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THE GEOLOGICAL HISTORY OF EAGLE LAKE LASSEN COUNTY, CALIFORNIA

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Introduction, Previous Work and Acknowledgments

The principal objective of this paper is to attempt to portray the geological history of Eagle Lake.

My first interest in the geology of Eagle Lake stemmed from an examination of the obsidian deposits in California. The Sixth Annual Report of the State Mineralogist (Hanks, 1886, part I, page 125) states that in Lassen County "obsidian is found in great abundance on the east side of Eagle Lake, a mile more or less from Clark's Ranch." No obsidian was found, in place, there. Evidently, however, considerable obsidian was carried there by the Indians and used for making arrowheads, a great many of which have been gathered from the shores of the lake.

Another statement that attracted my attention was to the effect that Eagle Lake was classed as a "landslide lake," (Davis, 1933, p. 201; Hinds, 1952, p. 86). "The barrier forming it appears to be a landslide on the southeast side." The examination of the shores of the lake clearly suggested that the lake was barred on its southeastern side by the ancient rocks and flows of basaltic lavas rather than by a landslide.

A further search of the literature revealed that there are very few published data regarding the geology of the lake and the surrounding landscape. One of the first accounts of Eagle Lake is that of Lieutenant E.G. Beckwith (1854, p. 45-46). While exploring the "Noble Pass" route from Mud and Honey lakes, across the Sierra Nevada into California, Lieutenant Beckwith states "soon after leaving our morning camp (July 2, 1854) the road led over a high, rocky butte, from which we had a fine view of the lake a few miles to the northeast. It is several miles in extent and is set beautifully blue in the mountains, which rise from 500 to 1000 feet above it, covered with majestic pines. It has no outlet. We gave it the name of Eagle Lake." There is a difference of opinion as to the origin of the name. Some say it was named mistakenly after the osprey or fish-hawk which has a wide wing-spread and builds nests near the lake. Old timers, however, claim it was named for the eagles which were often and still are occasionally seen there.

Russell (1885), in his *Geological History of Lake Lahontan* does not mention Eagle Lake, California, but his map (p. 31-32) shows that lake to be a part of the same hydrographic basin including Honey Lake and other lakes of the Lahontan system. Diller (1907) presents a reconnaissance topographic and geologic map of the southern half of the Honey Lake quadrangle, just to the south of Eagle Lake. Although he does not mention the latter, some of his data are of value in the interpretation of the historical geology of Eagle Lake.

Farris and Smith's *Illustrated History of Plumas, Lassen, and Sierra Counties* (1882, pp. 398, 399) contains an interesting account of the early years of those counties. It describes an attempt to convey water from Eagle Lake (which now has no surface outlet) by means of a long tunnel, to the head of Willow Creek and thence down that creek to irrigate the semiarid lands north of Honey Lake. The project started in 1875 but was not completed until many years later. It proved to be ineffectual and had the bad result of lowering the lake about 30 feet.

Snyder (1917, pp. 34-41) states that Eagle Lake appears to have been connected at one time with Lake Lahontan, as it contains two channel or lacustrine species of fish that flourished in the ancient lakes. Kimsey (1954, p. 396) found that four of the five species of fish in Eagle Lake are of Lahontan origin. Hubbs and Miller (1948) called attention to a gravel beach about 60 feet above the 1924 level of the lake, at which time the irrigation project was no longer operative. Furthermore, Kimsey (1954, p. 396) states that "although the latest period of near desiccation was caused by the irrigation project, there is evidence that the lake had great natural fluctuations and has in the past reached a much lower level than at the present. Conversely, several much higher levels in the past are indicated by wave-cut terraces. The most definite of these is about 50 feet above the level of 1924. Other more indefinite terraces are situated about 30 feet higher than this, and sometime in the past, during periods of heavy precipitation, lake water may have flowed directly into Willow Creek."

Hanna (1924, pp. 30-38) gives a brief description of the lake and is the first to publish a good description of a number of mollusk shells which occur in great numbers on most of the beaches.

Probably the most recent article relative to Eagle Lake is that of Noble (Collier's, September 3, 1954). Under the caption "The Lake that Time Forgot," the author provides an entertaining account of the lake and the peculiar assortment of animal life, some of ancient lineage, which live in its waters or on its surrounding shores.

I wish to express my sincere appreciation for the counsel and assistance of Mr. Charles W. Chesterman of the California State Division of Mines and Geology (particularly in the identification and petrography of the rocks) and to Dr. G Dallas Hanna and Mr. Allyn G. Smith of the California Academy of Sciences for the determination of the mollusks. Thanks are also due to Mr. Curley Dahl and to Mr. and Mrs. Samuel Webb who have homes at Spaldings on Eagle Lake, and who assisted in many friendly ways during the course of the field work.

Geography

Eagle Lake, one of the largest natural lakes in California, lies in an intermountain valley in the south central part of Lassen County, northeastern California, about 20 miles northerly of Susanville. It occupies a comparatively small, closed drainage basis of about 500 square miles and has a surface area of approximately 31 square miles. The lake is twelve miles in length and has an average width of about four miles. Elongated, in a roughly northeast-southwest direction, the lake has a very irregular shore line, the northern part of which is indented with several long basalt-flow peninsulas.

Pelican Channel, less than one-half mile across, divides the lake into nearly equal parts. The northern portion has an average depth of less than ten feet and is partly surrounded by a low, wide, sandy shoreline, in part covered with swamp grasses. South of Pelican Channel the lake is considerably deeper. Recent measurements made by Mr. Caldwell (oral communication, 1957) show that a large area of the southern part of the lake is uniformly 60 feet deep. More or less a quarter of a mile from the east shore, however, the bottom drops an additional 20 to 30 feet and then rises abruptly over what appears to be a sharp ridge that approximately parallels the east shore.

The principal tributary stream is Pine Creek, which flows into Delta Bay on the northwestern side of the lake. Several other short, intermittent streams flow into the lake, the largest of which are Merrill Creek and Papoose Creek on the southern end.

The configuration of the lake's shore-line is characterized by: (a) the low-sloping, sandy to loamy lands which extend from the southwestern tip northwestward around three-fourths of the shore-line except where abruptly broken by the rocky, narrow peninsulas on the north and northeast sides, and the low basaltic ridge that forms Pelican Point; (b) the steep, narrow shore along a four-mile segment on the extreme southwest and further to the east,

PLATE 1

(Upper figure) View southeast across Eagle Lake showing Black Mountain on the left and Gallatin Peak on the right.

(Lower figure) View at the southern end of Eagle Lake looking easterly across Gallatin Beach toward Gallatin Peak on the right and Black Mountain on the left.

where the steep western slope of Black and Gallatin peaks impinge on the shore-line on the southeastern side; and (c) the Gallatin sandy beach on the south shore.

Surrounding the present shore-line, there is conspicuous evidence that at times in the past the lake was considerably higher. Along the more gently sloping shores there are widespread beach sands, containing a myriad of mollusk shells. These beaches range from 25 to 35 feet above the present lake level and about 30 to 40 feet above this there are wave-cut terraces and lime encrusted rocks which indicate a long period of high waters. About one-half mile up from its mouth, Pine Creek cuts through a nearly pure deposit of diatomite, which is overlain by 15 to 20 feet of beach sands.

The terrain immediately surrounding the lake is varied. A low, sloping, crescent-shaped, basalt-covered area, nearly nine miles in length and four miles at its greatest width, makes up the western side. There is a rise of about 100 feet from the shore, at the crescent's greatest width, to the abrupt slope of Whale-back Mountain, which rises to an elevation of 6,696 feet above sea level, nearly 1,600 feet above the level of the lake.

To the north of the lake are the typical basaltic Modoc Plateau highlands, whereas, on the east and south, rough mountains with 7,000-foot peaks surround the lake except for a comparatively narrow gap on the eastern central side near the head of Willow Creek, a branch of Susan River which flows into Honey Lake. The lowest point in the gap is only 75 to 85 feet above the present level of the lake, and marks the location of a pre-existing outlet. There are large springs a little over one mile below the lake, which form the headwaters of Willow Creek. Nearly a mile south of the lowest part of the gap, and through a ridge of recent basalt that rises 250 feet above the lake, is the ineffectual water tunnel that connects the lake with Willow Creek.

