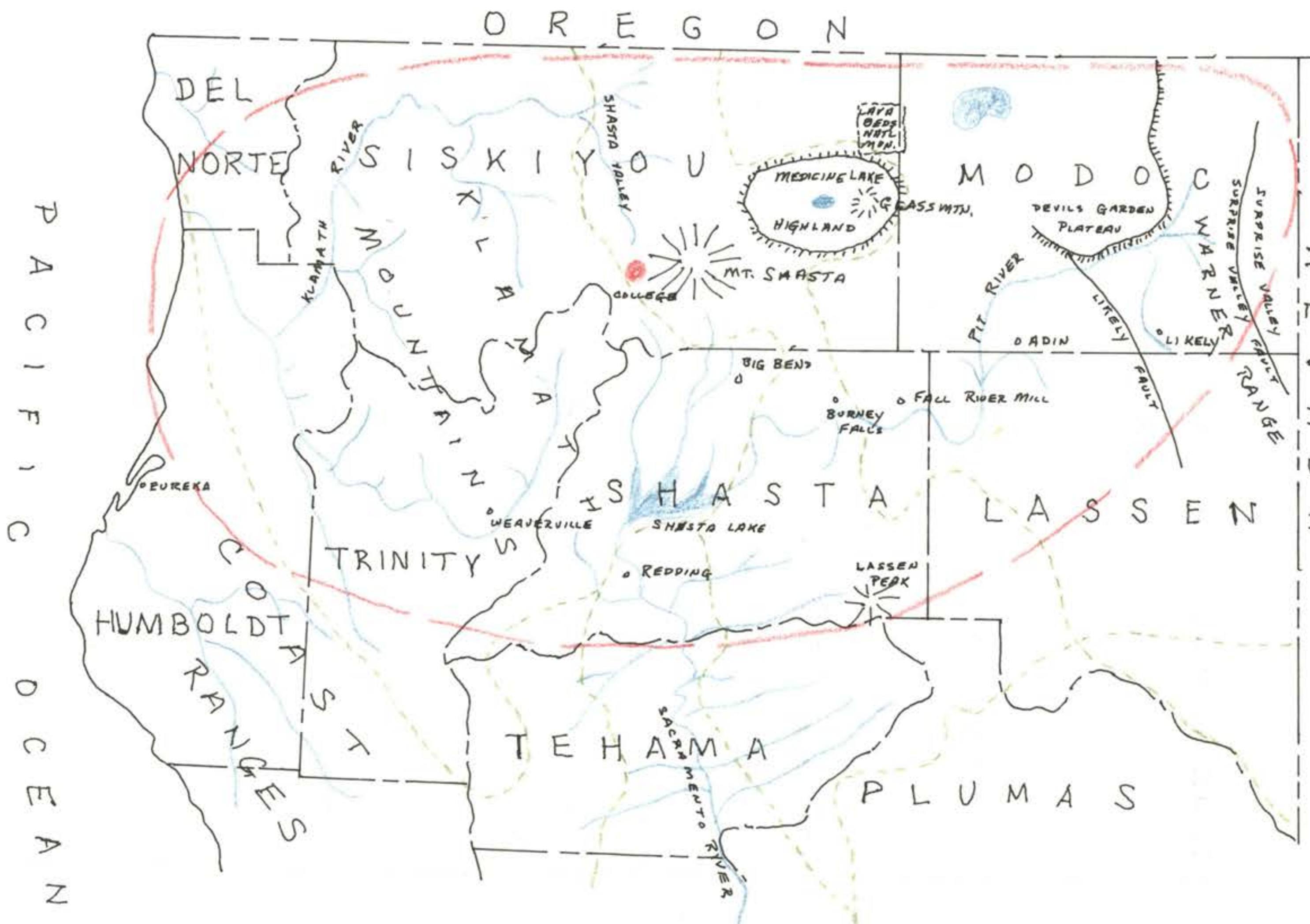

Figure 2. Map showing the area of northern California near the College of the Siskiyous

scattered meadows, glacial lakes and incised streams in summer, make the Warner Range an attractive feature in this otherwise rather arid corner of California. High in the central part of the range is the South Warner Wild Area, in which the flora, wildlife and alpine scenery are preserved in their original natural state. Large herds of mule deer and dense evergreen forests are found in the higher reaches of the west side, and near the crest of the range; by contrast, much of the steep, rocky east side of the range appears almost barren.

The range consists mainly of layered andesitic pyroclastic rocks--tuff, tuff-breccias, agglomerates--with intermingled andesitic flows. These rocks, which have been termed the Cedarville series, include Oligocene and Miocene units, and are the oldest known rocks in this eastern area.[2] There are older rocks in the Klamath mountain area to the west. In the northern end of the Warner range, near the Oregon border, a series of rhyolitic rocks is present as flows and shallow intrusions into the andesites; masses of obsidian also are present. In the southern portion of the Warner Range, and on its western flank, basaltic and andesitic flow rocks were poured forth in late Tertiary and Pleistocene time to cover large areas of the Cedarville rocks. Uplift of the Warner Range apparently began in mid-Tertiary time with a combination of arching, tilting and uplifting forces.

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[2]Russell, R. J., 1928, Basin range structure and stratigraphy of the Warner Range, northeastern California. <u>California Univ., Dept. Geol. Sci. Bull.</u>, vol. 17, no. 11. pp. 387-496.

