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A RECONNAISSANCE

OF THE

GYPSUM DEPOSITS OF CALIFORNIA

BY

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WITH A NOTE ON

ERRORS IN THE CHEMICAL ANALYSIS OF GYPSUM

BY

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A RECONNAISSANCE OF THE GYPSUM DEPOSITS OF CALIFORNIA.

By Frank L. Hess.

INTRODUCTION.

The growing use of gypsum as wall plaster (hard plaster) and in cement, as well as for minor uses, such as in stucco and as a fertilizer, has created a large demand for knowledge of gypsum deposits. In most States such knowledge is more easily obtained than in California, where the gypsum deposits are largely in long stretches of sparsely inhabited regions in the nearly arid territory along the east side of the Coast Range and in the Mohave and Colorado deserts.

Little has been published about the deposits, and accurate information concerning them is not easy to obtain. The only works known to the writer that treat of the gypsum deposits of the State are listed below, and in each of these the information is meager:

Irelan, William, Jr. Eighth Annual Report of the State Mineralogist, Sacramento, 1888, pp. 538, 688.

Gives a short description of the gypsum deposits at Point Sal, Santa Barbara County. Dr. Stephen Bowers gives a description of a gypsum deposit in the Ojai Valley, Ventura County, which is repeated in Fairbanks's report.

Hobson, J. B. Point Sal gypsum mines: Tenth Ann. Rept. State Mineralogist, Sacramento, 1890, p. 601.

Gives a cross section of the rocks, including gypsum deposits, at Point Sal. No description is given.

——— Eleventh Annual Report of the California State Mineralogist, 1892.

Mention is made of gypsum deposits in Kern, Los Angeles, San Benito, and San Bernardino counties. The descriptions lack detail and are unimportant.

Crawford, J. J. Twelfth report of the State Mineralogist, Sacramento, 1894, pp. 323–325.

Short descriptions of gypsum deposits in a number of counties of the State.

——— Thirteenth Report of the State Mineralogist, Sacramento, 1896, pp. 503–504.

Gives a brief notice of a number of the gypsum deposits of the State.

Fairbanks, H. W. Gypsum deposits in California (in "Gypsum deposits in the United States"): Bull. U. S. Geol. Survey No. 223, 1904, pp. 118–123, 1 map.

Includes a few general remarks upon the gypsum deposits of the State and brief memoranda upon the individual deposits.

Aubury, Lewis E. The structural and industrial materials of California: Bull. California State Min. Bur. No. 38, 1906, pp. 281–288.

Gives a short general description of gypsum; its uses; methods of manufacture of plaster of Paris; distribution of gypsum deposits in the State; a catalogue of occurrences and their owners; and brief accounts of the deposits. Little geologic description is attempted.

In an endeavor to supplement what was known the writer spent a part of the winter of 1906–7 in a reconnaissance of various gypsum-bearing localities of the State. The time and money available did not permit visits to several other areas where deposits of more or less importance are said to occur, and for lack of time the deposits visited could not be examined in detail.

DISTRIBUTION OF THE DEPOSITS.

The gypsum deposits that give promise of possible commercial importance are south of San Francisco Bay (see Pl. I), and most of them are associated with Tertiary strata; a few occur in Pleistocene beds. Many deposits are found in the Coast Range, from San Benito County southward into Los Angeles County. These deposits are generally shallow, are covered by a thin skin of soil, or lie on the surfaces of knobs or ridges, with here and there one on a hill slope or in a ravine, and are of the variety known as gypsite.

At Point Sal, Santa Barbara County, and at Palmdale, Lang, and Castaic, Los Angeles County, gypsiferous strata interbedded with clayey material have been worked. Beds that seem, from the descriptions obtainable, to have the same general characteristics as these occur at several points in the Colorado Desert.

In the San Joaquin Valley, in the Mohave Desert, and probably in the Colorado Desert are many areas that become lake beds during wet seasons, and some of these beds carry considerable deposits of gypsum. Such deposits do not exist in all the periodic lake beds, and whether they form depends on the nature of the rocks drained by the streams feeding the lakes. In the Palen Mountains, between the Colorado and Mohave deserts, there are said to be large deposits of alabaster, which appear to be the only extensive beds of the kind in the State.

CLIMATE.

The climate of all that portion of California which contains the gypsum deposits described in this report is so dry that the most moist of the lands are semiarid and the less favored portions are arid. Along the west side of the San Joaquin Valley, in the lower hills of the Coast Range, temperatures of 110° to 125° F. are frequently recorded in summer, while in the Mohave Desert, according to common report, these temperatures are exceeded. Iron lying on the ground in the sun during the summer can not be handled with the bare hand without great discomfort. The soil, and especially the sand, gets so hot that it is painful to the newcomer to walk in it.

The seasons are often spoken of as wet and dry, because nearly all the rain that falls in the region comes during late autumn, win-

MAP SHOWING DISTRIBUTION OF GYPSUM DEPOSITS IN CALIFORNIA.

ter, and early spring. However, the wettest winters are probably not so damp as the summer season in the eastern portion of the United States. Naturally, with such heat and such dearth of rain the humidity is low in summer, so that water evaporates very rapidly and the rocks are quickly dried, the water being drawn out of them for great depths. These climatic conditions have much to do with the formation of the gypsum deposits, and will be referred to in the descriptions of the deposits.

IMPORTANCE, CLASSIFICATION, AND DERIVATION OF THE DEPOSITS.

The importance of the gypsum deposits as possible objects for commercial exploitation can be discussed to advantage by considering at the same time their derivation. The deposits fall naturally into four groups, according to their origin—(1) efflorescent deposits, (2) periodic-lake deposits, (3) interbedded deposits, and (4) veins.

Efflorescent deposits.—The deposits of the first group are formed by the evaporation of water that has percolated through gypsiferous sandstones or shales. The gypsum thus formed is of the variety known as gypsite.[a] It is buff or creamy to rust colored, soft, and easily crumbled in the hands. Some of it is so powdery that it resembles wood ashes, and is frequently referred to as "amorphous." Under a microscope, however, it is seen to be made up of small plates of gypsum that are entirely crystalline. It is easily worked with a pick and shovel, and many deposits can be dug with a spade or stiff shovel alone. A deposit near McKittrick is worked by first plowing and then handling with a horse scraper.

Nearly all these deposits are thin and of rather narrow extent, though some of them are 10 to 15 feet thick and have an area of several acres. Most of the deposits lie on the tops of hills or ridges. Owing to the small area of most of the individual deposits they are of economic value at only a few places.

Periodic-lake deposits.—Deposits have been formed in some places by the crystallization of gypsum from the waters of intermittent shallow lakes. The material of these beds is generally granular and crystalline, the particles ranging from minute specks to grains one-quarter inch in breadth, and thin in proportion. These deposits are locally of economic importance, and one is worked at Amboy, in the Mohave Desert. The mode of formation of these deposits is described on pages 24–25.

[a] In this report the term "gypsite" will be applied to those unconsolidated gypsum deposits in which the gypsum is so finely divided that individual grains are not readily discernible to the eye. Other deposits of the mineral will be called gypsum, alabaster, or selenite, as may seem most fitly to apply to the particular variety under consideration.

Interbedded deposits.—The interbedded gypsum deposits of California are of two principal varieties. One that is now worked at Palmdale is composed of thin beds of somewhat impure gypsum, in thickness ranging from a fraction of an inch to 3 or 4 inches, interstratified with much more impure clayey material. Such deposits were probably formed by precipitation from a shallow sea into which large amounts of sediment were poured. At only a few places are the deposits sufficiently pure and large to be worked.

A second variety is composed of thick, interbedded strata, taking the form of alabaster, very pure and white in color. Naturally, the two varieties grade into each other, as at Point Sal, where in places the gypsum is clear and white, while at others it is of the clayey form mined at Palmdale and Castaic, Los Angeles County.

Of deposits of the second variety, only those in the Palen Mountains are known, and a railroad is not at present near enough to these to permit them to be worked at a profit.

Veins.—Gypsum veins are of the variety often known as selenite, in which the gypsum is crystalline and glassy, occasionally taking a finely columnar form, known as satin spar. Such veins are formed by the solution of gypsum from the surrounding rocks or from other deposits, the material being reprecipitated in cracks through the rocks. No veins of commercial importance are known to exist in the State.

DESCRIPTION OF DEPOSITS IN DETAIL.

EFFLORESCENT DEPOSITS.

GENERAL STATEMENT.

The efflorescent deposits lie along the Coast Range, extending southward from San Benito County to Los Angeles County in an area that is nearly coincident with the Tertiary sandstones and shales throughout this region.

It was not possible to visit all the deposits, but enough were examined to permit general conclusions to be drawn as to all of them. Their derivation and geology are of great importance in determining their extent. They have heretofore been regarded as interbedded deposits,[a] but such a view gives an erroneous idea of their probable extent, for, if they are efflorescent, instead of reaching to an unknown depth, they can be but shallow, and differences in composition of the parent rock, in its depth of covering, in the position of the deposit with regard to drainage, and in the surface exposed to solution through the fine division of the mass all tend to narrow their extent.

[a] Fairbanks, H. W., Gypsum deposits in California: Bull. U. S. Geol. Survey No. 223, 1904, pp. 118-123, 1 map. Also various California state mining reports.

DEPOSITS BETWEEN MENDOTA AND THE LOST HILLS.

PAOLI MINE.

The deposit that has been called the Paoli mine is in Fresno County, on a ridge on the north side of Tomey Creek, 18 miles southwest of Mendota, in the SW. ¼ sec. 1, T. 16 S., R. 12 E., Mount Diablo base and meridian, and adjacent lands. It lies from 400 to 800 feet (barometric measurement) above the floor of the valley. Tomey Creek, which flows by the foot of the hill, carries water only during wet seasons and empties on the plain a mile or two farther east.