General Geology

The Eagle Lake area lies in the southwestern corner of the Modoc Plateau geomorphic province (Jenkins, 1938, plate I). This province is characterized by a thick accumulation of lava flows, tuff beds, and many small volcanic cones. North-south faults are common and there are occasional lakes, marshes, and sluggish flowing streams. The southern Cascade Ranges, dominated by Lassen Peak, commence to rise only a few miles west of the lake and merge with the Sierra Nevada province a few miles farther south. A narrow triangular point of the great Basin Range province of Nevada, which includes Susanville and Honey Lake, separates the Modoc Plateau province from the Sierra Nevada just south of Eagle Lake. The latter province dominated by the great 400-mile-long fault block, with a steep rugged scarp on its eastern front and a gentle western slope, is marked on the north "where bed-rock disappears under Cenozoic volcanic cover of the Cascade Range" (Jenkins, 1938).

Viewed in a broad way the Eagle Lake area is perhaps more closely allied with the dominant geomorphic features of the Modoc Plateau than with the other provinces. However, it is a border province. Certainly most of the rock formation and physiography are like those of the Modoc Plateau but it imperceptibly merges with the Cascades on the west and with the Basin Ranges on the east and south. Furthermore, the topography about the lake shows a number of fault scarps and, bordering the southeast shore of the lake, on Gallatin Peak is an area of ancient plutonic igneous and metamorphic rocks (the latter probably Calaveras) which are identical in appearance with those of the Sierra Nevada province of the Taylorsville Region (Diller, 1908) a few miles to the southwest.

The same type of basin-range faulting, which characterizes the Basin Range province of which the Warner Range is a part, is found in the Eagle Lake area and continues to the north and northwest as far as the eastern flank of the Cascade Range. So except for the incidence of the widespread, recent fluid lavas which make up much of the Modoc Plateau, the Eagle Lake region could be considered a part of the Basin Range province; the area surrounding Mahogany and Gallatin peaks being a segment of the Sierra Nevada in a sea of basaltic lavas.

Geologic History

It may be advantageous to summarize the general sequence of geological events which took place in regions immediately surrounding the Eagle Lake area, to serve as a foundation for the more detailed presentation of geological data relating to the Lake area. See table 1.

The regions selected are parts of the geomorphic provinces previously discussed. Although the writer has on several occasions, visited the areas involved in this summary, he wishes to give full credit to Williams, (1941, 1949, Peacock, (1931), Powers, (1932), Anderson, (1933, 1941), Russell, (1928), and Diller, (1908), for data obtained from their publications.

Some of the geological events shown on table 1 which are particularly pertinent in a portrayal of the geological history of Eagle Lake, require a more complete presentation. Insofar as possible, this has been done chronologically. Millions of years, so far as we know, long before the birth of Eagle Lake, a part of what is now the complex of older rocks of the northern Sierra Nevada province extended northward at least into the southern half of the Eagle Lake area.

Figure 1. Geologic sketch map of Eagle Lake area including geomorphic provinces.

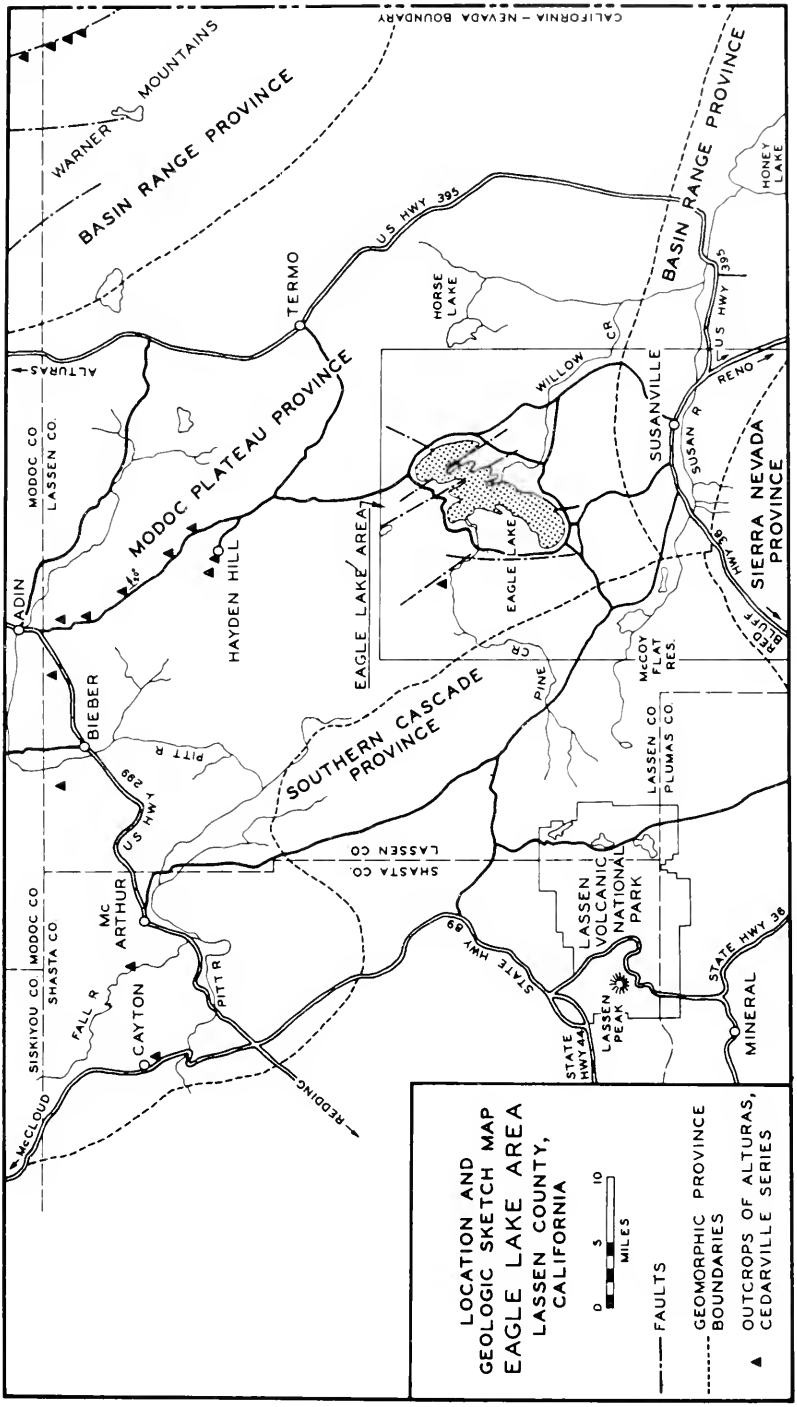

LOCATION AND
GEOLOGIC SKETCH MAP
EAGLE LAKE AREA
LASSEN COUNTY,
CALIFORNIA
0 5 10
MILES
FAULTS
GEOMORPHIC PROVINCE
BOUNDARIES
OUTCROPS OF ALTURAS,
CEDARVILLE SERIES
CALIFORNIA – NEVADA BOUNDARY
WARNER MOUNTAINS
BASIN RANGE PROVINCE
MODOC PLATEAU PROVINCE
SOUTHERN CASCADE PROVINCE
SIERRA NEVADA PROVINCE
BASIN RANGE PROVINCE
EAGLE LAKE AREA
EAGLE LAKE
HONEY LAKE
HORSE LAKE
TERMO
US HWY 395
ALTURAS
MODOC CO
LASSEN CO.
ADIN
HAYDEN HILL
BIEBER
PITT R
US HWY 299
MC ARTHUR
CAYTON
FALL R
McCLOUD
REDDING
SISKIYOU CO.
MODOC CO
SHASTA CO.
LASSEN CO
SHASTA CO.
WILLOW CR
SUSANVILLE
SUSAN R
RENO
RED BLUFF
PINE CR
McCOY FLAT RES.
LASSEN CO
PLUMAS CO.
LASSEN VOLCANIC NATIONAL PARK
LASSEN PEAK
STATE HWY 89
STATE HWY 44
STATE HWY 36
MINERAL