Although faults bound the Warner Range on both sides, like the Sierra Nevada, the east scarp is conspicuously abrupt, whereas the western flank of the range slopes relatively gradually. Near the southern border of the area shown on Figure 2 (p. 15) decreased uplift of the Warner Range causes it to blend gradually with an irregular terrane of Pliocene shield volcanoes and intervening flat plains once filled with large Quaternary lakes, which extend for many miles south of the area described in this paper.

The Modoc Plateau province is characterized by extensive Tertiary and Quaternary basaltic lava flows, volcanoes and cinder cones. The principal plateau district, known as the Devils Garden, occupies nearly 1,000 square miles in the north central part of the area. Here, floods of olivine basalt formed a veneer from several tens to several hundreds of feet thick over the diatomaceous and ash-rich lake-and stream-laid sediments that are known as the Alturas formation.[3]

Much of the Devils Garden plateau is bordered by an abrupt cliff several hundred feet high, where the soft underlying Alturas sediments have been eroded away, leaving a broad valley. The edges of the basalt flows that cover the plateau surface form a conspicuous dark-colored rimrock at the top of the plateau-bordering cliffs. Diatoms and vertebrate fossils (mainly mouse teeth) found just below the rimrock indicate a late Pliocene to early Pleistocene age for

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[3]Powers, H. A., 1932, Lavas of the Modoc Lava Bed quadrangle. Am. Mineralogist, vol. 17, pp. 253-294.

these sediments; the overlying basalt flows are considered to be Pleistocene. In this relatively arid part of the area, the youthful lava plateau surface supports only a sparse vegetation, mainly of juniper trees and sagebrush. Parts of the plateau are covered with clusters of conspicuous circular soil mounds, from four to five feet high and from 30 to 40 feet in diameter. The mode of origin of these mounds is undetermined, but they are suspected of being at least in part caused by accumulation of wind-blown, ash-rich silt around clumps of vegetation.[4] Elsewhere on the plateau, somewhat older, and more deeply weathered Tertiary basalts are covered by deep soils and merchantable pine forests. Pronghorn antelope, only a few herds of which remain in North America, are occasionally glimpsed on the Devils Garden plateau.

To the south of the Devils Garden Plateau in the Modoc Plateau province, is a terrane of Tertiary basaltic and pyroclastic rocks, broken by normal faults into northwest-trending fault-block mountain ridges with large alluviated valleys intervening. Pleistocene stream and lakebed sediments as much as 1,000 feet thick occur in these broad valleys and are covered in turn by a veneer of Quaternary lakebed sediments. The fault-block ridges consist primarily of Miocene basaltic flow and pyroclastic rocks in which diatomaceous lake-laid sediments are locally abundant. An extensive series of Recent and Pleistocene basalt flows, that are more typical of the

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[4]Masson, Peter H., 1949, Circular soil structures in northeastern California. <u>California Div. Mines Bull. 151</u>, pp. 61-71.

Modoc lava plateau, separate this fault-block area from the Medicine Lake Highland and Cascade Range area to the northwest and west. In the north central portion of the Modoc Plateau area, the surface is modified by north-west and north-trending normal faults that divide the Tertiary and Quarternary lava surface into elongated blocks, with broad sediment-filled lake basins between.

To the west of Devils Garden, and ordinarily included with the Cascade Range province, is the isolated mountainous mass known as the Medicine Lake Highland, named after Medicine Lake, which occupies a central depression in the Highland.[5] This prominent region was apparently a shield volcano built up of andesitic lava flows in Pliocene time. Late Tertiary violent eruptive activity in the area was followed by a collapse of the central part of the mass, to form a caldera. Abundant eruptions of andesitic, basaltic, and rhyolitic lava flows and cones around the rim of the caldera in Pleistocene and Recent time accentuated the central depression, and, with minor modification by Pleistocene glaciers, are responsible for the present configuration of the Highland. Among the interesting rocks that are exposed in the Highland are extensive masses of pumice, scoria and obsidian. Perhaps the most spectacular body of obsidian in California is Glass Mountain at the northeast edge of the Highland, a recent flow of glassy gray to black rhyolitic obsidian, about a thousand years old.

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[5]Anderson, C. A., 1941, Volcanoes of the Medicine Lake Highland, California. <u>California Univ., Dept. Geol. Sci. Bull.</u>, vol. 25, pp. 347-422.

The flow is about a mile long, more than half a mile wide and more than 150 feet thick at its snout.[6] The toe of this tremendous mass of volcanic glass is an irregular heap of angular fragments, the larger of which weigh several tons. Several smaller "mountains" of obsidian occur in the central and western part of the Highland. More than 50 Recent volcanic cinder cones that range from barely perceptible mounds to perfectly formed cones nearly a thousand feet high are scattered around the top and flanks of the Highland. Most of the cones consist of reddish to black Recent basaltic cinders and scoria, but a few, like Pumice Stone Mountain, are mantled with a white blanket of fragmental pumice and pumiceite that was apparently explosively blown out of volcanic vents on the Highland, and settled over much of the adjacent landscape.