The outcrops of gypsite begin on a low hill less than 100 feet above the creek bed, and occur over a large part of the crest of a gradually rising ridge for nearly a mile. The rocks are soft and clayey, containing fine sand with interspersed pebbles of chert, igneous rocks, and glaucophane schists. There are occasional thin beds of diatomaceous shales, and beds of sandstone containing large numbers of Tertiary barnacles. The dip is about northeast, at angles ranging from 15° to 30°. The hills here are largely structural, with abrupt faces on the southwest and gentler slopes on the northeast. The gypsite occurs on the edges of the softer layers in irregular deposits whose distribution is due almost entirely to the strike and width of the outcrops. From the main ridge following Tomey Creek four other ridges extend like fingers to the north, and gypsite deposits are found on these at a number of places. Gypsite is found also at several points in the intervening gulches beneath a thin layer of soil. The thickness of the deposits is hard to determine, as they had been cut through at only a few points, but it appears to run from 3 to possibly 15 feet. The latter depth, however, if reached at any place is exceptional, and the average depth probably does not much exceed 3 feet.

On the theory that the deposits were interbedded, a short tunnel was run into the hill 30 or 40 feet below one of the deposits, but it encountered only a friable sandstone.

The gypsite is of a creamy or buff color and can be worked with a pick and shovel—at many places with a shovel alone. At some points it has been partially dissolved and reprecipitated, so that it is considerably hardened, but the hardened part is not more than a few inches thick and can be readily worked with a pick. The gypsite is easily crushed and most of it could be handled by screening without crushing. Ordinarily the gypsite is covered by a few inches of soil, below which for a few inches it is very free from foreign matter, containing occasional pebbles of the same sort as those found in the sandstone. These pebbles increase in number downward. At a depth of 2 or 3 feet they become abundant, and at a greater depth the gypsite forms the smaller part of the mass, the larger part

being the sandstone of the underlying rock. In the gulches there are places to which the gypsite has been washed from the ridges by freshets and in which it now forms deposits several feet thick, though sufficient prospecting has not been done to show their exact dimensions. There is almost no gypsite on the sides of the hills, its absence being due probably to its solution and washing away by rain water. The gypsite remains on the tops of the hills, but on their sides, which receive not only the falling rain but the run-off from the upper parts of the hills, it is dissolved and carried away. Occasional torrential rains carry the gypsite from above and deposit it in the valleys so quickly that it is not dissolved, but is moved like so much earth or sand. Deposits in the gulches are rare and are generally mixed with considerable earth.

A specimen of the purer material from the Mendota No. 1 claim was analyzed by E. C. Sullivan, of the United States Geological Survey's chemical laboratory, with the following result:

Partial analysis of gypsite from north side of Tomey Creek, Fresno County, Cal.

Lime (CaO)	28.3
Sulphur trioxide (SO_3)	39.5
Water driven off at 60° C	.3
Water driven off at 300° C	18.6
Chlorine (Cl)	Trace.
Iron oxide (Fe_2O_3)	.6

This is equivalent to 85 per cent of gypsum. In 1894 [a] E. W. Hilgard published the following analyses of specimens from these deposits:

Analyses of gypsite from Tomey Creek, Fresno County, Cal.

No.	Locality.	Gypsum.	Clay.	Sand, moisture, carbonate of lime, etc.
1	Summit of main ridge	95.24	1.98	2.78
5	Second spur, middle of crest	94.74	1.52	3.74
6	Third spur, in canyon	92.90	2.60	4.50
7	Fourth spur, near road	82.20	8.21	9.59

Some gypsite was mined from these deposits several years ago, when a cabin and a small amount of machinery were erected. The gypsite was mined for land plaster and used on the ranches of the San Joaquin Valley as an antidote for alkali. No work, except assessment work, has been done on the claims for a number of years. Water is very scarce and what is to be had is not fit for drinking. Drinking water must be brought from Mendota, 18 miles away. The plain is almost as flat as a floor and the soil makes good roads, so that teaming is easy and, for such a distance, hauling is very cheap.

[a] Twelfth Rept. State Mineralogist California, 1894, p. 323.

On the south side of Tomey Creek similar deposits occur and have been prospected to some extent.

DEPOSITS NEAR THE PAOLI MINE.

A few miles south of Tomey Creek, along Cantua Creek, like beds were once worked in a small way for land plaster, and similar deposits may be found wherever the same rocks outcrop along the foothills.

COALINGA DEPOSITS.

In the NE. ¼ sec. 22, T. 20 S., R. 14 E., Mount Diablo base and meridian, about 4 miles northwest of Coalinga, is a deposit which was worked to a small extent for land plaster a number of years ago. The gypsite overlies a sandstone that lies next to a coarser fossiliferous stratum having a dip of about 30° NE., occupying the top of a small hill, and may be followed for about 200 feet along the strike of the rocks. This sandstone has been determined by Ralph Arnold and Robert Anderson,[a] of the United States Geological Survey, to

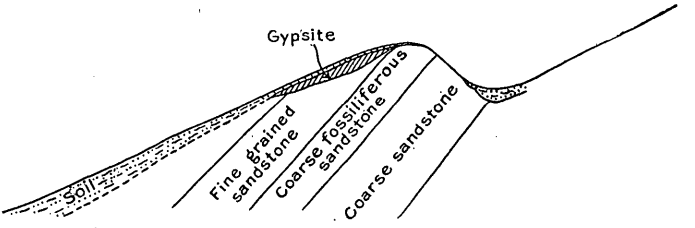


FIGURE 1.—Idealized section through gypsite deposit 4 miles northwest of Coalinga, Cal. Not drawn to scale.

be near the base of the Tejon formation of the Eocene. The general relations of the gypsite and the country rock are shown in figure 1. At a depth of 2 or 3 feet pebbles begin to appear in the gypsite, and below that they form so much of the mass that the material would have to be screened for use. (See Pl. II, *B*.) The gypsite is light buff, very soft and friable, and could be largely shoveled from the face. Occasional small stringers are harder, but all could be worked with a pick. The gypsite is so soft that small animals and insects burrow through it.

A partial analysis of a specimen of gypsite from this deposit, made for Arnold and Anderson by R. C. Wells, of the United States Geological Survey's chemical laboratory, gave: $CaSO_4$, 71.6; SiO_2, 0.8.

About 7 miles northeast of Coalinga, on the top of a hill half a mile S. 20° E. of the Home Oil Company's wells, is a gypsum claim, on which a small area about 20 by 50 feet has been stripped to a depth of 1 or 2 feet. The gypsite below this is very impure, containing many fragments of fine-grained shale.

[a] Personal communication.

Three miles west of Coalinga, on the east side of a hill in the S. ½ sec. 35, T. 20 S., R. 14 E., gypsite outcrops at a number of places through a distance of about a quarter of a mile. Prospect holes have been sunk at a number of points and shallow excavations have been made. The deposits are very similar to those just described as occurring northwest of Coalinga, but are of somewhat larger extent. There is apparently from 2½ to 3 feet of fairly good gypsite, but below that the foreign matter forms too great a proportion of the material to allow profitable working. The deposit is overlain by about a foot of soil. The stratum covered by the gypsite is a soft sandstone, which is in many places very pebbly. The weathering of the sandstone leaves a layer of loose pebbles on the surface, and where gypsite has formed these pebbles are contained in it.

A specimen collected by the writer from this deposit was partially analyzed by E. C. Sullivan, of the United States Geological Survey's chemical laboratory, with results as follows:

Partial analysis of gypsite from S. ½ sec. 35, T. 20 S., R. 14 E.

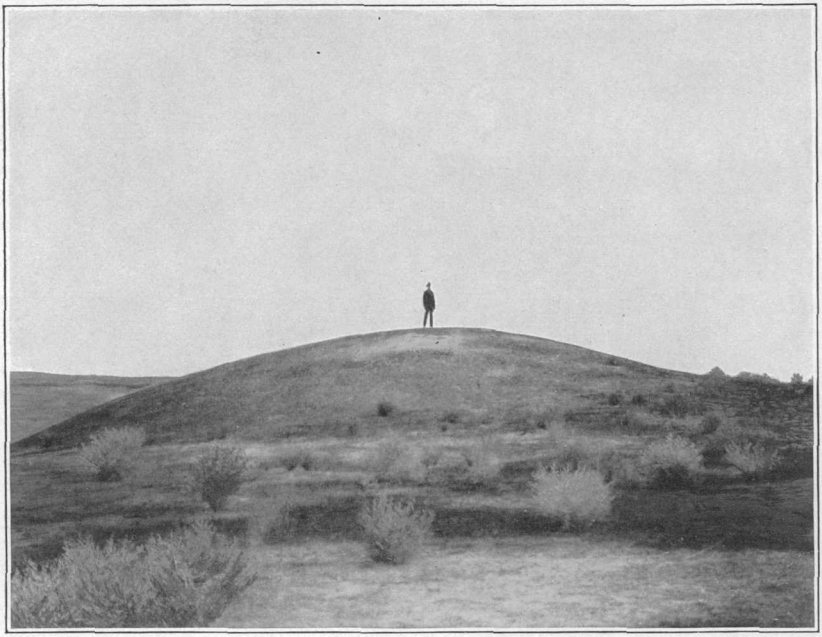
Lime (CaO)	26.6
Sulphur trioxide (SO_3)	34.4
Water driven off at 60° C	.5
Water driven off at 300° C	16.1
Chlorine (Cl)	Trace.
Iron oxide (Fe_2O_3)	1.2

This analysis gives an equivalent of 74.1 per cent gypsum. A tunnel near the summit of the hill on the west side shows many narrow veins of crystalline gypsum cutting the sandstone. There are small nodules of kaolin from one-half to 2½ inches in diameter along one of the bedding planes of the sandstone. These nodules have probably not been formed by the kaolinization of granitic pebbles, as they contain no visible quartz grains. It seems possible that they may have been pellets of clay rolled on an ancient shore line.

Mr. N. L. Palmer, of Coalinga, states that gypsum is to be found also in sec. 34, T. 20 S., R. 16 E., about 1 mile south of Stanley station on the Southern Pacific Railroad; in secs. 32 and 33, T. 21 S., R. 16 E., 6 or 7 miles southeast of Coalinga; and in sec. 34, T. 20 S., R. 14 E., 3 miles west of Coalinga.

