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RECONNAISSANCE

OF THE

BORAX DEPOSITS OF DEATH VALLEY AND MOHAVE DESERT

BY

MARIUS R. CAMPBELL

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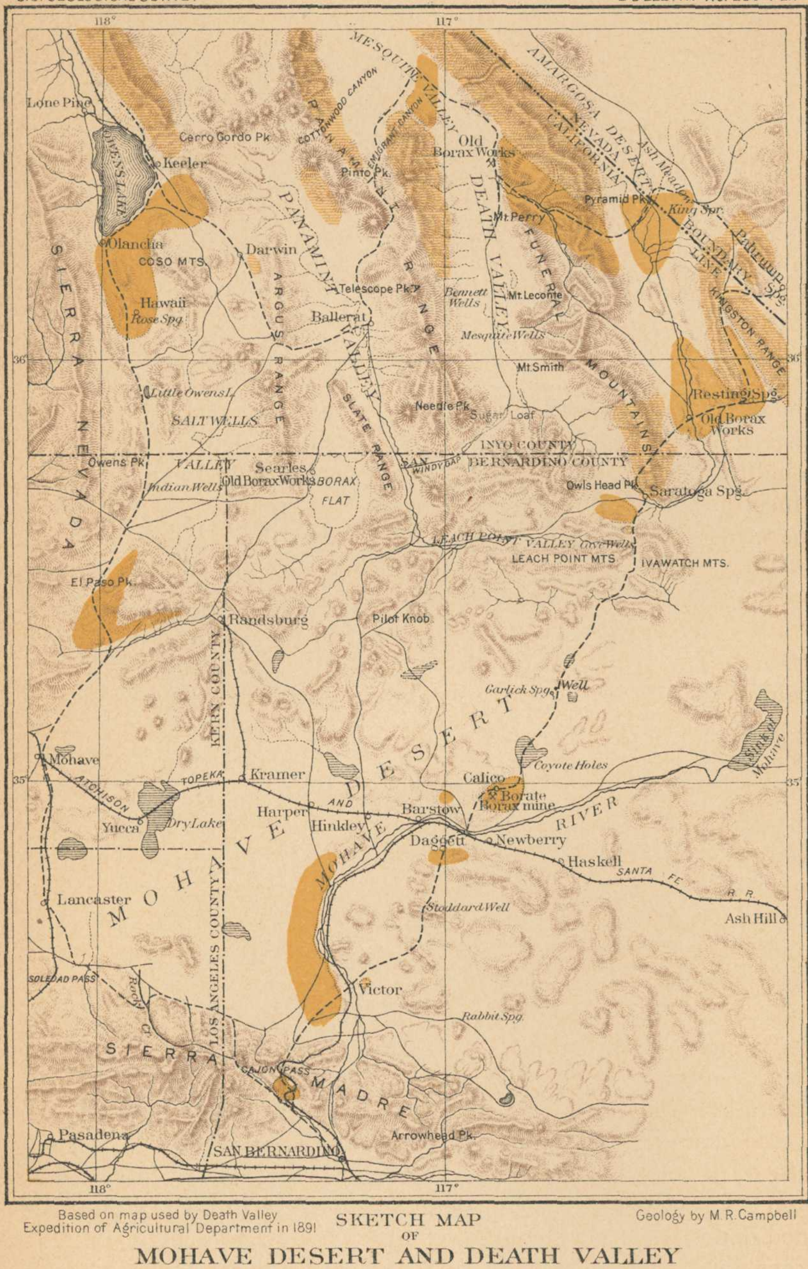

Based on map used by Death Valley Expedition of Agricultural Department in 1891

Geology by M. R. Campbell

SKETCH MAP OF MOHAVE DESERT AND DEATH VALLEY

showing location of known areas of Tertiary lake beds and old sedimentary rocks

Scale

0 5 10 20 30 40 50 miles

Tertiary lake beds — -----Route of travel — Old sedimentary rocks

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RECONNAISSANCE OF THE BORAX DEPOSITS OF DEATH VALLEY AND MOHAVE DESERT.

By Marius R. Campbell.

INTRODUCTION.

The occurrence of deposits of borax in the United States, so far as known, is limited to the States of California, Nevada, and Oregon. The industry has passed through several stages of development since its inception in this country. Originally borax was obtained by evaporating the waters of Clear Lake, about 80 miles north of San Francisco, where it was first produced on a commercial scale in 1864. Subsequently the lake water was enriched by the addition of crystalline biborate of soda, which was collected from the alkaline marsh surrounding the lake. The industry flourished at this and other lakes in California until, in the early seventies, borax in large quantity and in a very pure condition was discovered on many of the alkaline marshes of western Nevada and eastern California. Refining plants were established in the vicinity of Columbus, Nev., and at several points in California, the most important of the latter being in San Bernardino County, at Searles's marsh, west of the Slate Range; in Inyo County, near Resting Spring; and at the mouth of Furnace Creek in Death Valley. These plants flourished for a time, even though the finished product in many cases had to be transported by teams to the railroad, a hundred miles distant; but the increased production of borax in this country, together with the importation of large amounts from Italy, so reduced the price that in a few years most of the plants were abandoned.