Just north of Medicine Lake Highland in the western extremity of the Modoc Plateau province, is Lava Beds National Monument, which comprises about 73 square miles of interesting and unusual features in the Quaternary basaltic lava flows ("Modoc basalt") that cover this region. The general Lava Beds surface slopes gently down to the northward, with local irregularities where cinder cones, explosion craters, chimneys, fault scarps, and individual lava flows are present. The Modoc basalt is generally a dark-colored, extremely rough-surfaced flow rock on which little or no soil or vegetation

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[6]Chesterman, C. W., 1955, Age of the obsidian flow at Glass Mountain, Siskiyou County, California. Am. Jour. Sci., vol. 253, pp. 418-424.

has formed. Some of the most recent flows appear to be less than a thousand years old. At least 12 prominent cinder cone buttes, that range from 50 to 700 feet high, are in the Monument. Mammoth Crater, the most spectacular of the several funnel-shaped explosion craters in the area, extends to 375 feet below the surrounding surface. Among the most recent features are the several groups of spatter cones, or chimneys, that were formed by the gradual accumulation of semi-molten lumps and clots of frothy lava around fumarole vents. These chimneys range from two to more than 50 feet in height, and from one to more than a hundred feet in diameter. Sinuous, log-like ridges which extend as far as several hundred feet from the bases of some of the chimneys, have hollow interiors and are in effect, miniature lava tubes formed on the surface. Small domes of lava, which range in diameter from two to about 20 feet, and which are believed to have formed as blister-like gas bubbles, occur at many places on the surface of the basalt flows.

Perhaps the most spectacular features of the Monument are the many caverns, or lava-tubes. Only where a tube, or tube-system, has a collapsed place in the roof is it accessible. Seemingly permanent ice beds occur in several of the caves; fossil remains of a mastodon and prehistoric camel were found in another. An astonishing variety of stalactitic forms ("lavacicles") occur on the walls and ceilings of many of the caves. Pictographs, stone artifacts, obsidian weapons, bones and human skeletons are evidence of Indian occupation of some of the caves.[7]

The structural features present in northeastern California are nearly all related to the north- to northwest-trending normal faults that may be traced through nearly all units that are older than Quaternary. Some idea of the probable magnitude of displacement of these faults is estimated from physiographic evidence, such as the height of the spectacular scarps that disrupt the lava surfaces and bound most of the fault blocks. The greatest visible displacement is the more than 5,500 feet of throw of the Surprise Valley fault. The fault-block mountains in the south central part of the area have scarps that indicate minimum vertical displacements of 500 to 2,000 feet. A number of sag-ponds and disrupted topographic features mark the position of the Likely fault, which trends northwest for about 40 miles from the south border of the map (p. 15) east of Madeline to the vicinity of Canby, and along which there has been major horizontal displacement. The Likely fault is named after the small town of Likely in the southeastern part of the area. Whether the Likely fault, or the abundant normal faults, continue northwestward beneath the Quaternary volcanic cover of the Devils Garden area is undetermined. The tilting of some of the fault block ridges down to the southwest is suggested by the

[7]Hinds, N. E. A., 1952, Evolution of the California landscape. California Div. Mines Bull. 158, pp. 109-115.

slope of land surfaces and the dip of layered rocks. Although dips as high as 30 degrees are not uncommon among the Miocene units, younger strata tend to be progressively less disturbed. Few folded structures have been recognized in the eastern area. A broad but gently folded anticline, which formed prior to the mid-Tertiary block-faulting in the Warner Range, trends north-northwest across the northern part of the range. Late Tertiary and younger strata partially conceal a parallel broad synclinal fold that lies adjacent to the southwest of this anticline.

Among the more interesting features of northeastern California are the extensive deposits of diatomaceous earth that formed in Miocene and Pliocene time. Conspicuous white outcrops of diatomite, inbedded layers, locally as thick as 25 feet, are seen along Highway 299. One of the most striking outcrops is at the Highway 299 crossing of Hat Creek. Pliocene diatomite of undetermined thickness and purity extends from this locality beneath a capping of Pleistocene basalt around the shores of Lake Britton. This diatomite unit may also be traced to the thin layers of diatomite exposed on the undercut cliff face of scenic Burney Falls in Burney Falls State Park. Pliocene diatomaceous beds, also of undetermined thickness or purity, occupy about 20 square miles along Willow Creek valley near the northwest corner of the state; here, too, the diatomite is capped by Pleistocene basalt flows. Miocene diatomite beds are extensively exposed west of Big Valley in the northern Big Valley Mountains, and at various places in the mountains northeast of Big Valley, as well as at scattered localities elsewhere in the area. Although prospect pits have been dug and samples from several localities have been analyzed, diatomite has not been produced commercially in this area.