TABLE 1. *General Sequence of Geological Events in Eagle Lake Area*

Epoch *Duration*	Southern Cascade Ranges (1) *Shasta and Lassen Mts.*	Modoc Plateau *Eagle Lake*
Recent 10,000 to 20,000 yrs.	Post glacial time. Conclusion of volcanic activity on Mt. Shasta; Recent lava flows of Mt. Lassen. Shallow lakes and filling of lake basins; e.g. Shasta and Butte.	Extensive spread of lavas, and young basalt flows, one of which closed old outlet and raised level of Eagle Lake. Rhyolite and obsidian group of lavas; e.g. Glass Mountain.
Pleistocene 1 million years	Main period of building of Shasta, Lassen and many Cascade Mts. Glacial period, Early Pleistocene and Pliocene lavas of Shasta are glaciated; lacustrine deposits of Pleistocene and Pliocene age.	Building of main part of Modoc plateau, basalt and platy andesite flows. Block faulting* and formation of shallow lakes of Glacial period - Lahontan age. Early Eagle Lake, with sediments derived from granitic and older metamorphics.
Pliocene 10 million years	Early stages of growth of Mt. Shasta and high Cascade Mts. Climate becoming much colder.	Lacustrine deposits such as Tulelake, etc. is considered early Pleistocene or late Pliocene. Widespread block faulting*. Andesite flows, tuffs, Rhyolites, obsidian, massive Warner basalt.
Miocene Oligocene 29 million years	Faulting and extensive volcanic activity over much of northern California, Oregon and Washington.	Eagle Lake biotite-dacite. Earliest rocks of Modoc Plateau are tilted tuffs, pyroclastics, dense basalt flows and more acid intrusive rocks, approximately correlative with Alturas-Cedarville series; e.g. tuffs, etc. near Hayden Hill, Adin, etc.
Eocene 20 million years	Diastrophism and start of long period volcanic activity. Recession of tropical seas.	
Cretaceous and Older	Little volcanic activity. Shallow sea lanes cover much of region. Jurassic and older rocks south of Lassen.	Tertiary river gravels resting on granitic rocks (quartz diorite, and aplite) and older metamorphics, probably Calaveras near southeast end Eagle Lake.

(1) Williams, Howell (1941, p. 14)

BASIN-RANGES	NORTHERN SIERRA NEVADA
Warner Range	*Honey Lake and Taylorsville District*
Limited areas of vesicular basalt underlain by obsidian and rhyolite; e.g. Sugar Hill. Underlying basalt flows probably equivalent to the Modoc basalts.	Partial desiccation of Honey Lake. Block faulting and latter stages of volcanism. Basalt, andesite and dacite extrusions and tuffs.
Major part extensive block faulting completed.* Widespread lake basins of Lahontan. Summit areas of Warner Range are post glacial. General Glacial Period.	Basaltic and Andesitic flows. Some faulting. Lahontan Lakes; e.g. Honey Lake, widespread and attained depth of 325 ft. during Glacial Period. Continued uplifts and deformation of drainage pattern. Sinking of some blocks.
Deformation which produced Warner Range, Goose Lake. Surprise Valley was early Pleistocene or late Pliocene. Basalt flows: start of extensive block faulting* Andesite, rhyolite and older obsidian flows. Very extensive Warner basalts, probably late Pliocene.	About close of Pliocene, there were great uplifts and faulting, building the great Sierra Nevada. End of auriferous gravel deposition of northern Sierra Nevada.
Upper Cedarville andesites, tuffs and agglomerates. Middle Cedarville lavas, Lower Cedarville pyroclastics, non-marine sediments, Lower Miocene (Chaney, 1928). Middle Oligocene (Axelrod, 1949).	Continental deposits, rhyolite tuffs. Some faulting and folding. Andesitic breccias. Widespread deposition of Tertiary auriferous gravels.
Some volcanic activity. Mostly acid lavas.	Start of gravel deposition uplifts and faulting. Early Tertiary andesites.
	The great batholithic intrusion of granitic and related rocks. Jurassic, Triassic, Carboniferous (Calaveras) rocks and deformations.

*Footnote: The basin range and block faulting reached maximum development in different areas at different times.

The ancient rocks--Sierra Nevada Complex. Gallatin and Mahogany peaks on the southeast side of the lake are largely made up of quartz diorite, some aplite, and a belt of highly metamorphosed rock which outcrop on Deans Ridge east of Gallatin Peak. These latter rocks closely resemble those of the Calaveras formation (Carboniferous) of the Taylorsville District, twelve to fifteen miles to the south.

The quartz diorite so closely resembles the generally called granitic rocks of the Sierra Nevada that for the sake of convenience are hereinafter called granitic rocks. They are a light-colored holocrystalline, medium-grained rock, composed chiefly of plagioclase feldspar, quartz, dark-green hornblende, biotite, and a very little pyroxene. The aplites are a quartz diorite aplite. They too, are light colored, very fine grained and composed of an alkaline feldspar, quartz, and a few flakes of biotite.

There is also a small area of quartz diorite surrounded by later lava flows, about ten miles southeast of the Lake. Furthermore, just to the south of Susanville, great masses of grandiorite and quartz diorite are exposed for many miles along the base of the Honey Lake or Diamond Mountain block fault.

The granitic and metamorphic rocks of the Gallatin Peak area cover an area of a little less that five square miles. Their western edge is within one-quarter mile of the lake. Recent basaltic lavas have flowed completely around the older rocks, but it is probable that prior to the advent of the recent basaltic flows, the granitic rocks bordered the lake shore, at least on the southeast side. This is evidenced by the fact that all of Gallatin beach as far west as Pikes Point, which is a low point of basaltic rock, as well as the beaches along the east side of the lake as far north as the irrigation tunnel, are composed very largely of clean granitic sands. Furthermore, the tunnel is reported to have cut granitic rocks beneath the lava flow, and a number of fragments of granitic and metamorphic rocks were found on one of the dumps of material taken out from the middle section of the tunnel.

Cretaceous sediments occur west of the Modoc Plateau in the drainage of Pit River. Evidently, shallow Cretaceous sea lanes extended over parts of that area. There is, however, no evidence of these rocks in the Plateau region.

Tertiary river gravels. The auriferous Tertiary or Neocene river gravels, as they were formerly called, of the Sierra Nevada Province, outcrop extensively in the Taylorsville Region, some 15 to 20 miles south of Eagle Lake. They were deposited in an old Tertiary stream, called by Diller (1908, pp. 60-79) the Jura River. Millions of dollars in gold have been produced from these deposits. Remnants of these deposits extend along tributaries of the Susan River, a few miles west of Susanville, and an isolated body of these gravels occurs near the top of the divide along the road which extends from the southern end of Eagle Lake into Willow Creek. This deposit covers only a few acres and lies upon the old metamorphic rocks of the Gallatin Peak area.