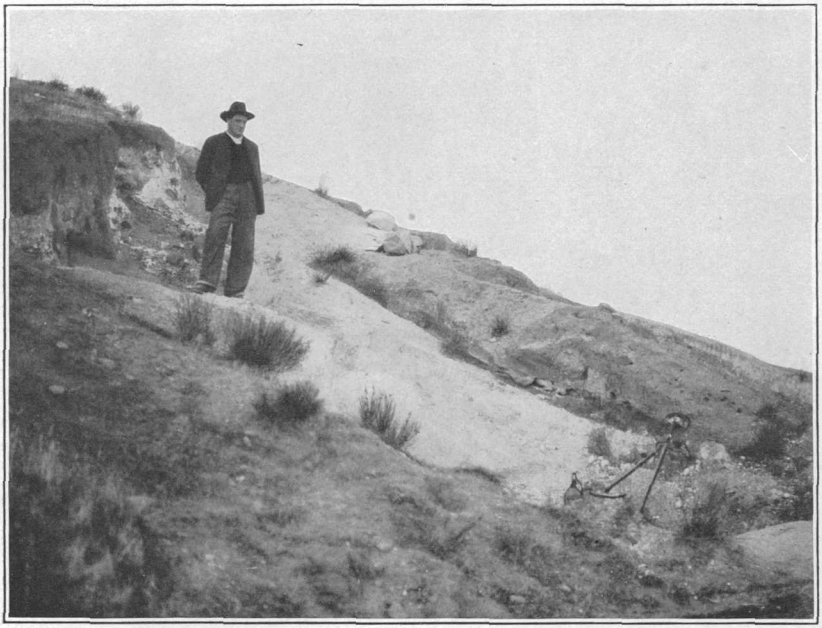
DEPOSITS NEAR DUDLEY, KINGS COUNTY.

About 6 miles southeast of Dudley, in the McLure Valley, or, as it is generally known, Sunflower Valley, Kern County, some thin deposits of buff gypsite, from 1 foot to 2 feet thick, overlying soft, siliceous Tertiary shales, have been prospected to a small extent, and have been shown to cover possibly an acre on a low mound in the NW. ¼ sec. 15, T. 25 S., R. 18 E. The gypsite is covered with 8 to 16 inches of soil and is much mixed with shale.



A. "THE OIL BUBBLE" IN THE LOST HILLS SOUTH OF TULARE LAKE.

A mound of gypsum, made by the evaporation of water seeping from the rocks below.



B. GYPSUM DEPOSIT 4 MILES NORTHWEST OF COALINGA.

Across a low range of hills of what is known locally as "porcelain shale" gypsite is found on many of the hilltops and ridges. A deposit on the property of the Visalia Oil Company, near the middle of the W. ½ sec. 22, T. 25 S., R. 18 E., about 7 miles southeast of Dudley, may be taken as an example of the deposits common to this locality. The deposit occupies the upper part of the east side of a north-south hill through a distance of about a quarter of a mile, and its width reaches 300 feet as an extreme, probably averaging somewhat over 100 feet. It lies on fine-grained sandstone and shales, on both sides of a fossiliferous, limy sandstone carrying *Ostrea vespertina* and *Pecten coalingaensis*.

The gypsite is buff in color and is hardened for 2 or 3 inches on the top, so that when dug it breaks in slabs a foot or more across. Below the crust it is so soft that it may be screened to get rid of pebbles and fragments of sandstone or shale without crushing. The deposit is 2 to 3 feet thick, the purer material generally being contained in the upper 2 feet. Sandstone or shale forms a large portion of the lower part of the mass, the proportion becoming greater with increase of depth and making up the bulk of the lowest part of the deposit. Gypsite occurs also on the hills in various other parts of the same section.

Mr. Orlando Barton, who lives near by and who has spent much time in examining the rocks of this region, states that deposits of gypsite occur on the following bodies of land in T. 25 S., R. 18 E., of which, owing to limited time, only those described were examined by the writer:

Gypsite deposits in T. 25 S., R. 18 E., near Dudley, Kings County, Cal.

Sec. 14, small bed in SE. ¼.
Sec. 20, about one-quarter acre in SE. ¼.
Sec. 21, 10 acres in SE. ¼.
Sec. 22, 20 acres in SW. ¼, NW. ¼, and SE. ¼.
Sec. 23, thin; various parts.
Sec. 25, 3 acres in SW. ¼.
Sec. 26, small amount in NE. ¼ and NW. ¼.
Sec. 27, 4 acres in NE. ¼.
Sec. 28, 30 to 150 feet wide, runs north-south in E. ½ of E. ½, the whole length.
Sec. 29, small amount in SW. ¼; several acres good gypsum in SE. ¼, reaches thickness of 4 feet.
Sec. 30, small bed good gypsum in southeast corner.
Sec. 34, small bed good gypsum in northwest corner.
Sec. 35, good bed 100 feet wide in SE. ¼, one-fourth mile long; small bed in NE. ¼.
Sec. 36, small beds in all but NE. ¼.

Mr. William Taylor, of Dudley, stated to the writer that gypsite deposits also exist in the NE. ¼ sec. 3, T. 26 S., R. 18 E., in Antelope Valley, the next large valley south of McLure Valley.

LOST HILLS.

In the San Joaquin Valley, a few miles south of Tulare Lake and about 25 miles west of Wasco, on the Santa Fe Railway, is a low range of hills, running northwest and southeast, probably a continuation of a range somewhat higher and broader, known as the Kettleman Hills, which separates the Kettleman Plains from the San Joaquin Valley. The Kettleman Hills are said by Arnold and Anderson[a] to be of anticlinal structure, and it is probable that the Lost Hills are formed by the southern extension of the anticline which here disappears under the floor of the valley. The rocks in place in the Lost Hills are probably a part of the Etchegoin formation, of upper Miocene age.

The country, like the foothills, is exceedingly dry, having an average annual rainfall of probably not more than 2 or 3 inches, and is even drier than the adjacent hills, the nearest of which are 8 or 10 miles to the west.

A county road from Wasco, the nearest shipping station, to Antelope Valley passes about 2 miles south of the Lost Hills. A traveler approaching the country from this road, when within half a mile or more of the hills, may notice gypsite in the piles of dirt thrown from holes dug by kangaroo rats and other rodents. In the W. ½ sec. 30, T. 26 S., R. 21 E., many such places were seen, and also in the western part of sec. 19. At a number of points the writer dug through the soil, which was from 6 to 24 inches thick. Below this earth covering the gypsite is generally soft and powdery, and of a creamy buff color, though at one or two places it was brownish and granular. It was not practicable with the tools at hand to dig to any considerable depth, so that the thickness of the gypsite was not determined. Mr. Orlando Barton stated that he had at a number of places dug into the gypsite to a depth of 4 feet without passing through it.

On the tops of the hills there is also a coating of gypsite, at many places without the usual covering of soil, which has probably been blown off, as the ground is dry and powdery and easily moved by the winds, which during a day sometimes pile it in drifts several feet deep. At one place in sec. 19, where a northeast-southwest draw cuts through the hill, the gypsum appeared to be from 6 to 8 feet thick.

On the south side of the draw, standing on a rather abrupt northern slope, is a mound known as "The Oil Bubble." (See Pl. II, *A*.) The mound, which is 10 to 15 feet high and about 65 feet in diameter, is composed of small crystals of gypsum, most of them less than one-quarter inch in length, mixed with enough clay to permit the mass to be easily kneaded. This mound also contains a small amount of

[a] Bull. U. S. Geol. Survey No. 357, 1908, p. 65.

material resembling greatly oxidized asphalt, stained slightly with native sulphur. At the time it was visited the mound was wet and sticky, and it is said to remain moist throughout the summer. It is reported to give off bubbles of gas, whence the name "Bubble," the supposed asphalt suggesting the name "Oil." The mound is formed by the evaporation of water carrying gypsum in solution, the clay probably being brought to the place by winds. The excessive dryness of the surrounding country makes it seem probable that the water comes from a considerable depth, rising through the Tertiary gypsiferous sandstones.

On the north side of the draw is a dark, fine-grained sandstone cemented by gypsum, of which it carries considerable amounts. It dips toward the northeast at a low angle, closely following the contour of the hill, and that it is of Pleistocene age, formed by the cementing of wind-blown sand by gypsum, is suggested, though there is a strong possibility that it is a phase of the Pliocene sandstones met in the Kettleman Hills farther to the northwest.

Above the sandstone lies about 2 feet of gypsite, and this is said to extend 6 or 7 miles northwestward along the hills. If the Lost Hills are to be regarded as an extension of the Kettleman Hills anticline from which the upper, nongypsiferous beds have been eroded, it seems probable not only that the hills contain other such beds of gypsite, but that alongside them, for their whole length, such deposits as were noted in sec. 30 will be found. It is not to be supposed that these beds will be equally thick or good in all places, and in spots the gypsite may be entirely lacking.

The beds in this locality are the most extensive that were seen by the writer in California. Whether they will be workable is problematic. At present the nearest shipping point is Wasco, on the Santa Fe Railway, 25 miles to the east. Water could probably be obtained by boring deep enough almost anywhere in the region. The deposits would need careful prospecting to ascertain their thickness and area, but this would not be difficult, as it could all be done with a shovel or a shovel and mattock. The ground could be easily stripped with teams and scrapers and the gypsite loaded into wagons directly from the scrapers by erecting a platform under which the wagons could be driven.

It seems possible that a railroad may be built along the base of the foothills of the Coast Range, in which case transportation would not be a serious matter, and if the deposits proved to be of sufficient extent the manufacture of cement plaster might then be undertaken.

Analyses of gypsum from sec. 30, made by E. C. Sullivan and R. C. Wells, of this Survey, are as follows:

Analyses of gypsite from south side of the Lost Hills, Kern County, Cal.

[Ground quickly to 40-mesh.]