Striking and unusual erosional forms, locally called "chimney rocks", are present in the tuffaceous beds of the Alturas formation and the Cedarville series in the far eastern part of the area. The chimney rocks, which have been noted in groups of three to a score or more in widely scattered localities, consist of remarkably regular conical mounds, reminiscent of beehive coke ovens, from five to 20 feet in diameter at the base, and 10 to 30 feet tall. They form only from massive, essentially homogeneous, flat-lying pumice lapilli tuff, or coarser pumice tuff-breccia, apparently as a result of wind and water erosion. Siliceous cementing material acts to harden the surface of these otherwise soft rocks; where this surface is breached, the wind scours deep hollows in the uncemented interior of the rock mass.[8]

A variety of plant and animal fossil remains has been found in different parts of the area. The smallest fossils are the microscopic diatom tests that comprise the Miocene, Pliocene and Pleistocene diatomite beds which are exposed in

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[8]California Div. Mines, Mineral Information Service, 1959, vol. 12, no. 6, pp. 5-7.

scores of localities scattered throughout the area. The largest animal fossil is the skull of a Pleistocene bison with horns which measured more than six and a half feet between tips that was found in a gravel deposit near McArthur. Other vertebrate fossils include a rhinoceros jaw of probable lower Miocene age found near Cedarville; mouse teeth of upper Pliocene or lower Pleistocene age found near Alturas; remains of camel, fox, peccary, horse, rhinoceros, unidentified carnivore, and mastodon types from the Pliocene Alturas formation near Alturas, and mastodon remains near Fall River Mill. Determinable leaf fossils include an Eocene flora from carbonaceous beds north of Big Bend; an abundant middle Oligocene flora from beds of the Lower Cedarville near Cedarville; middle Miocene flora from three localities between Adin and Canby; and a middle Pliocene flora from the Alturas formation near Alturas. Gastropods of upper Pliocene age have been found near Alturas and near Dorris. Petrified wood is widespread in the Oligocene and Miocene rocks exposed on the east face of the Warner Range; fragments of petrified logs, stumps and roots are especially abundant about two miles east of the range crest northwest of Eagleville. The state of preservation of many of the fossils found in this area is excellent, and from the abundance of types found, and ages represented, it appears possible that further work may yield a rather complete record of Tertiary life in this area.[9]

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[9] Ibid., p. 25.

North - Central California

A characteristic feature of the Cascade Range in north-central California is the occurrence of numerous volcanic cones ranging in size from very small ones to others which rise thousands of feet above the general level of the country. Cones made of basalt have broad gentle slopes; those formed of andesite lava are distinctly steeper. These have all been built largely or wholly in Quaternary time, some of them late in that period. Most outstanding of the volcanic cones are Lassen Peak and Mt. Shasta. The College of the Siskiyous is located at the base of Mt. Shasta.

Mt. Shasta is the supreme peak of the range in the state standing 14,161 feet. It is made up of irregular layers of lava alternated with fragmented volcanic material.

Viewed from the east, Shasta appears to be a single mountain, but from other positions it has the form of a double cone, for a small volcano, Shastina, rises boldly from its western side. Shasta, like many volcanic giants similarly constructed, has rather gentle slopes near the base while its upper part becomes increasingly steep. This slope change is caused primarily by the difference in fluidity of the earlier and later lavas; the later lavas, being much more sticky when erupted than were the earlier, formed shorter, thicker flows which piled up around the central vent making terraces ending in steep, high steps. River and glacial action have added their effects, for above 8,000 feet there has been deep erosion while below 5,000 feet much deposition by streams, gravity streaming and glaciers has aided in reducing the slope.

Besides the two main cones, there is a line of small cinder cones and plug domes located along a north-south fracture traversing the summit of Shasta and a very prominent plug dome, Black Butte, which rises more than 2,500 feet above the western base of the mountain. Lava flows of rather late date have been erupted along the base of the volcano.

Although the main volcano appears to be deeply scarred by erosion, actually it has been marred very little for the deepest canyon, that of Mud Creek, cuts only 1,500 feet into it. Thus a small part of the structure of the cone is visible. That part is composed very largely of lava flows, layers of exploded fragments being relatively few. Of the latter, the most abundant exposures are in the walls of Mud Creek Canyon. The last explosions of Shasta came from the summit vent and produced the Red Banks, a deposit of pumice mantling the cirque heads on the south side of the peak. The crater of the volcano lies beneath a snowfield about 200 yards across. At the margin of the snowfield is a small hot spring.

A view of Shasta from the west shows a broad, low cone rising from its long southern slope. This appears to be a miniature shield volcano of the Hawaiian type, surmounted by remnants of a cinder cone. The lavas composing the main part of this volcano were very liquid when erupted and spread over a wide area even though the slopes they traversed were quite gentle. Most of the flows went southward though one was partly diverted to the north and changed the course of Panther Creek. The longest outpourings from the shield volcano descended the canyon to the Sacramento River for more than 40 miles as long, narrow tongues. The river has cut through the flows, exposing in some places gravels that lay in the bottom of the canyon when the lava invaded and in others the bedrock into which the Sacramento had cut its canyon. Excellent sections of these flows may be seen at Shasta Springs where Mossbrae Falls pours out in great volume much of the underground water coming from Mount Shasta and at other places farther down the canyon. This water is heavily charged with mineral salts.

The main cone of Shasta seems to have attained its present elevation before the large minor cone, Shastina, began to form. It is possible that an east-west fissure developed about the same time as the north-south one earlier described, the two intersecting at the top of the volcano. The first eruptions along this east-west fracture built a small cone about a mile and a half west of the summit of Shasta, and somewhat later Shastina began at a second vent a half mile farther west. Until late in its history, Shastina was constructed from short, quite viscous flows which issued from a single vent, but the last principal eruptions came from fissures which opened on the west side of the cone.