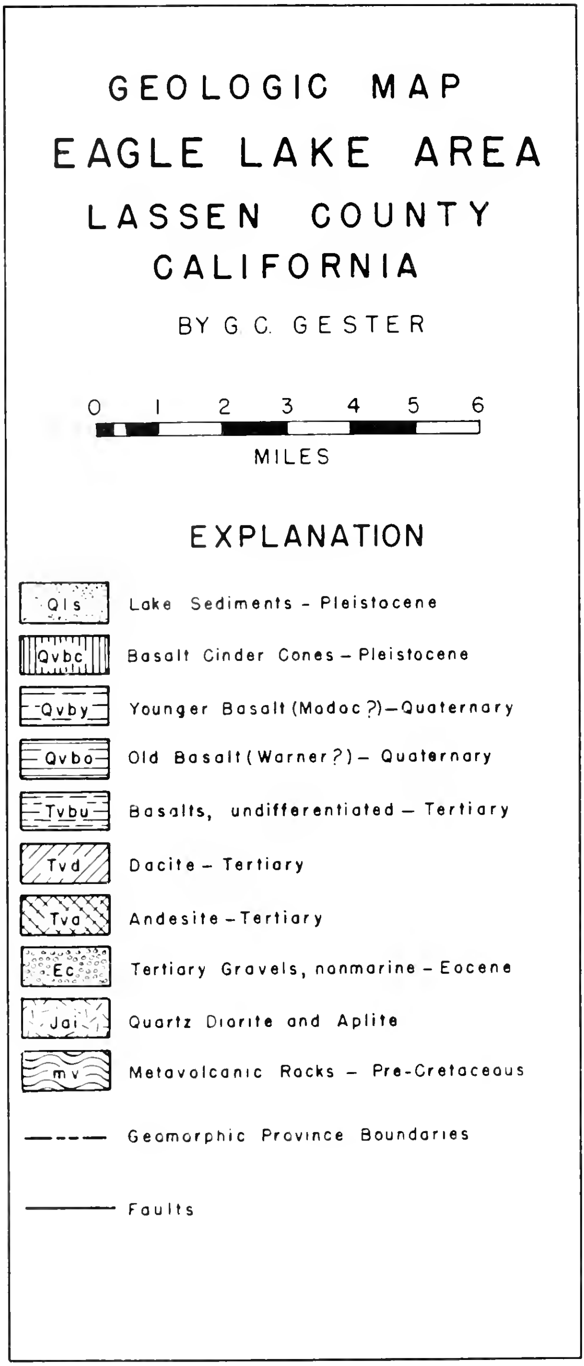
THE CEDARVILLE-ALTURAS SERIES. Except for the granitic and metamorphic rocks previously described, the oldest rocks of the Modoc Plateau form a series, consisting largely of volcanic rocks, characterized by an abundance of pyroclastic material. These rocks are usually tilted, warped, and faulted, and may be correlated with the Alturas formation of the Alturas and Tule Lake areas and/or the Cedarville series of the Warner Mountains where a thick and varied section is exposed by block faulting. The latter are considered to be of Miocene age by Russell and Chaney (1928, p. 412), but Axelrod (1949 p. 1936) believes the Cedarville series, at least the lower part, is of Oligocene age, and the Alturas, of Miocene age.

The Cedarville series consists of a preponderance of andesitic material in the form of agglomerates, tuffs, flows, and dykes, with lesser amounts of rhyolitic intrusives, rhyolitic tuffs, and basaltic flows. There is a probability that some of the lacustrine sediments mentioned later may belong to this series.

Although the Cedarville series of the Warner Mountains, as described by Russell (1928, p. 402), is very largely composed of andesitic pyroclastics, the lower division contains some thin but extensive non-marine sediments, in part lignitic, and in the upper division there are some peculiar tuffaceous cones, sometimes called "bee-hive cones."

Four miles northwesterly from the mouth of Pine Creek, and extending some distance in a similar direction, is a large body of biotite dacite. C. W. Chesterman, of the California State Division of Mines and Geology, kindly examined the rock and states as follows: "In hand specimen, the rock is light gray in color and shows scattered phenocrysts of fledspar and biotite. Under the microscope the rock is porphyritic and shows phenocrysts of feldspar and biotite enclosed in a perlitic glassy groundmass."

"There are two feldspars present: oligoclase with a composition of (An15) and sanidine. The oligoclase seems to be the commonest of the feldspar and appears in well formed twinned and zoned crystals. Inclusions of glass and biotite are common in the feldspars. Scattered throughout the groundmass are small lath-shaped crystals of oligoclase. The crystals tend to have parallel orientation. Quartz is rare and shows wavy extinction. Biotite occurs in well formed crystals and is pleochroic in shades of dark golden brown and greenish brown. Hornblende is also rare but occurs in dark btown subhedral crystals. Because of the scarcity of quartz, one is tempted to call the rock a trachyte, however, the refraction index determination of the glass indicates a more acid composition and because of this the rock should be called biotite dacite."


GEOLOGIC MAP
EAGLE LAKE AREA
LASSEN COUNTY
CALIFORNIA
BY G. C. GESTER
0 1 2 3 4 5 6
MILES
EXPLANATION
Qls
Lake Sediments - Pleistocene
Qvbc
Basalt Cinder Cones - Pleistocene
Qvby
Younger Basalt (Modoc ?) - Quaternary
Qvbo
Old Basalt (Warner ?) - Quaternary
Tvbu
Basalts, undifferentiated - Tertiary
Tvd
Dacite - Tertiary
Tva
Andesite - Tertiary
Ec
Tertiary Gravels, nonmarine - Eocene
Jai
Quartz Diorite and Aplite
mv
Metavolcanic Rocks - Pre-Cretaceous
Geomorphic Province Boundaries
Faults

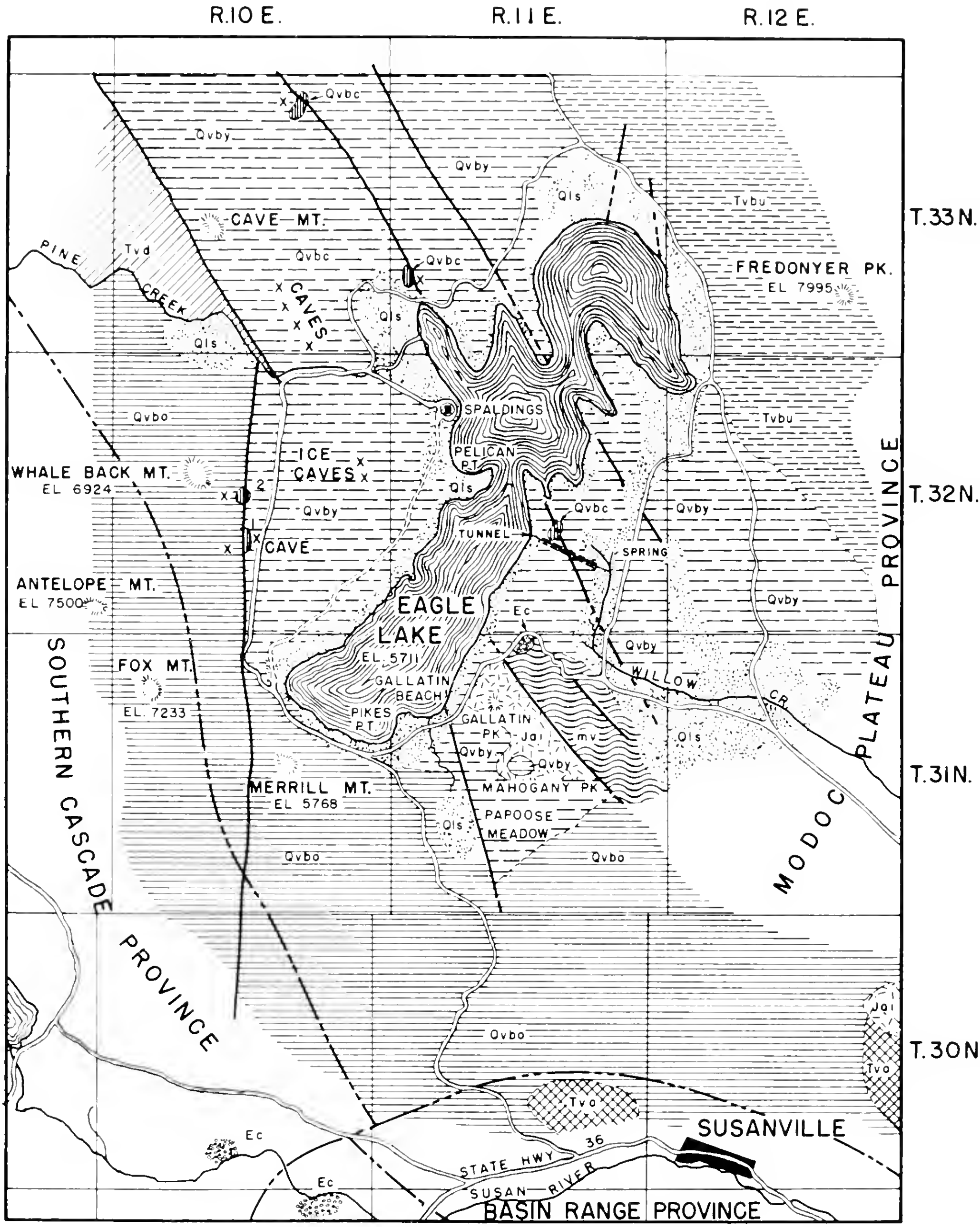


Figure 2. Geologic map of Eagle Lake area.