About 1890 it was found that the borax crust on most of the marshes is a secondary deposit, being derived from the leaching of beds of borate of lime in the Tertiary lake sediments that abound in the region. This discovery revolutionized the borax industry, for the bedded deposits are much more extensive, are more easily accessible, and are in a purer condition than the marsh crusts. The marshes were abandoned and a mine was established on a bedded deposit at

Borate, 12 miles northeast of Daggett, San Bernardino County, Cal. At the present time this plant, owned by the Pacific Coast Borax Company, is the chief producer of borax and boracic acid in this country. The value of this deposit led to extensive prospecting in various parts of the territory and to the discovery, in Death Valley, of enormous deposits that far excel those now being worked near Daggett.

The borax of Death Valley, as well as that near Daggett, occurs in a regular stratum, interbedded with the semi-indurated sands and clays that make up the bulk of the strata. These beds are generally regarded as of Tertiary age, and they are supposed to have been deposited in inclosed bodies of water.

Since the bedded deposits of borax always occur in association with strata of this character, it is probable that careful study and search will reveal deposits of this nature in localities other than Death Valley and Daggett.

For the purpose of locating outcrops of lake beds and studying their relations and contents, the writer made a rapid reconnaissance across southern California in the spring of 1900. The trip was too hastily made to permit of detailed examinations or of observations much beyond the line of travel, but many facts were found which have a bearing upon the occurrence of borax and its distribution, and these are embodied in the following paper. Of necessity the writer does not enter into a systematic treatise of the subject, but presents, in the form of an itinerary, the data gathered during this trip.

GENERAL DESCRIPTION OF THE REGION.

Mohave Desert is located in Kern, Los Angeles, and San Bernardino counties, Cal. It lies in the angle between the Sierra Madre on the south and the Sierra Nevada on the west. From these bounding mountain walls it stretches eastward to Colorado River and northward to Death Valley.

This desert forms a part of the Great Basin. It is extremely arid and has no well-determined drainage lines. The few small streams that drain the snow-capped mountains on the border of the desert flow toward the interior, and are soon lost in the arid plains through which they flow.

The surface is considerably diversified. In the western end it is generally regular and nearly level, but in the remaining parts it is composed of isolated knobs and short ranges of mountains having no noticeable system of arrangement and separating stretches of desert composed of vast alluvial fans and playas.

Toward the north the mountains become more prominent, and in Inyo County form ranges which have a definite though somewhat complicated system of arrangement. North-south ranges are the most prominent in this region, but a second system trending northwest and southeast unites with the former, giving to the country a peculiar crossbarred appearance.

The most noted surface feature of the region is Death Valley, which lies 50 miles east of the Sierra Nevada and only a few miles west of the Nevada State line. This valley has a length of about 50 miles and an average width of from 5 to 10 miles. At the lowest point its floor is supposed to be about 480 feet below sea level, while on either side tower rugged mountains which reach nearly to the region of perpetual snow. Funeral Mountain, on the east, is supposed to have an altitude of from 5,000 to 7,000 feet, while Panamint Mountain, on the west, rises to an altitude of over 10,000 feet. Death Valley is not only the lowest point in the surface of the United States, but it is also regarded as the hottest place in the country. At the ranch maintained near the mouth of Furnace Creek by the Pacific Coast Borax Company the summer temperature is reported to reach 137° in the shade; but by means of a double roof and running water, habitation is rendered possible even in this intense heat.

Death Valley received its sinister name from the fact that in 1849 a band of emigrants wandered into the valley and most of them perished from thirst before an avenue of escape was discovered. Periodically tales of the suffering and death of travelers who have attempted to cross the valley are revived and widely circulated, but these are generally exaggerated, and should be accepted with considerable allowance.

Mohave Desert and the Death Valley region are desolate in the extreme, but wherever sufficient water can be obtained ranches have been established, and their brilliant green is a welcome sight to the traveler, weary of the interminable desert waste and the dark, forbidding mountains.

GEOLOGY ALONG ROUTE TRAVERSED.

SAN BERNARDINO TO PAHRUMP VALLEY.

After outfitting at San Bernardino the writer proceeded north across the range of mountains that separates the valley of southern California from Mohave Desert. The route lay up Cajon Canyon, on the main road through the pass of the same name.

Cajon Canyon.—This canyon cuts entirely across the range, following, in a general way, fault lines along which extensive movements have taken place in recent geologic time. The major fault extends in a northwest-southeast direction, cutting across the range at a very low angle. This fault apparently bounds the San Bernardino Mountains on the south in the vicinity of Arrowhead Springs. From this point it extends in a nearly straight line up Cajon and Lone Pine canyons, and finally it reaches the edge of Mohave Desert in the vicinity of Rock Creek.

So far as could be determined from the débris brought down the canyons, the high mountains south of the fault are composed of dark-green hornblende-schist, and the low ridges north of the fault are made up of coarse gray granite, with occasional outcrops of white marble and other highly metamorphosed sedimentary rocks.