The almost perfectly preserved summit crater of Shastina is a bowl-shaped depression about 300 feet deep and half a mile in diameter. Within it are two more or less conical mounds which may be plug domes with much broken tops. In the western side of the crater is a deep breach and below this lies a huge V-shaped gash; possibly both of these features resulted from violent downward directed explosions accompanying the elevation of the domes within the crater, a not uncommon feature at volcanic mountains.

Later explosive eruptions occurred at lower elevations, most of them centering about 3,000 feet below the rim of the Shastina crater, though activity progressed westward so that some occurred 7,000 feet below or at an elevation of about 5,000 feet above sea level. Dark flows of blocky lava also poured from the fissures covering a considerable area; the longest descended almost to the present town of Weed on Highway 99. These recent flows cannot be more than 200 years old.

Rising conspicuously near Highway 99 not far from the town of Weed is the prominent eminence known as Black Butte whose summit stands about 2,500 feet above its surroundings. From some places the Butte appears to be an almost perfectly conical mountain, but elsewhere this form is seen to be modified by a series of arcuate ridges from 200 to 1,000 feet below the top and located on the northwest side. The diameter of Black Butte is about a mile and a half. The whole of it appears to be made of great blocks of lava which become larger toward the top, only a few crags of coherent rock being visible.

The common belief is that this mountain is a volcano like

Cinder Cone of Lassen Park and various others, but actually it is a plug dome very heavily mantled with talus. The core may be cylindrical in form with a diameter of little less than a mile. As the mass rose, cooling and contracting, it was heavily fractured and the great banks of talus formed. Field evidence shows that prior to the protrusion of this dome, explosive eruptions occurred, but whether a small cone was built has not been determined. Black Butte is one of the latest products of Shastan activity and its completion very likely took place in a few years, a striking contrast with the many thousands of years required for the building of Shasta.[10]

Glaciers today cover a very small area on Mount Shasta, about three square miles, whereas not far back in Pleistocene time ice apparently blanketed the entire peak. Of the valley glaciers, the Hotlum on the northeastern side is by far the largest, accounting for almost half the total extent of the ice. Bolam and Whitney to the west of Hotlum and Konwakiton on the south side of the mountain are the others. Hotlum glacier descends to an elevation of about 9,000 feet, the lowest point reached by any of the ice tongues; its maximum thickness is about 300 feet.

Evidence of the fairly late coverage of the volcano by ice is provided by the abundance of morainal deposits around the base. The glacial history is not well enough known to

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[10]Williams, Howel, 1932, Mount Shasta, a Cascade volcano. Jour. Geol. vol. 40, pp. 417-429.

determine whether there were various stages, though very likely such was the case as may be inferred from their existances farther north in the Cascade Mountains of Oregon, in the nearby Klamath Mountains, and in the Sierra Nevada.[11]

When the glaciers reached their maximum, they descended into Shasta Valley west of the peak, crossed it, and rose to a height of about 4,000 feet along the mountain slopes on the western side. On the southwest, the ice covered Quail Mountain probably was joined by other glaciers coming eastward from the Klamath Mountains. In the principal valley on the north side of Mount Shasta, the ice was probably at least 1,000 feet thick, while on the south it rose within 100 feet of the top of Red Butte as is proved by polished and striated rock. All but the highest points of Gray Butte were overwhelmed, as were the cinder cones, lava domes, shield volcano and probably Bear Butte farther south.

Especially fine glacial features are the great cirques on the southwest side of Mount Shasta and some of lesser magnitude on the east. The most perfect cirque is at the head of Cascade Gulch between Shasta and Shastina. There are well-preserved moraines in the cirque. Elsewhere high on the mountain good moraines are scarce except at the ends of existing glaciers, but there are some examples on the plateau southwest of Horse Camp. The road to the town of McCloud along the south base of the mountain cuts through a group of

[11] Hershey, O. H., 1903, Some evidence of two glacial stages in the Klamath Mountains of California. Am. Geologist, vol. 31, pp. 139-156.

side moraines, while in the canyons of Whitney and Bolam Creeks these deposits lie beneath recent flows of blocky lava.

In spite of the abundance of snow and ice on Mount Shasta, there are few large streams and these cease to flow during the winter; most of them are restricted to the north and east sides of the mountain. The cause of the scarcity of water is the porosity of the lavas and the glacial debris. The water sinks below the surface flowing underground to the base of the cone where it comes out in many good sized springs, notably on the south and southwest sides. The finest display is at Mossbrae Falls in the Sacramento Canyon.

Traces of avalanches are numerous at elevations of about 8,000 feet where the steep upper slopes gradually flatten out toward the mouths of cirques. Frost wedging apparently dislodges large masses from the highest ridges; in some cases they race over snowbanks increasing in volume as they go. One by the side of the trail up Mount Shasta near Horse Camp, occurring probably not more than 50 or 60 years ago, plowed a path half a mile long through tall timber.

Close to the southern end of the Cascade Mountains where they adjoin the Sierra Nevada, lies an area which has been set apart as Lassen Volcanic National Park.[12] This area

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[12] Williams, Howel, 1932, Geology of Lassen Volcanic National Park. California Univ., Dept. Geol. Sci. Bull., vol. 21, no. 8, pp. 195-385.

has many hot springs, geysers, boiling lakes, fumaroles and volcanic cones. Lassen Peak last erupted with numerous violent explosions during the years 1914 through 1917.