About 20 miles north of Eagle Lake, near Hayden Hill, low-tilted rhyolitic and andesitic tuffs are exposed. Just to the east of Hayden Hill are tuffs similar in some respects to the bee-hive cones. Well bedded, folded and tilted tuffs and diatomite deposits, the latter of Miocene or Pliocene age (Dr. G D. Hanna, oral communication) outcrop along the highway for a distance of 10 to 13 miles south of Adin. Westerly from Adin, near Bieber and Pittsville and to the north, covering large areas near Tule Lake and Alturas, as well as in several other localities in the Modoc Plateau, there are prominent exposures of andesitic flows, pyroclastics, rhyolitic intrusives, tuffs, and basaltic intrusives. These are considered to be in part Cedarville and in part Alturas.

Following the eruption and deposition of the Alturas-Cedarville series, which apparently covers extensive areas, it is clearly evident that in most, if not all of the Modoc Plateau, there was a prolonged period of deformation, accompanied by block faulting, erosion, and extrusion of lava. Hinds (1952, p. 82) believes that this deformation started toward the end of the Pliocene or in the early part of the Pleistocene epoch.

Lake beds were formed in the graben depressions developed by block faulting in the andesitic and basaltic lava flows. Charles W. Chesterman of the California State Division of Mines and Geology (oral communication) as well as Anderson, (1941, pp. 352-353) and Powers, (1932, p. 267) have confirmed this observation. According to Powers, (1932, pp. 266-267) "after extensive block faulting of the Cedarville andesite, a great thickness of lake beds was deposited in the fault graben depression and built up widespread plateaus, above which the upthrown blocks rose. The first sediments were deposited in large shallow lakes. They were covered by widespread flows of basalt. Recurrence of faulting then formed a number of small grabens in the basalt surface in which lake beds were formed by deposition, which has continued to be present."

The lake bed sediments are composed largely of sands, silts, ash, and diatomaceous material. There are numerous localities in northeastern California where such deposits exist and a lesser number of the basins still contain lakes. Tule, Dixie, Humbug, Big Meadows, and Goose, are good examples of these lakes in northeastern California. Tilted lacustrial deposits, tentatively classed as late Pliocene or early Pleistocene, composed of silt, rhyolitic tuff and diatomite were noted south of Goose Lake (near Joseph), a short distance both south and west of Alturas, near Termo, around Bieber and north of the Warner bridge on the Pit River, near Cayton. At the latter locality is one of the largest diatomite deposits in northern California.

Some of these lakes and lake beds are older than the very extensive lava flows called the "Warner basalt" which are so prevalent in northeastern California. Some are later, and rest on a floor of Warner basalt. No attempt was made to study the stratigraphy, structure, and age relationships of these lake beds. This is a very interesting problem, well worthy of investigation.

The Warner or older basalts. The Warner basalts are described by Russell, (1928, p. 416) "as being the most widespread rock surfaces in Modoc County." He states that in the Warner Range, "they are concordant with the underlying Cedarville series." However, there are basaltic flows in the northern part of the Warner Range, identical in appearance with his Warner basalts, which are not conformable with the Cedarville. Both Anderson, (1941, p.353) and Powers, (1932, p. 267) place the Warner basalts of the Medicine Lake Highlands, and Modoc Lava Bed Quadrangle, as being younger than the Cedarville and separated by a period during which block faulting took place.

Certainly this series of basaltic flows called the Warner basalts, but probably divisible into at least two groups, are very widespread in northern California. They cover more than half of Modoc County and extend far southward into the northern and central parts of Lassen County. They constitute the "Older Basalts" of the Eagle Lake area and were extruded from many widely separated vents over a considerable period of time. The flows probably range in age from lower to upper Pleistocene. At some localities in the Medicine Lakes Highlands, the Warner basalts are glaciated.

These basalts are reasonably constant in their appearance and composition. They are in general of a soft dull gray color, more or less uniform grain, and range from medium vesicular to medium dense. They are composed of honey-yellow olivine crystals and a lesser amount of a pyroxene in a matrix composed of plagioclase laths. They can in many places, particularly in the Eagle Lake area, be distinguished from the "Recent Basalts" by a characteristic weathering. On and near the surface, the exfoliation of the fractured basalt, accompanied by the effect of freezing and thawing produces a boulder-like appearance to the rock, whose outer surfaces are concentrically weathered. Time is a major factor in the weathering process and such effects are not observable in the younger basaltic flows.

Pleistocene lakes - transition to the somewhat later equivalents. Throughout much of this long period of deformation and volcanism, another natural phenomenon was taking place; namely, the great Pleistocene Ice Age, accompanied by mountain sculpture and by the birth, the rise, and fall of great lakes, the largest of which is called Lake Lahontan. This lake covered enormous areas in Nevada and extended into eastern California. Other smaller lakes of the same epoch in northern California and Oregon had a more precarious existence, owing to the various stages of crustal deformation and extrusion of lava.

No definite events occurred in the Eagle Lake area to mark sharply the division between Pleistocene and Recent times. Honey Lake became partially desiccated, changing the lake, which according to Russell (1885, p. 31, pl. V) was 360 feet deep in Pleistocene time, to a shallow remnant of its old grandeur. The long period of deformation was nearing its end and there were lesser amounts of faulting. The main building of Mts. Shasta and Lassen had been accomplished but active volcanic action continued throughout most of the Modoc Plateau and adjoining regions. This volcanic activity resulted in producing platy andesites, the dacites as well as the rhyolites, tuffs, and obsidians of Big Glass Mountain, and the upper parts of the Warner Range. These were followed by the even more recent widespread flows which modified both the lakes and landscapes over wide reaches of the Modoc Plateau region and, as will be seen later, marked a division in the geological history of Eagle Lake.

The Ancient Eagle Lake--Lake Acapsu'kati

Lake area. The lake area, as shown on figure 2, The Geologic Map of Eagle Lake,is comparatively small and it has been necessary to look at regions some distance removed from that particular area in order to decipher its geological history.

There is much truth in the old Indian legend which says that the lake is very old. So ancient is the lake and so much has happened since its origin that it seems desirable to divide its history into two stages: (a) the ancient Eagle Lake or to use the Indian name, *Acapsú'kati*, and (b) the Eagle Lake of today.

The original floor and basin. What was the original floor of Lake Acapsu'kati? How and when did it come into being? We know that granitic rocks and the old metamorphic rocks, must have at least formed a part of the southeastern shore of the lake and probably part of its bed. Rocks correlative with the Alturas-Cedarville series are exposed in a belt of dacitic lavas northwest of the lake and are present 40 to 50 miles to the north of Hayden Hill near Bieber and south of Adin. So it is reasonable to believe that at one time the granitic and older rocks of Gallatin Peak were in contact with Alturas-Cedarville equivalents in the lake area and that these were later, in part covered by the older or Warner basalts which, as shown on figure 2 surround the old lake basin on the south and as far north as Pine Creek on the west. Furthermore, the lower part of the undifferentiated basalts on the northeast segment of the lake may belong to the old basalt group. Just when and by what process the original lake basin was formed we do not positively know. It may have resulted from the damming of a stream by a lava flow or landslide or more probably, like some of the lake basins, of the Modoc Plateau, it was formed in a fault graben depression.