North of the granite hills lies an obscurely marked valley, separating the granite range from immense accumulations of gravel which lie upon the southern edge of Mohave Desert. The origin of this valley is not well understood, but it seems possible that a fault has occurred along this line, and that the mountain on the south has dropped away from the gravel that formerly rested upon its flanks.

At the intersection of Lone Pine and Cajon canyons the granite range is replaced by low hills of sandstone and conglomerate. This formation occupies a rudely triangular area on the west side of the creek, and at the extremities of the outcrop the beds extend across the stream and are visible for a short distance in the eastern wall of the canyon.

The beds are made up of granitic débris in which feldspar fragments are so abundant as to give the rocks a decidedly pinkish tinge. Coarse, well-rounded gravel is abundant, and waterworn bowlders 12 inches in diameter are of common occurrence at certain horizons. Some of the beds are sufficiently indurated to stand up in prominent cliffs, but most of them disintegrate readily into coarse sand and gravel. The rocks are considerably disturbed, being thrown into anticlines and synclines with dips of from 10° to 30°.

The age of this formation is not definitely known. Fossil shells are reported as occurring in beds associated with a coal seam near the base of the series, but the writer was unable to find the locality, and search in another portion of the series was not rewarded by fossils of any kind. Marine Eocene fossils have been found in similar rocks on Rock Creek, and the fossiliferous beds, according to report, are associated with coal.[a] Similar fossils are reported from other localities in the southwestern end of Mohave Desert. It seems probable, therefore, that these various outcrops, which hold similar positions relative to the old granitic land mass and are composed of the same kind of material, were deposited at the same time and in the same body of water.

The data at hand are not sufficient to enable one to determine whether the crustal movements which tilted these beds into their present position, and which presumably occurred soon after their deposition, were common to the entire Mohave Desert region or were limited

[a] J. E. Spurr, unpublished manuscript.

to this range of mountains. It seems probable that movements so profound would have an appreciable effect on sediments lying on the southern edge of the desert, but no such effect is seen in the horizontal lake deposits 8 or 10 miles north of Cajon Pass. It is therefore probable that the beds in Cajon Canyon were deposited and folded prior to the existence of a lake in the desert near Victor.

That this region has undergone profound changes since the disappearance of the lake in the vicinity of Victor is shown by the elevation of the great mountain mass south of the Lone Pine Canyon fault to its present position, by the accumulation of gravel on the southern margin of the desert to a thickness of 1,000 feet, and by the depression of the granite range several hundred feet below its former level.

Mohave Desert or Victor.—The summit of Cajon Pass has an altitude of 4,100 feet, and it is formed of the gravel beds just described. In passing into the desert the road descends over the surface of the gravel at the rate of about 100 feet per mile. The gravel grows gradually thinner and finally disappears, leaving the surface composed of beds of fine material, lying in a horizontal position.

These beds are made up of sand and clay sufficiently indurated to stand up in nearly vertical cliffs along Mohave River. They carry alkaline salts, but, so far as known, no borax has been found in them. The presence of alkaline deposits seems to indicate clearly that the body of water in which they were deposited lay in an inclosed basin, and that at times the aridity of the climate was so great as to cause the water to evaporate, leaving its alkaline constituents on the floor of the basin.

No fossils have been found by which to determine the geologic age of these beds. They have been classed as Eocene and correlated with beds of this age in the western end of Mohave Desert; but the latter carry a marine fauna, and are therefore not necessarily of the same age as the lake beds at Victor. As previously mentioned, the writer feels inclined to correlate the marine Eocene of the western Mohave Desert region with the beds in Cajon Canyon and to refer the lake beds of Victor to a later epoch. It seems possible that Victor Lake was one of a long string of lakes reaching across the country just east of the Sierra Nevada, which Mr. Clarence King[a] called the Pah-Ute Lake of the Miocene epoch; or it may have been in existence during the deposition of similar beds north of Owens Lake, in which Mr. Walcott discovered fossils of Pliocene age.[b]

At Victor the lake beds are confined to the territory lying west of Mohave River. According to Mr. Spurr[c] this relation holds down the river at least as far as the point where the course changes from

[a] U. S. Geol. Expl. Fortieth Par., Vol. I, p. 454.

[b] The post-Pleistocene elevation of the Inyo Range and the lake beds of Waucobi embayment, Inyo County, Cal.: Jour. Geol., Vol. V, pp. 340–349.

[c] Unpublished manuscript.

north to northeast. Beyond this point the conditions are unknown. Mr. Spurr also reports that lake beds show at intervals along the road from Harper to Randsburg, nearly as far as Fremont Peak. North of the Santa Fe Railway the beds are disturbed, dipping generally to the south from 10° to 15°. Since the connection between these beds and the horizontal sediment about Victor has not been determined, it is uncertain whether they are of the same age or whether the tilted beds belong to the older or Eocene series.

Daggett.—In order to obtain information regarding the eastward extent of these beds, the writer crossed from Victor to Daggett by the old stage road which runs by Stoddard Wells, 15 miles east of Mohave River. For a distance of 28 miles no lake beds were encountered. The country is generally mountainous, the valleys are comparatively narrow, and the rocks are either igneous or highly metamorphosed sedimentaries.