Northwestern California

On topographic maps of California, the Klamath Mountains are seen to be continuous with the northern Coast Ranges, but the two regions are treated as separate geomorphic provinces because of significant lithologic and topographic differences. The chief basis for defining the two provinces lies in a natural grouping of the principal rock units of each province with regard to intrusion by granitic rocks. The principal rock units of the Klamath Mountains range from early Paleozoic to middle Late Jurassic in age, and are intruded by granitic rocks. In the northern Coast Ranges the principal rocks range from Late Jurassic to Cretaceous in age, and there is little evidence that they have been intruded by granitic rocks. The principal rocks of both provinces, however, are intruded by abundant mafic and ultramafic rocks.

The drainage system of the northern Coast Ranges has a trellis pattern, with the major streams that rise within the area flowing northwestward to the ocean. This linear pattern contrasts sharply with the dendritic drainage pattern of the Klamath Mountains.

The Klamath Mountains are comprised of four concentric, arcuate belts that are concave to the east. From east to west the belts are (1) the eastern Paleozoic belt, (2) the central metamorphic belt, (3) the western paleozoic and Triassic belt and (4) the western Jurassic belt.[13] The formations of the eastern belt are undifferentiated Silurian and Ordovician rock, the Copley greenstone of Devonian age, and Kennett limestone formation of later Devonian age, and the Bragdon formation of Mississippian age which is composed of shale, siltstone, sandstone and congomerate. The metamorphic rocks of the central belt are mainly quartz-mica and hornblende schists of the Abrams and Salmon formations, and generally have been considered the oldest rocks of northern California with ages speculated to be pre-Devonian to pre-Cambrian. The western Paleozoic and Triassic belt includes mildly metamorphosed shales, sandstones, cherts, greenstones, and limestones which have very few, and poorly preserved fossils. The western Jurassic belt includes the slates and shales with interlayed mica schists and greenschist of the Galice formation of middle Late Jurassic age.

Sedimentary rocks of latest Cretaceous through Tertiary age occur in both the northern Coast Ranges and Klamath Mountains. They cover an extensive area underlain by the Jurassic and Cretaceous strata along the west side of the Sacramento Valley. In the Coast Ranges they are chiefly marine in origin, whereas in the Klamath Mountains and Sacramento Valley

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[13]Irwin, W. P., 1960, Geologic reconnaissance of the northern Coast Ranges and Klamath Mountains, California. <u>California Div. Mines Bull. 179</u>, pp. 20-30.

they are mainly continental.

None of the older rocks of the Klamath Mountains are well known; there has been little work done in this area, much of which is still unmapped.

Rocks of Quaternary age cover only a small percent of Northwestern California. They include valley fill, coastal and river terrace deposits, landslide debris, glacial deposits, and beach and dune sands. Some of the terrace deposits are as high as 400 feet above the present streams, and more than 100 feet thick. During the early days the terrace and stream gravels were mined extensively for placer gold. Owing to their economic interest they were studied along the upper reaches of the Trinity River by Diller, who referred to them as auriferous gravels.[14] One deposit a few miles south of Weaverville, underlies a terrace 175 feet above the Trinity River. The upper 115 feet of the deposit is reddish, poorly stratified clay, sand and gravel. It is underlain by 19 feet of blue gravels, sand and clay with a thin carbonaceous layer near the base. Fossil bones and shells are associated with the carbonaceous layer, and indicate a Pleistocene age. The bones are of mammoths, deer and ground sloths, while the shells are similar to those of living fresh-water species.

Alpine glaciers formed at many places in the Klamath Mountains and in an adjacent small area of the northern

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[14] Diller, J. S., 1911, The Auriferous gravels of the Trinity River basin, California, U. S. Geol. Survey Bull. 470, pp. 11-29.

Coast Ranges, but none are now present. Evidence of the former presence of glaciers is at most places topographic, but deposits of glacial debris are found at some places. In many of the higher mountains, cirques, bedrock basins, marshy meadows and U-shaped valleys are common features of the landscape.

Volcanic rocks are not found in the Klamath Mountains, although they are abundant in the Cascade Ranges adjacent to the east, and to a lesser degree in the Coast Ranges to the south and west.

Landslides are abundant features in much of northwestern California, particularly in the Coast Ranges. They are most common and widespread throughout the central belt of Franciscan formation where they are perhaps the foremost mode of degradation of the landscape. Although many of the landslides are measurable in terms of square miles, few are shown on the geologic map.