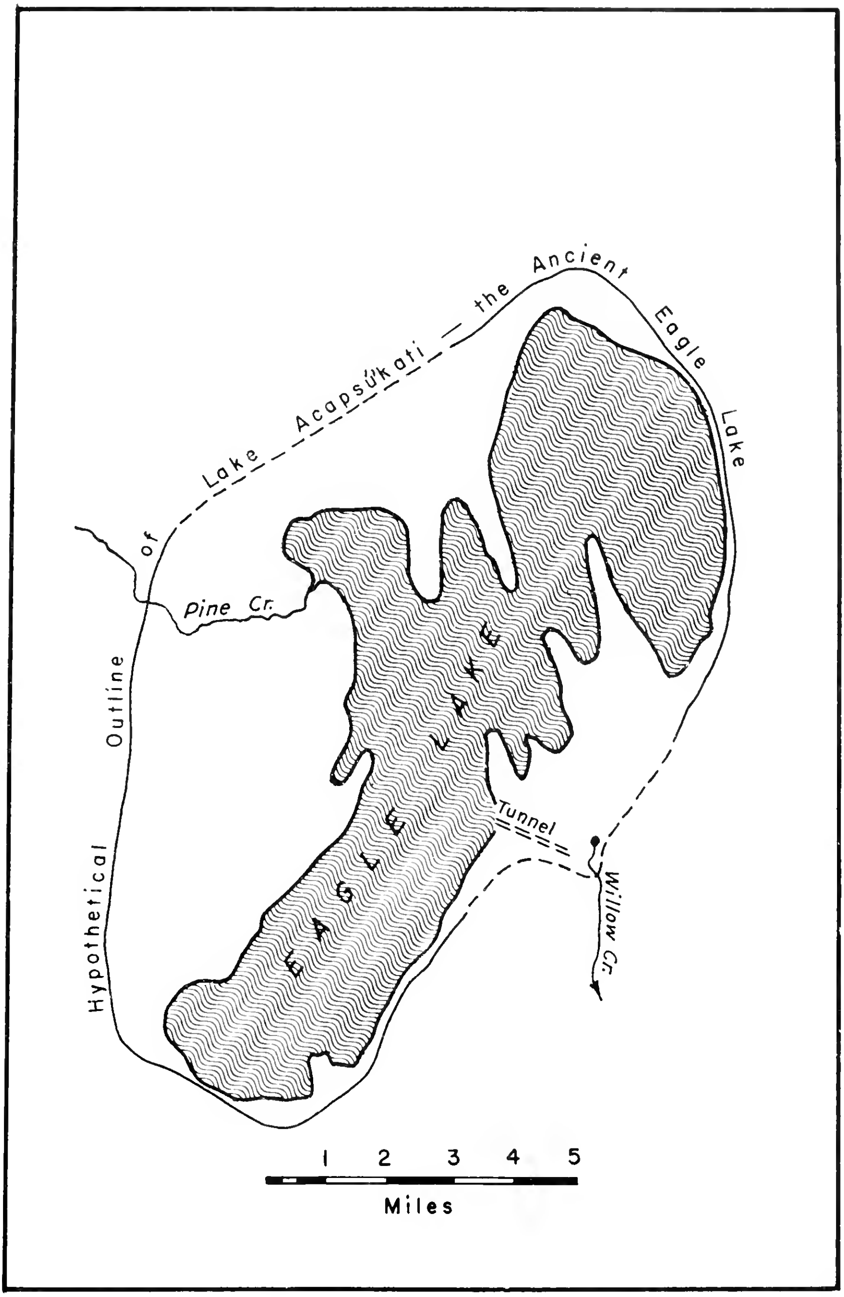


Figure 3. Map of Eagle Lake and Hypothetical Outline of Lake Acapsú'kati.

TABLE 2. *Comparative Elevations Shown in Eagle Lake Water Level*

	Elevation above sea level
United States Geological Survey bench-mark on southeast shore of lake.	5,105 ft.
Water level near bench-mark, July 1957	5,103 ft.
Base of lake - cross-bedded sands in tunnel between 850 and 900 feet from present shore line - approximately	5,105 ft.
Reported level of lake just prior to opening tunnel	5,133 ft.
Aneroid elevation - top of abundant shell beaches	5,128 ft.
Aneroid elevation-top of white alkali incrustations	5,143 ft.
Aneroid elevation - top of well defined wave cut terrace	5,178 ft.
Aneroid elevation - top of poorly defined upper terrace	5,188 ft.
Fredonyer Peak Quadrangle - Highest contours each side of the Willow Creek - Eagle Lake divide	5,160 ft.
Estimated elevation-top of divide between Willow Creek and Eagle Lake	5,180 to 5,190 ft.

FAULTS. There is abundant topographic evidence of faulting in the lake area but a part of it is obliterated by the younger basalt flows. No serious attempt was made to accurately delineate all these faults. The Fredonyer-Horse Lake Mountains, just to the east of the lake ares, suggest a fault block. There is good topographic evidence of a fault which extends in a northwesterly direction from Willow Creek Valley through Big Dry Lake-Lower Dry Lake and thence diagonally across the northern half of Eagle Lake. Three recent basaltic cinder cones along this trace suggest a line of crustal weakness. A couple of miles to the north there is good topographic expression of a nearly parallel fault. On the western side of the lake there is evidence of a fault that extends along the eastern base of the Fox and Whaleback mountains from near the southwest toe of the lake northward to Pine Creek where it intersects one which follows up Pine Creek in a northwesterly direction. There is a fault that extends along the eastern side of the lake. According to Kemnitzer (1921, pp. 192 and 193) the Eagle Lake earthquakes of July 18 to 24, 1921, were on this fault. The greatest disturbance was on July 21, with an intensity of 5 on the Richter scale; the epicenter being in the lake. He states, "The topography about the lake shows a number of fault scarps, the lake itself evidently having been formed by gigantic faulting. Due to the ellipse formed by the iso seismals, whose major axis extends in a NE.-SW. direction, the located fault plane extends along the east shore of Eagle Lake. There is no doubt that a subterranean movement occurred along the fault plane on its east shore. Computations from the seismographic records at Berkeley located the epicenter of these shocks at the middle of Eagle Lake."

Although the evidence is not absolutely conclusive, it is my hypothesis that the original lake basin is a graben, formed during the period of deformation that was so general in the Modoc Plateau and which took place after the deposition of the Alturas-Cedarville series. In other words, Lake Acapsú'kati was contemporaneous with the older lakes and lake basins of the plateau region, which was considered to be of late Pliocene or Early Pleistocene age.

The lake basin is a down-dropped block between the faults (a) along the eastern side of the lake and (b) the base of the mountain mass that forms the range of abrupt mountain peaks on the west. The northern half of the graben is cut, and probably modified to some extent, by northwest-trending faults that cut diagonally across the lake. The broad, gently sloping but rough-surfaced crescent-shaped lowlands on the westside of the lake are composed of recent Modoc basalts that flowed into the Acapsú'kati lake basin, and into the lake itself.

Periods of faulting. There appear to have been two periods of faulting or recurrent movement along zones of weakness on the eastern side of the lake. The older was instrumental in shaping the eastern side of the original basin in which Lake Acapsu'kati formed. It raised the block on the east side of the lake, which includes the granitic and metamorphic rocks, the older basalts and probably representatives of the Cedarville series, although the latter are no longer exposed in that area. More recent faulting and younger basalt flows have in part obscured the earlier movements. Two such faults, having northwest trends, cut diagonally across the southern portion of the northern half of the lake. Furthermore, as shown on the geologic map, figure 2, there is a fault along the eastern side of Papoose Meadow. This fault, apparently on the ancient line of movement, which helped form the lake, extends in a north-south direction into the lake and thence in a general north-easterly direction along the eastern side of the southern portion of the lake. The soundings which were taken in this part of the lake indicate the presence there of an abrupt narrow ridge which probably represents the trace of a fault scarp. How far this fault or fault zone extends into the north half of the lake is indeterminate. However, the topography along the northeast strongly suggests a more or less parallel fault which extends southward into the headwaters of Willow Creek.

Further geological data regarding the ancient lake. The lake and lake basin area afford some other good evidence and interesting data regarding the geological history of the ancient lake.

(1) *Upper sand deposits.* In addition to the spread of recent lavas on the northwestern side of the lake, there are some more or less isolated sand deposits, which from their location, a mile or more from the present lake, and the fact that they do not contain any mollusk shells so common in the present lake beaches, indicate that they may represent older lake-shore deposits.

(2) *Diatomite deposit.* The diatomite deposit along Pine Creek, nearly a mile from its mouth, is very pure and composed of a variety of fresh water forms which Dr. Hanna (oral communication) believes may be of Pleistocene age. The deposit is exposed along the lower portions of the banks of the creek for a distance of about one-quarter mile. It ranges in thickness from 12 to 14 feet, and is overlain by 20 to 30 feet of soft, medium-to-fine grained beach sands that contain occasional clam shells. At one locality there is a brownish organic clay that separates the diatomite from the overlying sands. Except at one locality, where the diatomite is tilted about 10 degrees northeasterly, possibly because of slumping, it is concordant with the overlying sands.