From Stoddard Wells the road follows a direct course N. 20° E. until it emerges into the valley of Mohave River 5 miles west of Daggett. A belt of Tertiary rocks having a width of about 1¼ miles is crossed by the road 4 miles south of this bend. The rocks are composed generally of fine clay and sand, containing a large amount of gypsum and other salts. Several thick beds of limestone were noted, which appear to have been the result of chemical deposition. The lower beds are composed of fragmental material; but in the upper part of the series occur many lava sheets which preserve the beds in high, even-crested ridges. This belt of rocks extends in a nearly east-west direction. The strata have been gently tilted along an axis running in the same direction, so that they now dip to the north about 5°.

The ridge formed by these beds appeared to extend westward for a distance of only a mile or two, and then to die out in the even expanse of desert which presumably extends to Mohave River. Toward the east the lake beds extend indefinitely. The question of the relation of these beds to the horizontal strata west of Mohave River is most interesting, and an examination of the western end of the beds just described might throw light on the relative age of these deposits.

Heavy deposits of gravel occur on the northern slope of the Tertiary ridge. They rest upon the lake beds in such a manner as to suggest that the northward slope of the surface is a structural feature due to the tilting of a block of strata in that direction. If that is true, these lake beds probably underlie the Mohave River Valley in this vicinity.

No borax was seen in this deposit, but the presence of other salts makes it seem probable that borax also is present. It was learned at Daggett that small deposits of borates occur there, but these reports were not verified.

Borate.—The principal deposit of boron salts occurs at Borate, about 12 miles north of Daggett, in the vicinity of the old Calico mining district. The mineral found here is borate of lime, or colemanite, and it occurs as a bedded deposit from 5 to 30 feet in thickness, interstratified in lake sediments. These lake beds are composed of semi-indurated clays, sandstones, and coarse conglomerates, with intercalated sheets of volcanic tuff and lava. The rocks are severely folded, the axes of the folds lying in an east-west direction. The lake beds extend in the same direction across the mountains for a distance of about 8 miles. It has been supposed that these deposits probably continue westward under the Pleistocene drift of the desert, but there is no evidence at hand to prove such an assertion. In fact, the lake beds at Borate do not come down to the foothills of the mountain; they are cut off and infolded with the crystalline rocks of the Calico district. Lake beds are present west of Calico Valley, and a bed of colemanite has been struck in a shaft in this locality at a depth of 200 feet.[a] Although the colemanite is interbedded with sand and clay, it is not coextensive with these strata. As a traceable bed it probably extends for a distance of a mile and a half; beyond this limit it is very thin, and in many places it is wanting in the section. At the Borate mine there are two outcrops of colemanite, either on parallel beds or on one bed that has been so closely folded as to give two parallel layers about 50 feet apart. The beds strike approximately east and west, and dip to the south from 10° to 45°. A railroad connects the mine with the mill, which is located on the west side of the mountain, and also with the Sante Fe Railway at Daggett.

South end of Death Valley.—From Daggett the route lay to the northeast, along the old Amargosa borax road and through a part of the country not heretofore described in any geologic report. The rocks are generally granitic, with here and there small areas of highly metamorphosed sedimentary beds. In the descent from Cave Wells into Death Valley, lake sediments were seen on the left of the road. These are identical in composition with the beds near Daggett. Many of them are strongly alkaline, but no beds of colemanite were seen. Later it was learned at Resting Spring that these sediments contain a bed of pure rock salt about 60 feet in thickness.

The beds composing this series strike northwest and southeast, and dip about 20° toward the northeast, or toward Death Valley. The northwestward extent of the deposit is not well known. As seen from Saratoga Spring, the rocks in the Owls Head peak resemble lake sediments with intercalated sheets of dark lava. The distance is too great to determine this with certainty; but it is, in a measure, corroborated by the occurrence, reported by Mr. Spurr,[b] of similar beds on the flanks of the Panamint Range at Windy Gap.

At many points in the Panamint Range south of Emigrant Canyon there are traces of recent and profound movement, and it seems altogether possible that the lake in which these sediments were deposited occupied a valley trending in a northwest-southeast direction across

[a] California Mining Bureau Report, Vol. XII, p. 35. [b] Unpublished manuscript.

the southern end of the Panamint Range. Structure lines following this direction are common in the Death Valley region, and they will be discussed more fully in connection with the Furnace Creek deposits of the northern end of the valley.

The rocks composing the southern end of Funeral Mountain are well exposed at Saratoga Spring.[a] They strike north and south, and dip to the east about 50°. They are limestone, shale, and quartzite, presumably of Cambrian or pre-Cambrian age. Several hours were spent in searching for fossils in these beds, but none were found.

The road to Resting Spring runs diagonally across this mountain to the northeast, following a fault that has sheared across the ends of the tilted strata forming the end of the mountain. North of the fault line similar rocks strike N. 60° E., and stand nearly vertical. Funeral Mountain was examined carefully through a strong glass to see if any Tertiary rocks exist in the southern part of the range, but nothing was seen that suggested their presence. Strata resembling that exposed at Saratoga Spring could be traced northward for several miles into the high summits, where they appeared to be broken and replaced by intrusive masses that form the bulk of the mountain.