	1.	2.	3.	4.
Lime (CaO)	25.3	29.9	29.5	29.9
Sulphur trioxide (SO_3)	35.1	42.8	40.7	40.8
Water driven off at 60° C	.9	.2	19.1	19.4
Water driven off at 300° C	16.9	19.3		
Chlorine (Cl)	None.	Trace.	None.	None.
Iron oxide (Fe_2O_3)	1.1	.3	.4	.3
Carbon dioxide (CO_2)			.7	None.
Silica (SiO_2)			5.3	6.1
Alumina (Al_2O_3)			1.7	1.4
Sodium oxide (Na_2O)			1.2	2.0
Potassium oxide (K_2O)			.6	.5
Magnesia (MgO)			None.	None.

Analyses 1 and 2 by E. C. Sullivan; 3 and 4 by R. C. Wells.

The first analysis shows an equivalent of 75.5 per cent of gypsum, so that about one-fourth of the material is foreign matter; the second sample contains the equivalent of 91.2 per cent of gypsum. The analysis shows a slight excess (0.6 per cent) of calcium sulphate, which may indicate the presence of either anhydrite (calcium sulphate not combined with water) or partially dehydrated gypsum. The third and fourth analyses are fuller and show the character of the impurities better. The amount of gypsum indicated is nearer the amount shown by the second analysis than the first.

DEPOSITS NEAR M'KITTRICK, KERN COUNTY.

The same Tertiary sandstones and shales that are so prominent in the southern part of the Coast Range are also the prevailing rocks near McKittrick, and as would therefore be expected gypsite deposits are found in many places in this neighborhood.

CALIFORNIA GYPSUM AND MINERAL COMPANY'S DEPOSIT.

This property is located on the north slope of a rather low hill in the S. ½ sec. 21, T. 30 S., R. 22 E., about one-half mile from McKittrick railroad station. The gypsite is overlain by 6 inches to 2½ feet of soil and is of a buff color. It has been mined at a number of places to a depth of about 2 feet, below which it contains too much of the country rock to be profitably worked. The rock beneath the gypsite is a fine-grained shale. In places the gypsite is somewhat hardened for 2 or 3 inches on the top, but the mineral below that can be easily handled with a shovel. Altogether, perhaps 3 or 4 acres have been exposed.

A partial analysis by George Steiger in the chemical laboratory of the United States Geological Survey of a specimen collected by the writer was as follows:

Partial analysis of gypsite from deposit one-half mile southeast of McKittrick, Cal.

Lime (CaO)	31.05
Sulphur trioxide (SO_3)	42.19
Water driven off at 60° C	1.49
Water driven off at 300° C	17.80
Chlorine (Cl)	Trace.
Iron oxide (Fe_2O_3)	.56

This analysis gives an apparent equivalent of 85.2 per cent of gypsum. Some hundreds of tons of gypsite for use as land plaster had been shipped from the deposit, and there is a small plant on the property for the preparation of the material.

ABBOTT & HICKOX DEPOSITS.

At the time of the writer's visit (January 8, 1907) Messrs. Abbott & Hickox held a gypsite claim in the NE. ¼ SW. ¼ sec. 30, T. 30 S., R. 22 E., about 2½ miles southwest of McKittrick. The deposit most worked is on the summit of a hill between 50 and 75 feet high. It is about 500 feet long by 200 feet wide at the widest point and is oval in shape. The gypsite is from 2 to 4 feet thick and is overlain by soil that is in places 2 feet thick, although in other places gypsite forms the surface. The average covering is probably 10 to 12 inches thick. The gypsite is passed through screens running 3 or 4 meshes to the linear inch. About 4,000 tons are said to have been shipped from the spot up to the time it was visited.

A partial analysis by George Steiger of gypsum from this deposit is given below:

Partial analysis of gypsite from deposit near McKittrick, Cal.

Lime (CaO)	30.32
Sulphur trioxide (SO_3)	43.09
Water driven off at 60° C	.25
Water driven off at 300° C	19.75
Chlorine (Cl)	Trace.
Iron oxide (Fe_2O_3)	.34

This gives an equivalent of 92.5 per cent of gypsum. On several of the hilltops near at hand the gypsite outcrops were accompanied by carbonate of lime, which seemed to be a replacement of the gypsite, and the two are in places more or less mixed.

OTHER DEPOSITS.

Considerable gypsite of character similar to that described above occurs in the SE. ¼ sec. 30, and some has been shipped. In places it reaches a thickness of 3½ feet.

About 1 mile south of the locality just mentioned, on the north side of a small gulch, is a deposit which is 9 feet thick and considerably hardened, but which does not seem to be of great extent. Parts of it are bleached almost white. This deposit also overlies a fine-grained shale which is in places much colored by iron oxide. The shale is yellowish gray, of low specific gravity, and contains many casts of foraminifers. It was carefully examined for diatoms, but none were found. The shale contains a very high percentage of silica, some calcium sulphate, a little iron oxide, and a very small percentage of clay. Borings made about 100 feet from the gulch are said to have shown the gypsite to be about 2 feet thick. A number of other deposits exist in secs. 28 and 29, T. 30 S. The gypsite and the underlying shales are at some places almost of the same color, so that it is not easy to tell where one leaves off and the other begins, since the gypsite is powdery and sifts down, disguising the appearance of the underlying rock. It was reported that on one claim the gypsite was 90 to 100 feet thick, but it is probable that the soft underlying shale has been supposed to be gypsite, as it does not seem possible, from the mode of formation of the gypsite, that it could have been so thick.

At the time of the writer's visit Mr. H. F. Brinkman, of Pasadena, Cal., was examining the deposits to determine their commercial value. Mr. Brinkman made the following estimate of the area and thickness of gypsite deposits in the neighborhood. The writer had no opportunity of verifying the figures outside of the areas given above.

Gypsum in the McKittrick district.

No.	Section.	Range.	Township.	Acres.	Thickness.
					Feet.
1	SE. ¼ sec. 8.	22 E.	30 S.	2	2
2	SE. ¼ sec. 6.	22 E.	30 S.	2	2
3	SW. ¼ sec. 6.	22 E.	30 S.	10	2
4	NW. ¼ sec. 14.	21 E.	30 S.	2	2
5	SW. ¼ sec. 30.	22 E.	30 S.	3	2
6	SE. ¼ sec. 3.	21 E.	30 S.	8	2–4
7	SW. ¼ sec. 3.	21 E.	30 S.	10	3
8	NW. ¼ sec. 3.	21 E.	30 S.	20	2
9	NE. ¼ sec. 3.	21 E.	30 S.	10	2
10	NW. ¼ sec. 4.	21 E.	30 S.	10	2
11	NE. ¼ sec. 4.	21 E.	30 S.	10	2
12	SE. ¼ sec. 4.	21 E.	30 S.	10	2
13	SW. ¼ sec. 4.	21 E.	30 S.	10	2
14	SW. ¼ sec. 2.	21 E.	30 S.	4	2
15	SE. ¼ sec. 2.	21 E.	30 S.	10	2–3
16	NE. ¼ sec. 1.	21 E.	30 S.	10	2–3

According to Mr. Brinkman deposits Nos. 1 and 2 contain about 4,000 tons and deposit No. 3 about 20,000 tons. Deposit No. 5 consists of powdery gypsite. No estimate was made of the extent of the deposits in secs. 30, 31, and 32, T. 30 S., R. 22 E., or in sec. 29. That in sec. 5, T. 31 S., R. 22 E., contains about 5 acres, and there is a little in sec. 4, T. 31 S., R. 22 E.

Samples of plaster of Paris made by Mr. Brinkman from gypsite from different localities in the neighborhood were all of a creamy to buff color, varying somewhat in shade, and a number of the shades would make attractive tints for wall coverings. The gypsite deposits follow the Tertiary sandstones and shales to the southwest, and many patches are reported to occur between McKittrick and Midway.

Mr. E. H. Andrews, of Midway, reports gypsite in the following sections in the area between McKittrick and Midway:

T. 30 S., R. 22 E., secs. 29, 30, 31, 32, 33, 34, and 35.
T. 31 S., R. 22 E., secs. 4, 5, 8, 9, 10, 17, 18, 19, 20, 21, 22, 26, 27, 28, 34, 35,11.
T. 32 S., R. 22 E., secs. 2, 2, 3, 11, 12, 6, 7, 17, 18, 20, 21, 22, 23, 26, 27, 34.
T. 32 S., R. 24 E., running diagonally from northwest to southeast.

Owing to lack of time the writer was unable to visit these localities.

DEPOSITS NEAR SUNSET.

In the country closely adjacent to Sunset are a number of small areas carrying thin deposits of gypsite, associated with shales like those found farther north along the Coast Range. None were seen or heard of that seemed to be of importance.

DEPOSITS NEAR BAKERSFIELD.

Deposits of gypsite occur on both sides of Cottonwood Creek, 16 miles east of Bakersfield. They are reached from Edison, on the Southern Pacific Railroad, by following the main road 4½ miles to the creek, and then traveling up the creek for 3½ miles. The deposits may also be reached from Pampa, from which they are about 5 miles distant. The deposits occur on the northeast side of the creek at the top of a steep slope, between 50 and 75 feet above the creek bed. A more gentle slope rises from the top of the steep bank, and on this slope gypsite may be found at a number of places, covering altogether several acres. At the edge of the slope the gypsite is 2 to 3 feet thick, grading into soft, earthy material below, probably the equivalent of the shales over which the gypsite lies in the McKittrick and other districts. The deposit is in the SE. ¼ SE. ¼ sec. 20, T. 29 S., R. 30 E., Mount Diablo base and meridian. A small amount of gypsite was shipped from this deposit several years ago for use as a fertilizer.

A number of claims on the southwest side of the creek are held by Mr. William Harmon. One of these is in sec. 28, where deposits have been opened to a small extent on the top of a hill about 200 feet above

the creek. The deposits are small and of no great value. In the narrow gulch east of the hill there is a deposit of impure, soft, powdery gypsite 6 to 8 feet thick, which is exposed for several hundred feet along the gulch. Its width and its thickness away from the creek are unknown. On the top of the hill east of the gulch, in the NW. ¼ sec. 28, there are other gypsite deposits similar to those on the west side.