Granite rocks are exposed over many hundreds of square miles in the Klamath Mountains province, but are not known in the northern Coast Ranges. In the Klamath Mountains the granitic rocks are widely distributed as batholiths, and are found within all of the principal areas of stratified rocks of pre-Cretaceous age. In the southern half of the province the granitic rocks occur in two rudely defined belts that reflect the Klamath Mountains arc. The eastern belt of granitic rocks includes the Shasta Bally batholith at the southern end as well as other batholiths and smaller plutons northward along the central metamorphic belt, and the eastern Paleozoic belt. The western belt of granitic rocks is chiefly in the western Paleozoic and Triassic belt. The largest body of granitic rocks of the western belt extends northwesterly from Hayfork Valley about 50 miles and is referred to as the Ironside Mountain batholith. This batholith is remarkably elongate and is the largest single area of granitic rocks exposed in the Klamath Mountains province. The granitic rocks of the western belt are chiefly hornblende diorite, whereas those of the eastern belt are chiefly quartz diorite and granodiorite. In the northern half of the province granitic rocks are not amenable to subdivision. The name Wooley Creek batholith is given to the area of granitic rock that is drained largely by Wooley Creek and that covers much of the Marble Mountains wilderness area in southwestern Siskiyou County. This batholith consists largely of quartz diorite that is rich in hornblende and biotite. Much of this area is poorly known.[15]

Ultramafic rocks are abundant in the northern Coast Ranges and Klamath Mountains provinces. Peridotite is the prevailing type of ultramafic rock. Pyroxenite and hornblendite are relatively uncommon. Most of the ultramafic rock has been altered to serpentine to a considerable extent.

The bulk of the northern Coast Ranges is carved out of

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[15]Irwin, W. P., 1960, Geologic reconnaissance of the northern Coast Ranges and Klamath Mountains, California. <u>California Div. Mines Bull. 179</u>, p. 80.

marine sedimentary rocks generally assigned to the Franciscan formation. This formation consists largely of graywacke, a type of sandstone made of unsorted angular mineral and rock grains that range in size from sand to clay. Most graywacke is gray to greenish gray on fresh surfaces, but is buff or brown when weathered. Because of its relatively high susceptibility to weathering, this rock does not tend to crop out prominently on natural slopes as do some of the less abundant rock types associated with it.

Other sedimentary rock types present in the Franciscan formation include black shale, radiolarian chert, conglomerate and a minor amount of limestone. The chert is a colorful rock composed essentially of very fine-grained quartz and crops out prominently because of its resistance to weathering. Most commonly it is found in sequences of thin beds, each an inch or so in thickness. Most Franciscan chert is brown, but some is green or white, and locally it is altered to red or yellow jasper. The unaltered chert normally contains abundant fossil remains of radiolaria, microscopic marine invertebrates that have siliceous skeletons, but unfortunately these have been of little value in dating the formation.

Interbedded with the Franciscan sedimentary rocks in many places are volcanic rocks that were emplaced largely as submarine lava flows. These are fine-grained rocks, and in most of them the ferromagnesian minerals have been altered to chlorite. The chlorite imparts a dull green color to the rocks and makes accurate identification of the original volcanic rock types difficult to determine in the field; as a result geologists usually refer to them as greenstone. However, laboratory study of specimens from numerous localities has revealed that most of these rocks were erupted as basalt. Chert and greenstone commonly occur together, the former having originated by precipitation of silica from sea water following the submarine eruptions. Greenstone, like chert, resists weathering and erosion more effectively than graywacke and shale, so it commonly occurs as bold, dark-colored outcrops on otherwise smooth, grassy slopes.

The nature of the Franciscan rocks indicates much regarding the environment of deposition. The unsorted character and angular nature of the clastic grains of the graywacke indicates very rapid and turbulent deposition into a rapidly sinking submarine trough. Occasional quiesence is indicated by the relatively rare accumulations of shale, and sporadic submarine volcanism by the widely distributed accumulations of greenstone and chert.

Neither the base nor the top of the Franciscan has been definitely recognized in the field, so its contact relationship and thickness can only be conjectured. It is generally accepted that the formation must be at least 25,000 feet thick, and it may be considerably thicker. Until recently, few significant fossils had been found in rocks assigned to the Franciscan in northern California, but now a number of localities have yielded fossils that range in age from Late

Jurassic to early Late Cretaceous.[16]

Flanking the Coast Ranges along the western margin of the Sacramento Valley is a sequence of wellbedded, fossiliferous sedimentary rocks that have had considerable influence on concepts regarding the age of the Franciscan. These are the Knoxville formation, of latest Late Jurassic age, and the overlying Paskenta and Horsetown formations of Early Cretaceous age, as well as some Late Cretaceous strata. This entire sequence, largely conformable, consists principally of dark gray silty shale with numerous thin beds of sandstone and some conglomerate beds. The oldest of these formations, the Knoxville, abuts against the major north-south fault that is considered the boundary between the Great Valley and Coast Ranges geomorphic provinces in this region. Over much of its length this fault is indicated by a long, narrow belt of highly sheared serpentine, and it separates schist and phyllite to the west from unmetamorphosed Knoxville shale to the east. The base of the Knoxville is not exposed along the fault, and the Knoxville and Cretaceous beds dip steeply to the east. The easterly dip of these sedimentary rocks away from the mountains has led to the concept that they once projected on over the Coast Ranges to the west, covering both the metamorphic rocks and Franciscan formation, and have subsequently been largely eroded away from the mountainous area. Thus the Franciscan

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[16]Ibid., p. 38.

was considered to be older than the Knoxville.[17] Certainly the largely massive Franciscan rocks are different in appearance from the well-bedded sediments of the Knoxville and Cretaceous formations of the Sacramento Valley sequence, but the similarity of the ages from Paleontological evidence of the rocks of the two provinces is not compatible with the concept of superposition of one over the other.