The summit of the pass through which this road runs is at an altitude of about 1,700 feet above Saratoga Spring, which is probably not far from sea level. The pass is deeply covered with gravel, which extends down the eastern slope, completely concealing the bedded rock on this side of the mountain.

Amargosa Valley at Resting Spring.—Lake sediments fill the Amargosa River Valley in the vicinity of Resting Spring. These beds are composed of sand and clay, but there are no beds of volcanic tuff or sheets of lava such as are found in many areas of similar beds. In this respect they resemble the lake beds in the vicinity of Victor, and it seems possible that they are of the same age. These beds are approximately horizontal, and in this respect they also resemble the Victor sediments.

The lake in which these beds were deposited was limited on the south by a rock barrier across the valley 3 or 4 miles south of the old borax works. The northern extremity was not seen, but lake sediments are reported to extend in that direction for a distance of only 6 or 8 miles. Toward the east the water reached beyond Resting Spring, and a narrow arm of the lake existed in the valley at the base of Kingston Mountain.

Although these beds are not folded, they bear evidence of considerable crustal movement since their deposition. The eastern margin that rests against the foot of the Kingston Range is 800 feet higher than the uppermost beds of the same series at the foot of Funeral Mountain. This indicates a depression toward the west in the direction of Death Valley. There seems to have been a local subsidence in

[a] See section by Gilbert in U. S. Geog. Surv. W. One Hundredth Mer., Vol. III, 1875, pp. 34, 170.

the middle of the lake also, for a small island shows the uppermost lake beds at a lower altitude than they appear on the western side of the basin.

The lake basin was apparently silted up to the level of the outlet, and since then Amargosa River has cut its way through the rocky barrier on the south and trenched the sediments to a depth of 150 feet. Evidently drainage conditions changed about the time the basin was filled, giving to Amargosa River sufficient fall or sufficient volume to trench its barrier at least 150 feet. It seems possible that the change was due to the sinking of Death Valley to its present position below sea level and 1,200 feet below the level of the lake near Resting Spring. The tilting of the sediments of this lake toward the west presumably was effected by the subsidence of Death Valley, and since this downward movement evidently postdates the period in which the lake beds of Death Valley were folded, it seems probable that the lake in Amargosa Valley was of late Tertiary age, and that it constituted one of the chain of lakes to which reference has been made.

The sediments deposited in this lake are strongly alkaline, but no deposit of borax was seen, nor are any reported from this locality. The borax works which flourished for a time in this basin depended, according to report, upon the marsh of Amargosa River for their supply of crude material. The borax on the marsh is probably derived from erosion of beds of colemanite in the northern end of Funeral Mountain, and since this erosion was presumably in progress during the deposition of the sediments about Resting Spring, it is altogether probable that beds of this mineral occur intercalated with the sediments of the lake. The occurrence of the borax in regular beds or its dissemination through the clay doubtless depends upon the degree of aridity of the climate during the existence of the lake. From the large amount of alkaline salts now visible in these sediments, it seems probable that the climate was sufficiently arid at times to cause the water to be largely evaporated, leaving its mineral contents as a crust on the bottom of its basin. It would not, therefore, be surprising to find in these sediments beds of borax derived from the great deposits of Funeral Mountain. Before the discovery of the bed of colemanite near the railroad the Amargosa works were of considerable importance. A wagon road was built between this point and Daggett and wells were dug and relay stations were established along the route, but the opening of mines on the bedded colemanite put an end to operations in Amargosa Valley.

So far as known, lake sediments do not occur east of this point. If a lake ever existed in Pahrump Valley its sediments have never been exposed by crustal movements, and they lie undisturbed in the bottom of the valley.

PAHRUMP VALLEY TO OWENS LAKE.

Amargosa Valley near Ash Meadows.—Near the California-Nevada State line Amargosa Valley was occupied by another lake, the sediments of which are to be seen on the road from Pahrump Valley to Furnace Creek in Death Valley.

The beds are similar in composition to those about Resting Spring, but the stream has not succeeded in cutting away the barrier that ponded the water, and the beds are only slightly dissected. The barrier at the lower end of the lake was presumably only a few miles south of the road, but to the north the water may have extended far into Amargosa Desert.

The easternmost exposure of these beds is at an altitude (barometer) of about 2,200 feet. From this they descend westward to about 1,850 feet at Amargosa River. This inclination is about the same as that which marks the beds near Resting Spring; hence the movement that produced it was probably common to the region east of Death Valley. These beds are not visible west of Amargosa River, but it is altogether probable that they rest against the foothills of Funeral Mountain. Since in this locality the mountain is composed of folded Tertiary rocks striking northwest and southeast, it is apparent that the two series are of different ages, and that the lakes which occupied Amargosa Valley came into existence after the disappearance of the lake in the north end of Death Valley and after the folding and elevation of its sediments into Funeral Mountain. This coincides with the statements heretofore made that lake-forming conditions appear to have prevailed at least during two distinct periods, the first of which may have been in the Eocene period and the last in Pliocene time.