A partial analysis by E. C. Sullivan of a specimen from this deposit is given below:

Partial analysis of gypsite from deposit near Pampa, Cal.

Lime (CaO)	28.1
Sulphur trioxide (SO_3)	34.8
Water driven off at 60° C	.5
Water driven off at 300° C	16.0
Chlorine (Cl)	Trace.
Iron oxide (Fe_2O_3)	.8

The analysis shows an apparent equivalent of 74.8 per cent of gypsum. In another gulch in the southeast corner of the NE. ¼ sec. 28, about one-quarter mile east of Mr. Harmon's cabin, gypsite from 10 to 25 feet thick is exposed on both sides for a distance of 100 yards. The gypsite is of about the same quality as that in the gulch already mentioned.

These gulch deposits are probably formed by the washing down of the gypsite from the hills above and are mixed with considerable earth. The deposits are about one-quarter mile from the contact of the soft Tertiary rocks with old crystalline rocks, which are here andalusite schists. Mr. Harmon states that much better deposits of gypsite occur near Caliente.

OTHER DEPOSITS IN THE COAST RANGE.

Along the west side and middle of the Coast Range many deposits of gypsite that are in all essential respects similar to those on the eastern slopes have been reported. They are particularly numerous along the east side of Salinas Valley.

The deposits east of Metz and Kings City, most of them in San Benito County but a few in Monterey County, have been briefly described in various reports of the California State Mining Bureau. [a]

SAN BENITO COUNTY.

The following descriptions are taken from a report entitled "Structural and industrial materials of California," published under the direction of Lewis E. Aubury, state mineralogist, 1906, pages 286–287:

[a] See bibliography at beginning of this bulletin.

In Bitterwater Creek canyon a number of detached gypsum deposits are found, running from Lewis Creek, in sec. 5, T. 19 S., R. 10 E., M. D. M., to sec. 17 or 18, T. 18 S., R. 9 E. The quality of the gypsum differs materially in the various exposures. [See also Bull. U. S. Geol. Survey No. 223, 1904, p. 120.]

F. Q. Alvarez, Bitterwater post-office: In sec. 5, T. 19 S., R. 10 E., and sec. 32, T. 18 S., R. 10 E., on the east side of the lower Bitterwater. The gypsum lies in or in close contact with a belt of serpentines which runs along the east rim of Bitterwater Valley. It is mixed with clay and often of a grayish color; some bowlders of white gypsum are, however, found on the surface. Several years ago some was excavated and hauled to San Francisco, but in later years the deposit has been idle.

Mrs. S. Chambers, Bitterwater post-office: In sec. 15, T. 18 S., R. 9 E., on the west side of Bitterwater Valley, some gypsum bowlders were excavated some years ago. In a well dug near the house a bed of gypsum about 3 feet thick was passed through. Three hundred yards northeast of the house some open cuts have exposed two beds of a fair quality of gypsum. The country rock is shale, but the gypsum is accompanied by a light-gray sandstone containing inclusions of gypsum.

J. F. Dunn, Hollister: On the Topo ranch, in sec. 17 or 18, T. 18 S., R. 9 E., on the divide west of Bitterwater Valley, a deposit of gypsum lying in a horizontal bed 3 to 4 feet thick has been opened for about 100 feet. It has only a solid overburden of 2½ to 3 feet, and is underlaid by shale. The gypsum is of fairly good quality. The deposit is 12 miles from railroad. [See Thirteenth Rept. California State Min. Bur., p. 504.]

J. C. Tully, Bitterwater post-office: In sec. 32, T. 18 S., R. 10 E. [See Alvarez deposit, of which it forms part.]

R. R. Tully, Bitterwater post-office: In sec. 11, T. 18 S., R. 10 E. Some detached bodies of grayish-colored gypsum, somewhat mixed with clay.

Estate of T. Williams (deceased), 1003 First street, San Jose: In the southwestern part of T. 19 S., R. 12 E., and the northwestern part of T. 17 S., R. 12 E., M. D. M., on Silver Creek, indications of gypsum have been found.

CARRIZO PLAIN.[a]

Gypsite occurs at numerous places on the southwest flank of the Temblor Range, immediately east of the Carrizo Plain, from the vicinity of sec. 16, T. 31 S., R. 21 E., to the Kern and San Luis Obispo county line, near sec. 36, T. 32 S., R. 22 E. The deposits are of the efflorescent type and most of them are of poor grade. They overlie the soft Miocene sandstones exposed on this flank of the range. Only assessment work has been done on these deposits. The gypsite is of so low a grade that under present costly methods of working and lack of adequate and cheap transportation facilities it is practically valueless. The locators make no secret of the fact that the work is done for the purpose of meeting the assessment requirements on their oil claims, so that these occurrences can in no sense be considered as actual gypsite prospects.

Plate IV, *A*, a view taken in sec. 7, T. 32 S., R. 22 E., shows one of the many gypsite workings in the Carrizo Plain on which work has been done to meet assessment requirements.

[a] Notes furnished by Ralph Arnold.

CORONA.

Unimportant amounts of gypsum occur on both sides of Gypsum Canyon, about 2 miles south of Corona. The larger deposits, from which between 200 and 300 tons have been shipped, are on the east side of the canyon, a short distance from its mouth, in a small gulch that lies between 50 and 100 feet above the floor of the canyon. The gypsite is at most 4 feet thick, and is overlain by 1 to 2 feet of soil. Its color is creamy, like that of the San Joaquin Valley, and it grades into the rock below in the same manner. The rock that it overlies is andesitic, but is so badly decomposed that its nature can not readily be told. Its appearance in the field suggests that it may be a tuff. In thin sections it shows considerable iron pyrites, together with some calcite, and it is possible that the gypsum is derived directly from this rock through the interaction of weathering pyrite and plagioclase feldspars. However, close by, on the side nearer the mouth of the canyon, are soft sandstones from which the gypsite may have come. These sandstones may outcrop above the deposit on the hillside, and the gypsum may have been carried to its present place by the stream that flows in the gulch in wet weather. Near the mouth of the canyon a tunnel run into the west side has 4 to 5 inches of efflorescent salts on the floor, while on the walls there is an inch or more. The efflorescence is composed largely of iron sulphate. Other small gypsum deposits are said to occur in neighboring canyons.

PERIODIC-LAKE DEPOSITS.

E. D. JONES DEPOSIT.

The E. D. Jones gypsum deposit is in the Kettleman Plains, Kings County, 200 yards north of an old schoolhouse in the NW. ¼ sec. 13, T. 24 S., R. 18 E., Mount Diablo base and meridian,[a] 5½ miles by road northeast of Dudley. It is in the flat floor of the valley, between half a mile and a mile from the nearest hills on the northeast and still farther away from those on the southwest. It presents some features that are so much different from the deposits in the neighborhood that it is placed tentatively among the periodic-lake deposits.

An excavation about 30 by 50 feet and 3 feet deep has been made. The bottom of the hole is on gypsum, so that the depth of the deposit can not be told. The gypsum is said to be found over an area of 80 acres, although it was seen by the writer only at the excavation. The gypsum, which is coarsely granular, is composed of an aggregate of small crystals up to one-half or three-fourths of an inch broad, is rather firmly coherent, and is overlain by a few inches of soil. Between the crystals the spaces are filled with material apparently

[a] Land description is taken from Thirteenth Ann. Rept. California State Mineralogist, 1896, p. 503.

less pure. The comparatively large size of the crystals indicates that the deposit was laid down in a periodic lake rather than by efflorescence. The presence of considerable quantities of water seems necessary for the formation of gypsum crystals of easily visible size. Robert Anderson, of the United States Geological Survey, has informed the writer that in the surrounding hills there seems to be evidence that this portion of the Kettleman Plains was at one time covered by a lake or an arm of Tulare Lake.

This deposit was worked for land plaster in the early nineties. A small mill for grinding was put up, but the wagon haul of nearly 40 miles to Huron, the nearest railroad point, makes production too expensive to be profitable. It is stated that selected samples from this deposit contained 94 per cent of gypsum. [a] A partial analysis by E. C. Sullivan of a specimen collected by the writer was as follows:

Partial analysis of gypsum from Kettleman Plains, California.

Lime (CaO)	19.1
Sulphur trioxide (SO_3)	27.3
Water driven off at 60° C	.8
Water driven off at 300° C	15.3
Chlorine (Cl)	Trace.
Iron oxide (Fe_2O_3)	1.1

This analysis gives an equivalent of only 59.2 per cent of gypsum. The specimen collected was thought to be representative, but hand sampling is almost invariably uncertain, owing to the small size of the specimen, to the narrow area from which it is taken, and to vagaries connected with the personal equation of the collector. In order to get reliable results a sample taken from such a deposit must be very large and must be collected with some sort of system that will enable the sampler to reach all available parts of the deposit, and the sample must then be carefully mixed and quartered to a convenient size for analysis. It is therefore entirely probable that either or both of the specimens analyzed may give a wrong impression of the deposit. They are both of value, however, in giving some idea of the purity of at least portions of the gypsum.

KERN LAKE GYPSITE DEPOSIT.

In what was once the bed of Kern Lake, but is now a part of a large farm belonging to the Kern County Land Company, gypsite has been exposed in secs. 26 and 27, T. 32 S., R. 27 E., Mount Diablo base and meridian, by an irrigating ditch that runs through the deposit for about three-quarters of a mile along the line between the north and south halves of the sections. The point is about 20 miles southwest of Bakersfield, but only 5 miles from the railroad station known as

[a] Thirteenth Rept. State Mineralogist California.

"Conner." Gypsum is also reported from a point one-half mile farther south, but none has been found nearer the center of the old lake, a point west of this locality. The ditch is 2½ feet deep, and gypsite forms its bottom and sides for a large part of the distance mentioned. The soil covering the gypsite is thin and very light and porous when dry. Over a large part of the known area the gypsum is less than a foot below the surface. The gypsite is creamy in color, finely granular, and in places is very free from dirt and foreign matter. Water from the irrigating ditch has cut channels from 8 inches to more than a foot in diameter through the gypsite, and they can be followed more than 50 feet on each side by the caving of the earth. Near the ditch the gypsite is reported to be 4 feet thick. The composition of a picked sample is shown by the following analysis by E. C. Sullivan, of the United States Geological Survey:

Analysis of gypsum from old bed of Kern Lake.