(3) *Granitic Sand Beaches.* The granitic sand beaches on the south and southeastern side of the lake are too large and extensive to have been derived from the comparatively small area of granitic rock on Gallatin and Mahogany peaks, so the sands must have come from a much larger area of granitic rocks that was later covered by the recent basalts which fringe that part of the lake.

(4) *Irrigation Tunnel.* Reference has also been made to the irrigation tunnel but this deserves further analysis. The tunnel is located on the eastern side, five and a half miles northeast of the southern end of the lake. A short canal, less than one-quarter mile long, connects the west portal of the tunnel with a small bay. This canal and the western 500 feet of the tunnel were deepened 8 to 10 feet sometime after the tunnel was originally opened. The canal is now partially blocked, but this does not prevent the free flow of water. A short distance in the tunnel, from the west portal, are a couple of large springs of cold, fresh water. The tunnel trends S.27°E. - a distance of about 6,000 feet to the headwaters of Willow Creek from whence the water originally flowed by canal, flume, and pipe for several miles to the cultivated lands. The tunnel was designed to be 10 feet wide by 12 feet high, but the western end has a greater vertical dimension owing to the deepening. Nearly

500 feet from the western portal, the tunnel drops about 25 feet at an angle of 30 degrees. It then follows a normal gradient to the eastern end.

The portal at the western end of the tunnel was cut in a hard, dark gray, olivine basalt. It is a vesicular rock and, at one locality, scoriaceous. The basaltic ridge through which the tunnel was driven rises abruptly above the west portal to an elevation of nearly 200 feet above the tunnel. The main source of this basaltic flow was apparently on Black Mountain, $1\frac{1}{2}$ miles to the south. It formed the long, northward extending ridge through which the tunnel is cut. However, there is a small, red, scoriaceous cinder cone just north of the tunnel.

A short distance east of the basalt flow ridge, and about 3,000 feet from the west portal, a vertical shaft intercepts the tunnel, which may have been driven in both directions from this point. The dump at the mouth of the shaft is large and the fragments of granitic and metamorphic rock found here are believed to have come from the tunnel.

At a point in the tunnel some 300 feet from the west portal which is nearly 600 feet from the lake shore, and about five feet above the floor, the tunnel cuts through a body of firm crossbedded fossilferous lake sands and minor strata of white marl. This was obviously a near-shore deposit of the old

Figure 4. View westward across Eagle Lake showing in the foreground the short canal through which the lake waters drain into the irrigation tunnel, and in the distance, Whaleback Mountain, a north trending ridge composed of "Older Basalts".

lake which was later covered by the basalt flow. It may have represented a part of the old surface outlet of the lake. The sands range from medium fine to almost coarse, with a few particles over 1/16 inch in diameter. The sand grains are subangular, and in general, coated with a white calcareous material. A large percentage of the sand grains have the appearance of being derived from granitic rocks and some are large enough to be identified as granitic rock fragments. A much smaller percentage is made up of a clear glassy material and dark particles derived from the basalts. A number of fragments of fossil shells, resembling *Carinifex*, are present in the sands. One fragment is clearly the apical portion of the shell. As described later, several species of mollusks are abundant on the shores and in the lake.

The elevation of the cross-bedded sand deposit in the tunnel is approximately the present level of the lake, which was lowered 27 to 30 feet during the early 1920's by drainage through the tunnel.

(5) *Correlation with the Lahontan Lakes.* The Eagle Lake area is a small isolated hydrographic basin, which forms a part of the much greater Honey Lake basin. The latter lake is now only a shallow remnant of a once great lake, over 300 feet in depth, (Russell, 1885, plate V and p. 32), that formed a part of the widespread system of so-called Lahontan Lakes of Pleistocene time. These lakes covered vast areas in Nevada, Utah, and extended into eastern California as well as eastern and southern Oregon. Eagle Lake has an elevation above sea level of 5,100 feet and is about 1,000 feet higher in elevation than Honey Lake. There is now no surface outlet for Eagle Lake but during some past period of time there was an open stream connecting the two lakes which permitted both fish and mollusks to migrate from Honey Lake and other Lahontan lakes into Eagle Lake. Hubbs and Miller (1948) and Kimsey (1954, p. 396) state that four of the five native fishes found in Eagle Lake are of Lahontan origin. Furthermore, Dr. Hanna (1924) and Allyn Smith (oral communication, 1957) believe that the fresh water mollusks, several species of which thrive in the lake and whose shells are very abundant in virtually all the beaches and terrace sands, originally came from the Lahontan lakes. Dr. Hanna (1924, p. 132) states, "A comprehensive study of the living and fossil mollusks of the entire Lahontan Basin is badly needed to secure data for geological correlation. We know that in it flourished a remarkable fauna of a few very prolific species. These belonged to genera which were widespread in the West during Pliocene and Pleistocene time. *Carinifex* was probably the most widely dispersed of all, although *Parapholyx*, *Lanx*, and *Vorticifex* occur over large areas."

The following mollusks were collected at Eagle Lake by the author and kindly determined by Dr. G D. Hanna and Mr. Allyn G. Smith of the California Academy of Sciences:

1. *Parapholyx mailliardi* Hanna
2. *Carinifex occidentalis* Hanna
3. *Planorbis parvus* Say
4. *Valvata humeralis* Say
5. *Physa* sp.
6. *Pisidum* sp.
7. *Lymnaea palustris* Müller
8. *Helisoma* cf. *H. subcrenatum* J. G. Cooper
9. *Goniobasis acutifilosa* Stearns
10. *Anodonta californiensis* Lea

The last two were not found on the shores of the lake but are abundant in the adjacent streams. Several of these species are still living in the lake and further search may reveal that all the forms are present.

The Eagle Lake of Today

When and how formed. The present Eagle Lake, a remnant of Lake Acapsú'kati, was formed in comparatively recent times, probably within the last thousand years, as the result of widespread flows of very fluid, vesicular basaltic lava. These lava flows altered the landscape around the lake and changed its size and shape. On the geologic map, figure 2, they are captioned, "Younger Basalts (Modoc?)," and they probably represent some of the more recent of the flows described by Powers (1932, p. 272) as the Modoc Basalt, and which cover large areas in the Modoc Plateau, Medicine Lake Highlands, and Lassen Volcanic National Park.

The younger basalts. The Younger basalt flows came from a number of sources, at probably somewhat different intervals of time. Some of the flows are characterized by the formation of cinder cones, a few of which will be mentioned later under "Economic Geology." Other flows apparently issued from fissure vents in the older basalts. One of these flows originated on Black Mountain on the southeastern side of the lake and covers a large area in that region. A part of it flowed northward, closing the old outlet of the lake. It is beneath this flow that the irrigation tunnel, previously described, cut the old crossbedded sands of the older lake. The long, narrow peninsulas which extend into the northern half of the lake all have the appearance of being composed of these recent basalts. The same is true of a large number of smaller points which extend into the lake, particularly Pelican Point, about 1½ miles south of Spaldings. On all of these peninsulas the basalt is more or less covered with a white calcareous coating, indicative of periods of partial submergence and of desiccation. Another large flow spread over a large segment of the western and northwestern sides of the old lake basin, crossed the mouth of Pine Creek, and pushed the lake shore eastward, producing the almost flat crescent-shaped area that lies west of the lake s shore.

The Younger basalts surround the lake, except for a comparatively short distance along the south side, where Older basaltic flows (Warner basalt?) approaches the shore line and an area of probably Older basalts that are exposed along the highway on the northeastern side. At both of these localities the basalts have undergone a more mature weathering than is characteristic of the Younger basalts.