Furnace Creek in Death Valley.—By far the greatest exposure of lake beds, and also the largest deposits of borax that are known, occur in Funeral Mountain, or, as they are more generally described, on Furnace Creek in Death Valley. These sediments lie diagonally across Funeral Mountain, in a belt whose reported width is 12 or 15 miles. On the north they are limited by an abrupt mountain wall of Paleozoic limestones, shales, and quartzites, which stand from 3,000 to 4,000 feet above the general level of the Tertiary hills on the south. The Paleozoic strata comprising this mountain front strike at right angles to the direction of the mountain face, and dip generally to the southeast from 30° to 60°. So far as could be determined without climbing, this escarpment extends in a straight line across the mountain, and it coincides in direction and presumably is continuous with the foot of the mountain which bounds Death and Mesquite valleys on the northeast. It undoubtedly marks the position of one of the great faults of the region, which extends parallel with the great structural features of central California.

From the character of the Tertiary sediments it seems probable that they were largely derived from the Paleozoic rocks composing the escarpment, consequently the movement that produced the scarp antedated the lake, and it is altogether possible that the valley in which the waters accumulated was formed by this movement. There are also some indications that recent movements have occurred along the same line; in fact, the general tilting of the Tertiary rocks to the northeast may be due to a recent depression on the south side of this fault line, or to the tilting down toward the northeast of the block of strata that originally formed the floor of the lake. The southern edge of these deposits has not been examined. It is reported, on what seems to be good authority, that the lake beds extend south from the forks of Furnace Creek for a distance of only 8 or 10 miles; it therefore seems highly probable that the territory occupied by these beds is narrow, and that originally it was the southeastern extension of Mesquite Valley.

As previously stated, the mountains and valleys of the Death Valley region appear originally to have trended northwest and southeast, and at a later date crustal movements operated in a north-south direction, dropping or tilting large blocks of strata and forming a new set of features at an angle of about 60° from the original lines.

The range of mountains on the east side of Death and Mesquite valleys is separated into two parts by the low gap formed on the lake beds. The mass lying north of these sediments is known as Grapevine Mountain, and that to the south, including the lake beds, is called Funeral Mountain.

The lake sediments of this region are similar to those previously described. They are composed of clay, sand, and gravel, with many beds of volcanic tuff and intrusive lava sheets toward the base of the series. Coarse gravel abounds near the contact between these beds and the Paleozoic rocks of Grapevine Mountain, showing that at the time of deposition this was a shore or boundary wall of the valley in which the lake was located. The strike of the beds is parallel with the northeastern margin, and the dip is 20° to 45° toward the northeast. The beds maintain this attitude on both sides of the range, and they do not dip under the valleys on either side, as they have been supposed to do.

Interbedded with the rocks of this series is a bed of colemanite (borate of lime), which, though probably not continuous, shows in outcrop in a number of places across the mountain, a distance of at least 25 miles. This constitutes the largest deposit known in this country, and presumably the largest in the world. The bed has been opened low in the foothills on the east side of the mountain 4 or 5 miles south of the Ash Meadows road. At this point the bed is visible for several hundred yards, and in the prospect pits it has a thickness of from 4 to 10 feet. It is said to exceed these figures, but no thicker sections were seen. The bed is composed of a mass of crystalline colemanite which mines readily and with little waste.

In the western foothills of Funeral Mountain a bed of this mineral is exposed in the ravines for a distance of a quarter of a mile, and along this outcrop it varies in thickness from a few inches to 20 feet. At no point is it a solid regular bed, but it consists of irregular masses and stringers of colemanite embedded in clay. The crystals are small, seldom exceeding a quarter of an inch in diameter, and the large masses are nearly pure. According to Superintendent Roach, of the Pacific Coast Borax Company, the largest mineral deposit occurs about 9 miles up Furnace Creek on a nearly direct line between the outcrops just described. At this point he reports a bed of boracite 60 feet in thickness. This was not seen by the writer, but there are strong indications of the presence of minerals of this character, and it is probable that large deposits occur in this locality.

Borax was once manufactured 2 or 3 miles north of the point where Furnace Creek emerges from the hills into Death Valley. The plant was situated on the margin of the alkaline marsh, and the crude material was derived from a certain part of the marsh where colemanite accumulated. It is now known that the mineral is derived by solution from the bedded deposit described above, and that its accumulation on a certain part of the marsh is due to the solution being carried to that place by a small stream.