Lime (CaO)	33.2
Sulphur trioxide (SO_3)	47.3
Water driven off at 60° C	None.
Water driven off at 300° C	19.7
Iron oxide (Fe_2O_3)	.1

The lime and sulphuric anhydride are both too high for pure gypsum, which contains 32.6 and 46.5 per cent, respectively, while the water is low (20.9 per cent in pure gypsum). Analysis apparently shows the presence of nearly 6 per cent of anhydrite (anhydrous calcium sulphate), which would leave about 94.3 per cent of gypsum. It is possible, however, that instead of containing anhydrite the material may include some partially dehydrated gypsum which would in no way be hurtful to plaster manufactured from it. It is remarkably free from other impurities. At some other points the gypsite is more or less mixed with earth. The lake received its drainage from the Tehachapi Mountains, on the south, which are composed largely of Tertiary rocks, presumably similar to those along the Coast Range and also to the rocks a few miles farther east. (See p. 6.) These rocks are highly gypsiferous, so that considerable amounts of gypsum would be carried into the lake, which was of great periodic variation in size owing to the unequal distribution of rainfall from season to season and from year to year, though it was at all times shallow. The saturation point for gypsum would possibly never be reached by the lake, even when the level of the water was near or below the surface of the soil, which, owing to its great porosity, will hold large quantities of water.

The deposition of gypsum from such a lake is apparently much the same phenomenon as the deposition of gypsite from rocks by the evaporation of water drawn to the surface by capillarity. The

shallow water near the shore line would be more highly saturated with gypsum than the deeper water, as the portion evaporated would be a much larger proportion of the mass. The hot sun would at the same time evaporate great quantities of water from the shore itself, which is formed of fine porous silt. The water would come, at least in part, from the already somewhat concentrated water along the edge of the lake, and as the water evaporated gypsum would be left behind in crystalline form. The flow of water once established would continue until capillary attraction could no longer lift the water from the depth to which it had sunk. In the absence of definite data, it may be supposed that the longer established channels by which the water escaped into the atmosphere would act much more rapidly than the newer ones that were allowed to form by the retreating shore line; that there would therefore be a movement of the water toward the side; and that there would be deposits of gypsite under certain areas from which evaporation was greatest and near which the shore most often lay. In the middle of the lake, where water stood oftenest and longest, probably no considerable deposits would form, as they would be again dissolved by floods in succeeding years.

It is probable that gypsite will be found at a number of points around the old medial shore of the lake—that is, around the shore which was its normal edge between the highest and lowest stages. If the deposits are of sufficient extent they would form a basis for the profitable manufacture of hard plaster, particularly as much of the land is not under cultivation.

BUENA VISTA LAKE.

Buena Vista Lake lies 5 or 6 miles west of the Kern Lake gypsum deposit, in the same shallow depression. A cut for the Sunset Railroad as it turns to the southwest to follow the shore of the lake exposes gypsite similar in appearance to that of Kern Lake. Nothing is known of its extent or thickness.

AMBOY.

Amboy, a station on the Santa Fe Railway in the Mohave Desert, San Bernardino County, about 225 miles from Los Angeles, is on the shore of a periodic lake, along the north side of which the railway extends in an east-west direction for 6 or 8 miles. The gypsum deposits are in the lake bed, probably stretching nearly around it. This lake bed is of a type common in the Mohave Desert and is a number of miles in extent. The surface soil is salty, so that almost no vegetation grows on it. The lake receives drainage from mountains on both the north and the south, but it is rarely that sufficient rain falls in the mountains to furnish the streams enough water to cover the surface of the dry bed. At the time of visit (January 22,

1907) a strong brine was reached in the lake bed at a depth of about 8 feet.

A small volcano rises 3 miles west of the lake, and from this streams of basaltic lava have run over the lake bed. In the bays between these flows gypsum is found throughout the area, and the winds have blown it up into small drifts across the tongues of lava. Over a portion of the area a light volcanic ash forms the surface soil, a foot or more thick, and below this soil gypsum is found to a depth of 6 to 8 feet, at which point the water level is reached. It is not known how far the gypsum may extend below water level. Many prospect holes have been dug along the north and east shores of the lake and gypsum was found only within about half a mile or a mile of the shore line.

The gypsum varies considerably in character, both longitudinally and vertically. In many places the gypsum nearest the surface is rather dirty, while below that is a stratum, 14 inches to 2 feet thick, of clean, white granular gypsum. In places the gypsum is cemented into a clean, spongy mass, which has little solidity but can be broken out in chunks a foot or more in diameter. At other places the gypsum crystals reach an inch or more in breadth but are thin in proportion. There is also considerable variation in the amount of dirt present. It is reported that gypsum occurs on the south side of the lake bed, and the probability is that the deposits will be found along a considerable proportion of its circumference. The character of the rocks in the hills is unknown, but there are crystalline rocks on both sides and more than likely young sedimentary rocks also.

In a prospect hole 2 miles east of Amboy no water appeared at a depth of 9½ feet and the gypsum does not have the salty taste which is common to the gypsum on the west side of the lake. Gypsum is found all the way to the bottom. The uppermost 2 feet is rather dirty. Below this is 2 feet of much cleaner material, while the lower 4½ feet is iron stained and dirty. The gypsum is coarse grained, the crystals reaching one-fourth inch across, and in general is loose but includes some hard layers and seams.

A sample of the lower 4½ feet of the gypsum exposed in the hole was taken by cutting a narrow strip from the top to the bottom of the stratum. A partial analysis of the sample by George Steiger is as follows:

Partial analysis of gypsum from a point 2 miles east of Amboy, Cal.

Lime (CaO)	28.1
Sulphur trioxide (SO_3)	34.9
Water driven off at 60° C	.8
Water driven off at 300° C	15.2
Chlorine (Cl)	1.4
Iron oxide (Fe_2O_3)	1.0

The water driven off at 300° C. is sufficient to hydrate a total of 72.7 per cent of gypsum. It is probable, however, that the rest of the calcium sulphate present, amounting to nearly 2 per cent, represents a larger portion of gypsum partly dehydrated by the fierce desert sun. Some explanation of this action is given under the next analysis. At many places on the lake bed the gypsum is whitened as if it had been put on a hot stove. In the sample analyzed there is 3.6 per cent of lime, which is probably in the form of carbonate, and a noticeable amount of chlorine, equivalent to 2.3 per cent of salt.

The Pacific Cement Plaster Company is operating on the west side of the lake, and has erected a mill at Amboy. This company is drawing its supply of gypsum from a point about 2 miles south of the mill. The surface is stripped by horse scrapers to a depth of about a foot, and the gypsum is then scraped up to a platform, through which it is dumped into tram cars below. (See Pl. III, *A*.) These are then hauled by team to the mill. The deposit is worked down to water level, a depth at this point of somewhat less than 8 feet. The level will undoubtedly vary from time to time. At this depth the gypsum is apparently of as good or better quality than at points above.

A partial analysis of a selected sample by George Steiger was as follows:

Partial analysis of gypsum from deposit 2 miles southwest of Amboy, Cal.

Lime (CaO)	32.7
Sulphur trioxide (SO_3)	44.7
Water driven off at 60° C	.2
Water driven off at 300° C	19.5
Chlorine (Cl)	.13
Iron oxide (Fe_2O_3)	.2

The water driven off at 60° C. is considered as hygroscopic. That driven off at 300° C. (19.5 per cent) is sufficient to hydrate fully 92.8 per cent of gypsum. Nominally this would leave 2.7 per cent of anhydrite, but it is probable that this is partially hydrated calcium sulphate, while a portion of the 92.8 per cent is also only partially hydrated, so that the sum of the two, 95.5 per cent, more nearly represents the amount available for plaster making. There is a small amount of lime present, probably as calcium carbonate, in which form it would amount to 2.5 per cent. The gypsum from the top to the bottom of the deposit would probably not be as pure as this analysis would indicate.

There is undoubtedly enough gypsum in sight to run several such mills as that now working for many years. Two salt works have been started on the lake bed a few miles east of Amboy to make use of the heavy brine.

OTHER LAKE-BED DEPOSITS.

Similar periodic-lake deposits of gypsum are said to exist south of Danby, on the Santa Fe Railway, and near Kelso, on the San Pedro, Los Angeles and Salt Lake Railroad. Similar deposits are also reported in the Colorado Desert.

INTERBEDDED DEPOSITS.

SANTA BARBARA CREEK.

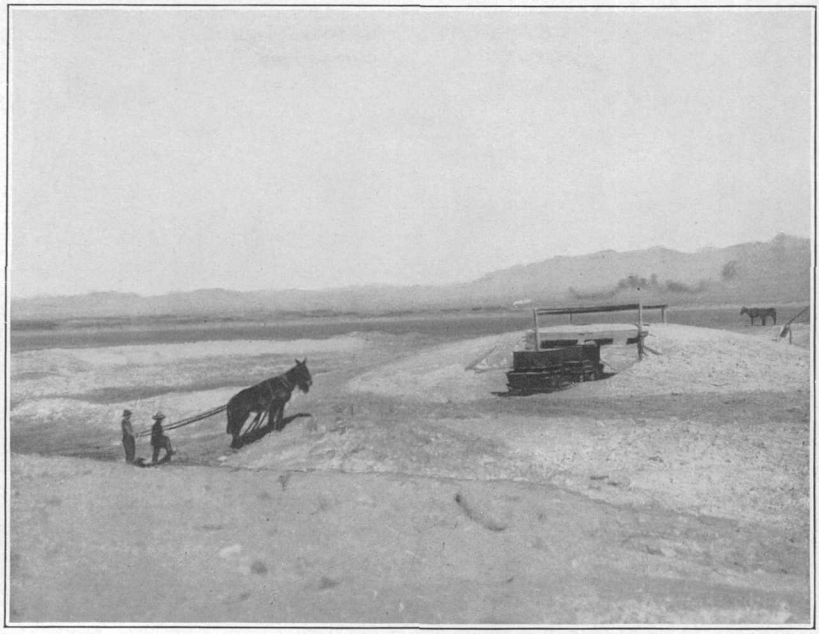
Deposits of alabaster described as 20 to 30 feet thick and traceable across the country for many miles were visited on the south side of an eastern branch of Santa Barbara Creek 32 miles southwest of McKittrick. The location of the claim was given as the SE. ¼ sec. 34, T. 9 N., R. 25 W., San Bernardino base and meridian. The outcrop occupies the end of a low point and is about 50 to 75 feet long by 20 to 25 feet broad and probably somewhat less in thickness. It has an apparent strike along the face of the hill, but a prospect tunnel driven to a length of 40 feet failed to find gypsum in other than thin veins, the largest of which is about 4 inches thick. The outcrop is composed of finely crystalline material, some of which may be classed as alabaster. It is in irregular masses, the largest of which is probably not over 2 feet long, and the clear material is in still smaller pieces. There are small pieces of beautiful pink and clear white material, though only a part of it is hard enough to be useful as alabaster. It occurs in a soft, clayey sandstone, which is probably Tertiary in age.