It is very difficult to differentiate the Younger and Older basalts when they are in contact. The majority of the Younger basalts around the lake are notably vesicular and still retain their unaltered surfaces. But this is not always the case. Some of the basalts of the peninsulas on the northern side of the lake show comparatively little vesiculation and the rock at the mouth of the west portal of the tunnel is particularly dense. However, a short distance within the tunnel dark scoriaceous basalt was penetrated. The Eagle Lake or Younger basalt is dark gray to almost black, except in the vicinity of the cinder cones where the iron of the rock has been oxidized giving it a brick-red coloration. The general appearance of the flows is so much alike that no attempt was made in the field to differentiate them. Some are aphanitic, but in others some minerals can be determined with a hand lens. The rock is composed of plagioclase (ophitic), pyroxene, olivine, glass, and iron oxides. The glass is often easily identified and the olivine is recognizable but it is not as prominent as in much of the Older or Warner basalts. The crystals are smaller in size and not so honey yellow.

Many flows of the Young basalts had their sources north and northwest of the Lake. The large spread of flows on the west-northwest side of the lake came from the direction of Cave Mountain. It is in one of these flows that the "Indian and Ice Caves" are found. The flows forming the long peninsulas which jut into the northern half of the lake had their origin to the north. On the other hand, the flows which formed the steep east side of Papoose Meadow appears to have flowed northward around the granitic rocks on the west side of Gallatin Peak. The summit of Mahogany Peak, a mile and a half south of Gallatin Peak, is a more or less scoriaceous basalt, surrounded by granitic rocks. The flow which forms the ridge through which the irrigation tunnel was driven had its source in Black Mountain about a mile to the south. Another but possibly contemporaneous flow formed the hills to the north and east of the tunnel and the peninsula that extends out into the lake to the northward from the headwaters of Willow Creek.

The changed configuration of the lake. These Younger flows of lava changed the configuration of Lake Acapsu'kati and formed the Eagle Lake of today, (see figure 3). The old lake had a more regular outline, and covered a larger surface area but was not as deep as the present lake, particularly during periods of the latter's highest waters. As previously mentioned, the recent basalt flows on the northwest end of the lake pushed the waters to the south and east over an area some four miles wide. Other flows formed the prominent peninsula and gave to the lake, particularly the northern portion, a very irregular outline. The Black Mountain lava flow closed the old outlet and then permitted the waters of the lake to rise to higher elevations. It was through this old outlet into Willow Creek that the fish and mollusks of the Lahontan lakes migrated into Lake Acapsú'kati.

Effect of climatic changes. It is probable that the Eagle Lake basin was influenced by the same climatic changes which caused the well marked rise and fall of the Lahontan Lakes, (Russell, 1885, p. 268). Kimsey (1954, p.295) believes that at some time in the past, the lake has undergone periods of great natural fluctuations and that some time during the past it reached a much lower level than the present. The evidence of extreme desiccation and of a water level much lower than the present is largely circumstantial. However, the white lime-incrustation along the shore and on rocks of former shores, up to 40 feet or more above the present indicate that these were periods of desiccation, and Grinnell (1930, p. 21) states "The first Government record of the level of Eagle Lake was in 1875, and that was of the lowest water known to date."

Fluctuations in the eagle lake water levels. Higher levels of the lake are indicated both by the lime incrustations and by wave cut terraces. The table of comparative elevations (table 2) shows that: (a) the present water level is approximately 30 feet below the level that existed just prior to the opening of the tunnel; (b) the base of the lake sediments, in the tunnel, is at nearly the same elevation as the present lake; (c) the large sand beaches, which carry abundant mollusk shells, slope gently upward to about 25 feet above the present shore; (d) white lime incrustations cover the rocks up to 40 feet above the lake; (e) there is a well defined wave-cut terrace about 75 feet above the present lake level at an elevation of ±5,175 feet and a poorly defined terrace about 10 feet higher.

The lowest part of the divide between Eagle Lake and Willow Creek is about one mile north of the tunnel. It is above the 5,160-foot contour and below the 5,200-foot contour at an estimated elevation of between 5,180 and 5,190 feet. Curley Dahl (oral communication) advises that he assisted in digging a series of shallow holes across the divide and found good evidence in the form of water-worn material that the lake during some period of high water flowed through this gap into Willow Creek.

Ancient outlet of lake and springs in Upper Willow Creek. It is probable that the ancient outlet of the lake, at an elevation of about 5,100 feet, was beneath the present divide which now separates the lake from the headwaters of Willow Creek.

Not far from the outlet of the tunnel are several large perennial fresh-water springs which flow into Willow Creek. These springs derive their water from Eagle Lake and are fresher than the lake water. This is probably due to the fact that the water has been filtered in passing through a considerable thickness of more or less vesicular basaltic rocks.

Economic Geology

The only known deposits of economic interest in the Eagle Lake area are the volcanic cinders or scoria. Material from some of these deposits has been extensively used locally for surfacing roads, both by the county and to a larger extend, by the lumber companies. There are seven cinder cones within the area covered by this report, but two of them are of no apparent economic value.

All the cones are believed to have formed at the time of the out-pourings of the recent Younger or Modoc basalts. However, the two southerly cones on the western side of the lake are closely associated with the older series of basalt flows and may represent vents or cones that have broken through the older lavas. They all have the same general characteristics and appearance of the cones on the Modoc Plateau. The predominating colors of the cinders range from red to reddish brown and black. However, in one cone there is some greenish and yellow material. The cinders take their color from the oxidation of the constituent iron-bearing minerals. The cinders range in size from a fraction of an inch to several inches and are mostly angular. A few lapilli and bombs are present, but are not so numerous as in some of the Modoc Plateau cones. A moderate amount of highly vesicular flow material is, in places, mixed with the cinders, and where present, cause some difficulties in the quarrying.

The mining of the cinders is an easy and simple operation. The material is loosely consolidated. It can be readily mined and moved by mechanical scrapers and dumped into bins or directly into the trucks. Because the cinders are used primarily for road surfacing, no elaborate machinery is needed for screening. Bombs and hard chunks of cinders or flow rock are removed by a grizzly at the top of the bin. These grizzlies are made of rails or iron bars placed a few inches apart.

The location of each of these cones is shown by numbers on the geologic map, figure 2.

Cone no. 1 is in the center of the N. E. ¼ of the N. E. ¼ of Sec. 28, T.32N., R.10E.. It is less than ½ mile west of the Eagle Lake road, on the west side of the lake. It is one of the largest and most extensively developed. The pit or opening along the side of the cone is 200 to 250 feet in length and attains a height of 20 to 25 feet. There is also an open cut on the east side of the cone. A large amount of material has been removed for surfacing nearby roads. There is a notable variation in the colors of the cinders. The brownish-black to black predominate but some layers have a yellowish and others a greenish cast.

Cone no. 2 is located near the southeast corner of Sec. 16 and the northeast corner of Sec. 21, a little over a mile north of cone no. 1 and about 250 feet higher up the western slope of Whaleback Mountain. It is a large cone, which on the southern side rises abruptly about 100 feet above the base of the lowest open cut. It is composed of material of the same character and color as in cone no. 1.

Cone no. 3 is in the W.½ of the N.W.¼ of Sec. 27, T.33N., R.10E. It is a typical cinder cone on the upper part of Ice Cave Ridge and has not been developed to any large extent.

Cone no. 4 is the cinder pit just to the north of Dow Butte Look-out Station. It is in the S.E.¼ of Sec. 3 and the N.E.¼, Sec. 10 of T.33N., R.10E.. There is a considerable quantity of cinder and highly scoriaceous basalt in the Dow Butte locality but the quantity of good cinder does not appear to be very large. The cinders are mostly of a brick red color.

Cone no. 5 is located in the S.W.¼, Sec. 30, T.33N., R.9E. about ½ mile north of the northwest bay of the lake. It is an elongated dome-like hill, upwards to 70 feet high and occupies about five acres. This cone was developed by an open cut 160 yards long along the western side of the hill. At some time in the past, there were some large loading bins at the pit but these are now in a state of ruin. A large quantity of good red cinder has been taken from the cone but except for very minor amounts, it has not been mined for several years.

Cone no. 6 is in the S.W,¼ of Sec. 22, T.32N., R.11E., just to the north of the irrigation tunnel. Much of the material is a highly scoriaceous basalt, a small amount of which was removed during the excavation of the western end of the tunnel.

Cone no. 7 This is a small cone composed largely of scoriaceous basalt that forms the top of Mahogany Peak. The vent for this cone apparently came up through the granitic rocks. It has no economic value and is located in the center of the E.½ of Sec. 16, T.31N., R.11E..

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