Death Valley contains an immense salt field, which may in time become valuable. It extends south from above the old borax works at least 30 miles. At the place where it is crossed by the road from Furnace Creek to Bennett Wells it is nearly 3 miles wide, and it probably varies from 2 to 4 miles in different parts of the basin. The salt is not white, like the marsh at Salton, in Colorado Desert, but it is brown with dust and sand that is constantly being blown upon it. The salt stands in pinnacles 2 to 3 feet in height, making a surface so rough that it is impassable for a horse until the projections are pounded down with a sledge. With the implements at hand the thickness of the crust could not be determined, but it can not be less than 1 foot of solid salt. A sample collected in the middle of the field on this road shows that the salt is composed of chloride of sodium, 94.54 per cent; chloride of potassium, 0.31 per cent; sulphate of sodium, 3.53 per cent; sulphate of calcium (hydrous), 0.79 per cent; moisture, 0.14 per cent; undissolved residue (gypsum and clay), 0.50 per cent; total, 99.81 per cent. The presence of the large amount of mechanical impurities, as well as the large percentage of sulphate of soda, would render refining necessary before the salt could be placed upon the market, a process that would be very expensive under present conditions of great scarcity of fuel and water and lack of railroad transportation.

Mesquite Valley.—In the northern end of Death Valley proper no lake beds were seen. The bottom of the valley is covered by an alkaline marsh, and this is surrounded by a sloping surface composed of the débris from the mountains. The line dividing Death Valley from Mesquite Valley is composed of low cliffs of lake sediments which appear to reach back under recent deposits, forming the floor of Mesquite Valley. These beds strike northwest and southeast and dip toward the northeast, as do the sediments on Furnace Creek; in fact, they appear originally to have been continuous, but with the connecting part in Death Valley now depressed below the drainage level, leaving the two outcrops separate but with similar strike and dip. No borax beds were seen in this region, but the strata have much the same appearance as the Furnace Creek beds, and careful search may reveal similar mineral contents. The available area of outcrop, however, is small, and hence extensive deposits need not be anticipated.

Panamint Mountain.—The route from Mesquite Valley lay to the south, up Emigrant Canyon, which divides the Panamint Range into two parts that are structurally and topographically separate and distinct. At an altitude of about 2,700 feet above sea level great accumulations of well-rounded gravel were encountered, which are a common feature from this point to the summit of the mountain, that stands at an altitude of about 5,200 feet. The origin of these deposits is a puzzling question. They are distinctly bedded, and the bedding planes dip 10° toward the east. They are interstratified with lava sheets which dip in the same direction, and with beds of white volcanic ash. These beds are traversed by many vertical faults, which can be seen distinctly where there is local induration of the gravel or where there occurs a bed of foreign material, as lava or volcanic ash.

From the traces of bedding in the gravel itself and from the bed of volcanic ash resting conformably upon the gravel beds, it seems probable that the deposit was laid down in water, and that its present altitude and disturbed condition are due to elevation and tilting of the block of strata upon which they rest. Since the dip of the Paleozoic strata composing this block, as well as of the gravel resting upon it, is toward the east, it seems possible that the block may have turned on a horizontal fulcrum, the eastern edge sinking and forming Death Valley and the western edge rising and forming Panamint Mountain. This hypothesis receives some support from the character of the topography of the mountain top. On the east side of the summit, at an altitude of about 4,700 feet, there is a wide flat. The basin is several miles in extent, and it looks like an ordinary stretch of desert transplanted to the summit of a rugged mountain. This topography does not resemble that of other mountains in this district. It appears to be old, and certainly leads to the belief that it was very recently elevated to its present position.

Panamint Valley.—Evidences of recent movement are also to be seen in Panamint Valley. Near the mouth of Wild Rose Canyon occur alkaline lake beds which have a thickness of 130 feet and an altitude above the bottom of the valley of about 1,000 feet. These were visible at only one point, presumably being generally covered by immense deposits of water-laid gravel several hundred feet in thickness. A similar deposit of gravel 500 feet in height occurs at Bellerat; it rises toward the east, and at the base of Telescope Mountain reaches an altitude of 1,000 feet above the valley floor. From the latter point wave-cut terraces extend south along the flank of the mountain for a distance of several miles. These shore lines and gravel deposits slope distinctly northward, while those at Wild Rose Canyon descend sharply toward the south. These facts seem to agree with the evidence already presented in showing that Panamint Mountain has recently been considerably elevated, at least at its extremities, but they also seem to indicate that its middle part has remained stationary or has recently subsided.

In this valley there is a small salt field, in the vicinity of Hot Spring, which is similar in appearance to that already described. The salt from this locality is said to excel that of Death Valley, but no tests were made and the report can not be verified.

Owens Lake.—Owens Lake lies in the great valley at the eastern foot of the Sierra Nevada. That this valley has been occupied by a much more extensive lake than exists at present is readily shown by a belt of lake sediments which extends from near Cerro Gordo Peak on the north, around the western flank of Coso Mountain, nearly as far as Little Owens Lake. Where they are crossed by the Darwin road these beds have a width of 8 or 10 miles. In composition they resemble the lake sediments of Funeral Mountain, except that the sandy portion is composed almost exclusively of débris from the coarse, gray granite which abounds in this region. As seen from the road, the uppermost beds are generally fine and wholly clastic, but near the lake an anticline brings to view sheets of black lava and great beds of volcanic tuff. Many of the finer beds show traces of alkaline constituents, but no borax was seen. North of the Darwin road the hills seem to be composed largely of volcanic tuffs, and they are capped by immense sheets of lava, which presumably have been extruded since the uplifting of the lake sediments.