FRENCH POINT.

In sec. 16, T. 8 N., R. 24 W., San Bernardino base and meridian, on the east side of Cuyama River, 6 miles above the mouth of Santa Barbara Canyon, is a hill known as French Point, which is described as being 200 to 250 feet above the river. A deposit of alabaster is reported to occur near the top of the hill, from which blocks a yard square and 10 inches thick are said to have been taken. An analysis shows that it contains over 90 per cent of gypsum. The locality is 25 miles from Sunset.

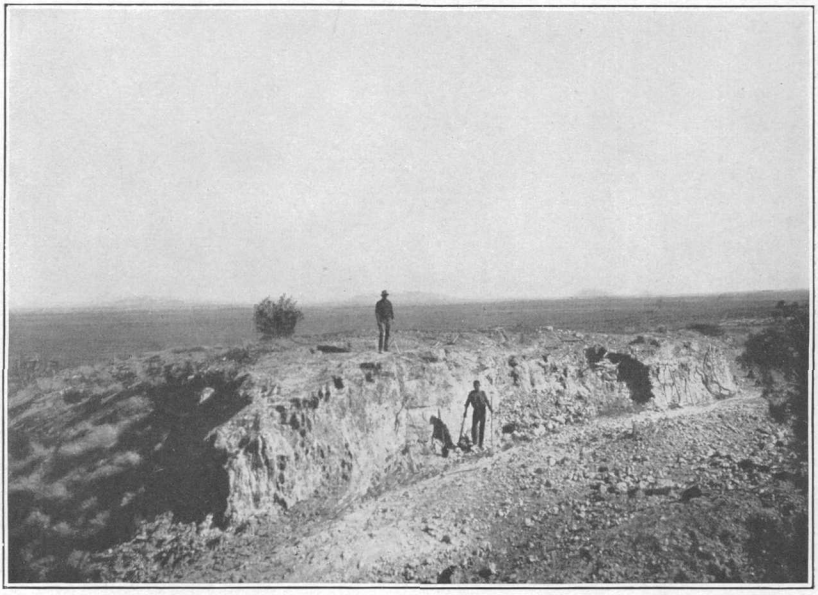
POINT SAL.

On Point Sal, Santa Barbara County, gypsum was mined for several years previous to and including 1889, at a number of points 1 to 2 miles from the coast. Of the former workings there now remain only caved open cuts and tunnels. The rocks are clayey shales only slightly consolidated, are overlain and underlain by harder rocks, and appear to be similar to those on Santa Barbara Creek, mentioned above. The gypsum-bearing rocks of Point Sal are of Miocene age. The gypsum in sight appears to be similar to that described near Santa Barbara Canyon, and is apparently not



A. GYPSUM DEPOSITS IN THE BED OF A PERIODIC LAKE AT AMBOY.

The gypsum is dragged onto the platform by a horse scraper and dumped into the tram cars beneath.



B. GYPSITE DEPOSIT 9 FEET THICK ON THE BROW OF A HILL 1¼ MILES SOUTHWEST OF PALMDALE.

in continuous beds, as it can not be traced into the gulches. Almost none is to be seen on the surface, and the beds are probably of little or no economic value. From 10 to 20 carloads of gypsum remain unshipped on the seashore. The gypsum is well solidified and of rather fine grain, containing considerable clay, although a small part is white in color.

CASTAIC.

Gypsum was mined during 1904 and 1905 by the Fire Pulp Plaster Company from a deposit in Charley Canyon, 12 miles north of Castaic, a station on the Southern Pacific Railroad in Los Angeles County. It is said to occur in a vein, 2 to 4 feet wide, in a soft, much jointed shale. The vein runs at about a right angle to the face of the hill, but was found too expensive to work, as the road in the canyon washed out after each heavy rain. The gypsum is said to be white, occasionally pink, in color and of excellent quality.

PALMDALE.

At Palmdale, Los Angeles County, a station on the Southern Pacific Railroad 69 miles north of Los Angeles, both efflorescent

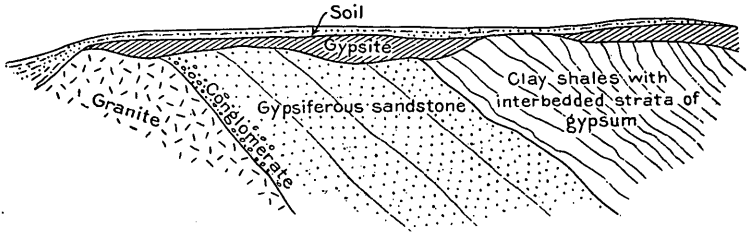


FIGURE 2.—Idealized section across hills 1½ miles southwest of Palmdale, Cal., showing relations of gypsite and gypsum to the country rock.

and interbedded gypsum deposits are found, about 1½ miles southwest of the railroad, on a low ridge along which runs the line surveyed for the canal to bring water from Owens River to Los Angeles. A considerably decomposed granite occupies a portion of the outer side of the ridge, and on it in places is a basal conglomerate containing large bowlders of granite. Over this is a series of gypsiferous soft sandstones and shales. With the shales thin strata of gypsum are interbedded, and on these sediments gypsite has formed in deposits similar to those farther north, along the Coast Range. The gypsum deposits occur through a length of about a mile or a mile and a half along the top and sides of the ridge. In places they have been washed down the sides of the hill, so that they cover the granite below. The accompanying sketch (fig. 2) shows the geologic relations. Two companies, the Fire Pulp Plaster Company and the Alpine Plaster Company, are working the deposits, and each has a plaster mill at Palmdale, to which gypsum is hauled in wagons.

The gypsite is 2 to 10 feet thick and is irregular in distribution and purity. At a number of places it occurs in small valleys in which it has been deposited by freshets that brought it down from the low hills above. In places it is much stained with iron, which has been brought in since the deposition of the gypsite, as is shown by stains following watercourses through the gypsite. The gypsite is ordinarily overlain by 6 inches to 1 foot of dirt, and excavations from which it is removed cover from a few hundred square feet to an acre or more in extent. The thickest deposits are on the brows of spurs of the main hill, where they reach a thickness of 9 feet. (See Pl. III, *B*.) The gypsite is creamy white in color.

A partial analysis by George Steiger of a specimen from one of these deposits which was being worked February 1, 1907, gave the following result:

Partial analysis of gypsite from Alpine Plaster Company's deposit, Palmdale, Cal.

Lime (CaO)	32.8
Sulphur trioxide (SO_3)	45.3
Water driven off at 60° C	.1
Water driven off at 300° C	20.5
Chlorine (Cl)	.06
Iron oxide (Fe_2O_3)	.30

This is apparently equivalent to about 77.3 per cent gypsum. The interbedded gypsum deposits also are worked by the Fire Pulp Plaster Company. The beds are not at all uniform in the quantity of gypsum carried and can be worked only in places. The dip is uneven, but is about 45° W. The gypsum strata reach in places a thickness of 3 or 4 inches, and all contain more or less clay. (See Pl. IV, *B*.) The rock is shot down with dynamite and then handled with forks to separate the gypsum from the clay. Some hand picking is also necessary.

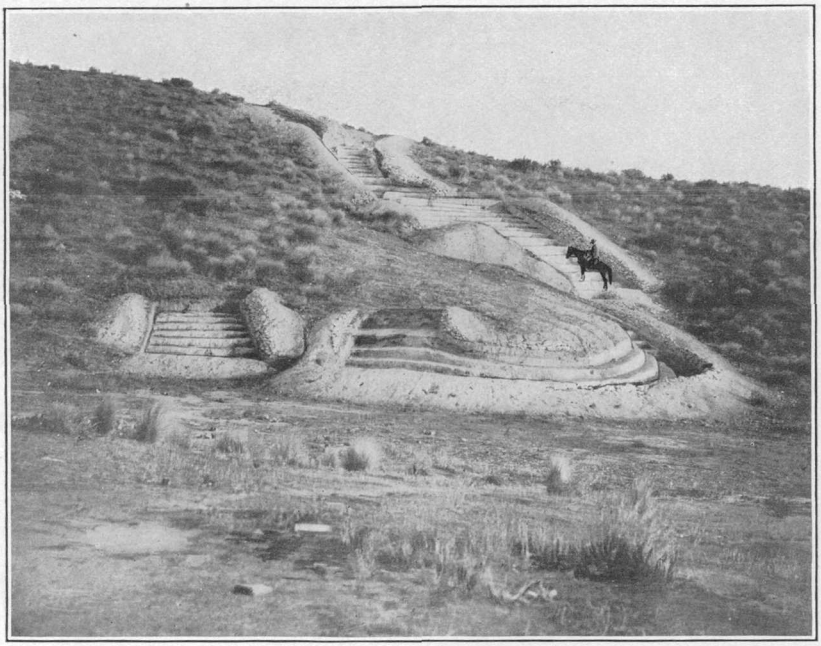
A piece of gypsum from one of the strata was partially analyzed by George Steiger, with the following result:

Partial analysis of rock gypsum from Palmdale, Cal.