Recent work by Irwin and Bailey has yielded a probable explanation for these confusing relationships.[18] They present evidence that the sediments of the Franciscan formation were deposited contemporaneously with the Sacramento Valley sequence. The differences in the appearances of the rocks of the two sections are held to have been caused by different mechanisms of deposition within the north-south trough (geosyncline) in which the sediments accumulated. Accordingly, the well-bedded sediments of the Sacramento Valley sequence were deposited along the uniformly subsiding eastern margin of the geosyncline. Contemporaneously, the rapidly sinking central portion of the great trough, lying to the west, accumulated similar debris, but it was carried in by massive submarine landslides and turbulent currents originating along the break in submarine slope and was thoroughly mixed that it was deposited essentially without bedding.

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[17] Taliaferro, N. L., 1943, Franciscan Knoxville problem, Am. Assoc. Petroleum Geologists Bull., vol. 27, no. 2, pp. 109-219.

[18] Bailey, E. H. and W. P. Irwin, 1959, K-feldspar content of Jurassic and Cretaceous graywackes of the northern Coast Ranges and Sacramento Valley, California. Am. Assoc. Petroleum Geologists Bull., vol. 43, no. 12, pp. 2797-2809.

Also, the central and tectonically active portion of the geosyncline, approximately represented by the present outcrop area of the Franciscan formation, received sporadic volcanic eruptions that resulted in local accumulations of greenstone and chert.

By latest Cretaceous or earliest Tertiary time the great trough in which the Franciscan rocks accumulated was nearly filled, and orogenic forces were initiated that created a mountainous area from the thick pile of sediments deposited in the sea. Uplift was accompanied by compressive forces that resulted in northwest-trending folds and faults in the Franciscan. The Cenozoic history of the region is largely one of erosion of these rocks after they were raised above sea level, although there was periodic marine flooding of locally depressed embayments and seaways.

The structure of northwestern California is highly complex and poorly known. In both the Coast Ranges and Klamath Mountain provinces the strata most commonly dip eastward. In the northern Coast Ranges the principal structures appear to be northwest-trending strike-slip faults of the San Andreas system, and subparallel folds. The boundary between the Coast Ranges and western Klamath Mountains is a high-angle reverse fault that for much of its length is nearly parallel to the faults of the San Andreas system. The southern boundary of the Klamath Mountains province is a transverse fault that is aligned with major transverse faults in the Sacramento Valley and the Coast Ranges, and may be related tectonically to the Gorda submarine escarpment.[19]

Economic Mineral Resources

The Warner Range, near the Oregon line, has produced gold, silver and cinnabar. Salt from brines of the alkali lakes in Surprise Valley is used locally. There are extensive deposits of diatomite in the Modoc Plateau area, though none has been developed commercially. Peat moss is obtained in Jess Valley and shipped widely for agricultural purposes. Most of the remaining mineral products of northeastern California are forms of the volcanic rocks common to the area. Volcanic cinders and pumice are obtained for use in building blocks, as light-weight aggregate, railroad ballast and road material. Some sand and gravel is obtained from Quaternary terrace and stream wash deposits. Selected pieces of Glass Mountain obsidian have been cut and ground to optical specifications for use as telescope mirrors.

The northern Coast Ranges are not as rich in known mineral resources as most other geomorphic provinces of California. There are a few gas and oil wells in western Humboldt County. Manganese deposits are widely distributed in the region though most of these deposits are small.[20] A wide variety of other minerals are present, but not in commercial quantities.

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[19] Menard, H. W., 1955, Fractures in the Pacific floor. Scientific American, vol. 193, no. 1, pp. 36-41.

[20] Taliaferro, N. L. and F. S. Hudson, 1943, Genesis of the manganese deposits of the Coast Ranges of California. Calif. Div. Mines Bull. 125, pp. 217-275.

Nearly all the gold deposits in northern California are in the Klamath Mountains province; this province ranks second only to the Sierra Nevada in gold production in California. Both placer and lode deposits are plentifully scattered throughout the province. Platinum occurs in many of the gold bearing placer deposits and is recovered as a by-product. Nearly 4,000,000 fine ounces of gold have been recovered to date.

Numerous large deposits of chromite are found in Del Norte, Siskiyou and Shasta Counties. The mineral Chromite is the only important commercial source of chromium. Most of the production of Chromite has been from small high-grade deposits, averaging about 45% Cr_2O_3; however, when these are depleted there are massive disseminated deposits averaging ten to 12% Cr_2O_3 which can be mined profitably.[21]

Copper, silver, mercury and manganese have been mined commercially in the Klamath Mountain province. Other metals found in lesser quantities are antimony, iron, molybdenum, nickel, lead and tin.

Miscellaneous stone, including sand, gravel, crushed rock, limestone for cement and dimension stone including sandstone, marble and granite is by far the most important mineral commodity at present. These are used chiefly for construction purposes and presently account for over half of

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[21]Wells, F. G. and F. W. Cater, Jr., 1950, Chromite deposits of Siskiyou County, California. Calif. Div. Mines Bull. 125, pp. 217-275.

the dollar value of the total mineral production of northern California.[22]

Indirectly related to geology through soil, topography and climate is the production of trees; lumber provides the main economy of this area in northern California.

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[22]Wright, Lauren A., Ed. 1957, Mineral commodities of California. California Div. Mines Bull. 176, p. 736.

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