On the eastern margin of this belt the rocks are nearly horizontal, but near the lake they are bent into sharp folds whose axes extend in an approximately north-south direction. In the southern end of the basin the beds rest unconformably against the rocks on the east side of the valley, and they generally dip from 10° to 25° to the west, or against the Sierra Nevada. From the topography in this valley it seems probable that after the lake beds were flexed they were beveled down to a regular surface, in which the present topography is carved.

Colemanite is reported as occurring at Lone Pine, north of Owens Lake, in a bed 1 foot in thickness, but the exact locality was not made public, hence the report could not be verified. Similar beds are also reported near the Darwin road, but nothing definite could be learned regarding them.

OWENS LAKE TO SAN BERNARDINO.

Redrock Canyon.—From Owens Lake the route lay south along the foot of the Sierra Nevada to Mohave station, and thence across Mohave Desert to the foot of the high mountains bordering the desert on the south.

No lake beds were seen on this route after passing Rose Spring, which is located at the southern extremity of the sediments of the Owens Lake basin, until Redrock Canyon was entered west of El Paso Peak. They are well exposed along this canyon for a distance of 6 miles, and dip to the west at an angle of about 20°. The basal portion of the series is composed of coarse, indurated sand, gravel, and volcanic tuff, with intercalated lava sheets. The upper portion is free from volcanic material, and fine clay predominates. Little alkaline material was seen. The beds have the appearance of being deposited near the shore of a large body of water, where such material was not abundant. It seems probable that these beds are connected with the Tertiary beds of El Paso Peak, which, from their contained fossils, are regarded as of Eocene age. It is therefore probable that the series exposed in Redrock Canyon also belongs to the Eocene period.

Mohave Desert.—From Mohave station to the south edge of the desert there are no beds of this character exposed. Buttes of crystalline rock occur at intervals along the route, but there seems to be no opportunity for lake beds to be present, unless they underlie the alkaline flat north of Lancaster. This seems possible from the fact that near this place flowing wells are obtained which probably have their origin in gravel beds from 200 to 300 feet below the surface.

From Lancaster the foot of the mountain was followed to the east as far as Sheep Creek Canyon. Throughout most of this interval the foothills are composed of coarse gray granite, against which rests the Pleistocene gravel that covers and conceals the desert floor.

At Sheep Creek the road crosses the mountain to the head of Lone Pine Canyon. It follows the latter to its junction with Cajon Canyon, where it unites with the road traversed at an earlier date.

RÉSUMÉ.

From the observations noted above and from descriptions of other geologists, it is apparent that lake sediments occur throughout a wide extent of territory in the Great Basin region. Some writers have supposed that the various outcrops are parts of one extensive sheet of sediment which was deposited in a widespread but shallow lake, and consequently that they are all of the same age.

The data gathered during the present reconnaissance shows that such is not the case. From the character and arrangement of the material composing these beds, it is apparent that most of the lakes occupied valleys, the bounding walls of which may be seen to-day with the coarse detrital material of the lake beds at their feet. As previously mentioned, the lakes undoubtedly existed at different geologic epochs, and from data now at hand it seems probable that lake-forming conditions existed practically throughout the Tertiary period (Eocene, Miocene, and Pliocene); but sedimentation was interrupted at intervals by violent crustal movement that tilted the earlier sediments and materially changed the topography of the country.

The conditions which led to the formation of many lakes in the past were certainly climatic. The climate was less arid, for at the present time lakes exist in this region only where they receive drainage from extensive mountain masses that receive more moisture than the average for the region. The aridity of the climate appears to have varied from time to time, producing variations in the character of the sediments being deposited. At times the water seems to have evaporated, leaving its mineral constituents in the form of beds of salt, soda, gypsum, and borax. Again, the lake was filled and beds of sand or mud covered the mineral deposits and preserved them for future use. It is possible that the existence of such mineral deposits does not mean the complete evaporation of the lake, but the conditions were similar to those prevailing to-day about Owens Lake and Great Salt Lake, where extensive alkaline deposits are accumulating.

The conditions which prevailed in this region during Pleistocene time have not been satisfactorily determined. They are evidently recorded in the great accumulations of unconsolidated gravel that occur at many points in Mohave Desert and the Death Valley region. These deposits have been regarded as indicative of lake conditions, as have also the salt fields of Death Valley and adjacent localities, but the evidence is far from conclusive.

It is well known that large lakes, like Bonneville and Lahontan, existed in the Great Basin in Pleistocene time, but these lakes, although transient, left unmistakable evidence of their existence in the form of sediments and terraces around the margins of their basins.

In Death Valley no such features have been recognized. If they were formed they have been so masked and disarranged by recent earth movements as to have escaped detection. It seems possible to explain the salt field of this valley by the evaporation of saline water brought in by Amargosa River in the period of floods which occasionally affect that stream, but which are not of so frequent occurrence as to produce a lake in Death Valley.

The evidence at hand is too meager to warrant the writer to attempt to present an outline of the Pleistocene history of this region; it can be done only after a more detailed study of the geology and physiography of the region.

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