Lime (CaO)	27.5
Sulphur trioxide (SO_3)	33.5
Water driven off at 60° C	.8
Water driven off at 300° C	15.6
Chlorine (Cl)	Trace.
Iron oxide (Fe_2O_3)	1.3

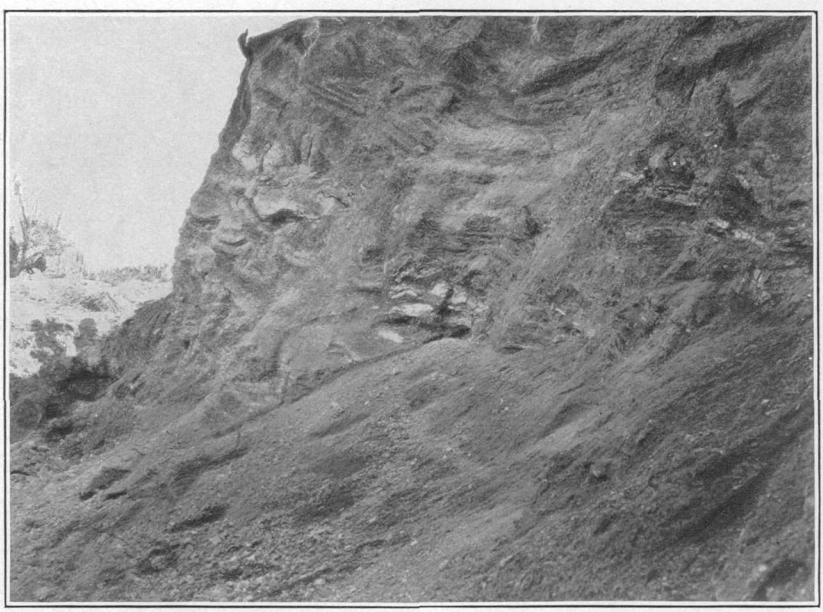
The specimen apparently carries 72.1 per cent of gypsum.

Similar beds outcrop at a point about 1½ miles northwest of the workings just described. They have been worked to a certain extent and a face 25 feet high and 50 feet broad is exposed in an excavation in the side of the hill. The beds here dip northeastward. Other



A. VIEW OF THE GYPSITE WORKINGS IN SEC. 7, T. 32 S., R. 22 E., ON THE CARRIZO PLAIN.

Done to meet assessment requirements on supposed oil land. Photograph by Ralph Arnold.



B. GYPSUM INTERBEDDED WITH CLAY SHALES 1½ MILES SOUTHWEST OF PALMDALE.

The whiter strata are gypsum.

deposits of gypsum are said to occur in the higher hills 6 or 7 miles south of Palmdale. Similar interbedded gypsum deposits are reported to occur at Lang, southwest of Palmdale, and the deposits at Castaic are said to be in the same rocks.

PALEN MOUNTAINS.

Extensive deposits of gypsum occur in the Palen Mcuntains between the Colorado and Mohave deserts, northern Riverside County, Cal. At present they are of no economic importance, being 50 miles from Parker and 60 miles from Danby, both on the Santa Fe Railway, and 70 miles from Mecca, on the Southern Pacific Railroad. The latter is the common way of approach. The new cut-off of the Santa Fe from Parker to Bengal will, however, probably pass within about 15 miles of the deposits.

The gypsum is very pure, occurring in extensive layers interbedded with limestone. Most of it is finely crystalline and compact and varies in color from transparent white to slightly reddish. A small percentage of the material is alabaster, finely granular, snow-white in color, and sufficiently compact for ornamental purposes. This material occurs in layers and lenses in the crystalline gypsum.

The gypsum beds range in thickness up to several hundred feet, with little or no interbedded limestone; the entire limestone-gypsum series is probably several thousand feet in thickness. In places the gypsum is the predominant formation, but elsewhere the limestone is by far the most abundant.

The gypsum-limestone belt is roughly about 3 miles long and from one-half mile to 1½ miles wide. It runs across the Palen Mountains in a general east-west direction, disappearing under unconsolidated desert deposits on both sides. It is bounded on the north by a great mass of granite and on the south by quartzites and shales, with intrusive igneous rocks of several varieties. The gypsum beds are largest and most abundant in the southern part of the belt. The strike of the beds varies between east-west and northeast-southwest, while the dip is at varying angles to the north.

A dark igneous rock occurs abundantly as an intrusive within the gypsum-limestone area, being especially abundant in the northern half of the belt. It cuts the gypsum beds more commonly than the limestone because of their softer nature. On account of this fact many of the gypsum beds are locally so intricately intermixed with igneous rock as to render them almost valueless. However, large portions of the area are free from these intrusives.

MARIA MOUNTAINS.

The gypsum-limestone series of the Palen Mountains reappears to the east from under the desert deposits and occurs throughout the extent of the Maria Mountains. In the western part of these moun-

tains limestone is predominant, but in the central portion gypsum deposits of even greater extent than those in the Palen Mountains are reported to occur.

MECCA.

In the Colorado Desert, 12 miles east of Mecca, are deposits of rock gypsum about the extent and purity of which reports differ considerably. Specimens seen and information obtained from various sources indicate that the occurrence is similar to that at Palmdale.

OTHER DEPOSITS.

At many places in the Colorado Desert the Miocene rocks carry interbedded strata of gypsum, which, however, are generally too thin to be of economic value.[a]

SUMMARY AND GENERAL REMARKS.

The gypsum deposits of the State may be divided into four classes—(1) efflorescent deposits; (2) periodic-lake deposits; (3) interbedded deposits; (4) selenite, or crystallized gypsum veins. Of these all except the fourth class—the veins—may locally be of value.

The efflorescent deposits are widely spread over the Coast Range and Tehachapi Mountains from San Benito to Los Angeles counties. They overlie a variety of Tertiary sediments, fine and coarse sandstones, and siliceous shales. In general they are of little or no value, but locally, where transportation is not too difficult, the deposits may be workable, as at Palmdale.

At a number of places visited claims on such deposits were nominally being held for the gypsum upon them. The gypsum at many deposits can be of no value until transportation is very much cheaper than it is now or is likely to be, and that at other deposits will never be of value. Many a claim owner will freely admit that he is really holding the claim for oil, but that under the existing laws he believes there is no legal way of holding an oil claim against jumpers until it can be prospected, no matter what expenditure of time and money is made upon it, while if it is taken up as a gypsum claim it may be held until a patent is obtainable by doing the annual assessment work.

Efflorescent deposits are formed by the evaporation of the water contained in porous gypsiferous rocks, which leaves its load of gypsum at the place where vaporization has proceeded to a point at which gypsum is precipitated through supersaturation.

The periodic-lake deposits are found in the San Joaquin Valley, the Mohave Desert, and probably in the Colorado Desert. The large deposit at Amboy is being exploited, and prospecting may show others to be of value also. In this and other desert lake beds the

[a] Communicated by W. C. Mendenhall.

waters are briny, but at Kern and Buena Vista lakes gypsum has been deposited from comparatively fresh waters. In the desert lakes gypsum is probably precipitated through supersaturation brought about by evaporation, but in the fresh-water lakes the gypsum is deposited just outside the normal shore line by the evaporation of water from the soil, the deposit being formed similarly to the efflorescent deposits on rocks, the soil drawing its supply of water from the somewhat concentrated solution along the shore of the lake.

Practically all the efflorescent and lake deposits except those in the briny lakes are covered by soil. From those that are not thus covered the soil seems to have been removed by wind or other agencies. The soil is thought to be not necessarily of later deposition, but to be older than or contemporary with the gypsite deposits. The summer heat is very great in all the localities and it is probable that the moisture drawn from the rocks and soil by the sun is vaporized at a depth of several inches below the surface, the depth varying with the locality, or at least it is vaporized sufficiently to precipitate the gypsum before it reaches the surface.

Interbedded deposits are found in Miocene clayey sediments at many places from the middle of Los Angeles County southward along the Colorado Desert, and at a few places northward. Locally these deposits may be workable, but they are generally lean. Interbedded deposits in the Palen Mountains are of unknown age and are reported to be of excellent quality and considerable size. Important veins of selenite are not known at any place in the State.

NOTE ON ERRORS IN THE CHEMICAL ANALYSIS OF GYPSUM.

By George Steiger.

Some difficulty was experienced with the determinations of water in the chemical analyses of gypsum made in connection with the foregoing work.

As is the custom in the chemical laboratory of the United States Geological Survey, the specimens were prepared for analysis by long grinding, to bring the materials to a very fine state of division. The water content in several specimens was so low as to throw doubt on the determinations; consequently the figures were checked by the estimation of water on the unground material. The new figures were several per cent higher than those previously found.

Some experiments were then made on a sample of pure selenite, and on one of very pure massive gypsum, each of which contained the theoretical percentage of water. The results proved to be of sufficient interest to warrant their being noted in connection with the present paper, as they go to show the totally fallacious results which

might be reported in an analysis of gypsum if proper attention is not paid to the preparation of the sample. Fine grinding of any rock in preparing the sample for chemical analysis is liable to cause serious error in the determination of water, though usually not to the extent of the one in question.[a]

The selenite was ground in a mechanical grinder and the water content was determined from time to time by heating a gram portion to a temperature of 300° or 400° C. The extent of rehydration of this material which had been ground and heated was then determined by allowing it to stand in a loosely covered crucible for various lengths of time. For lack of time the rehydration of the ground material before heating was, unfortunately, not determined.

TABLE 1.—*Extent of rehydration of ground and heated gypsum by exposure to air.*

Time ground.	Content of water.	Air slacked.	Water reabsorbed.
Hours.	*Per cent.*	*Days.*	*Per cent.*
5	16.65	.....	.....
10	12.57	2	1.53
		5	1.47
		8	1.47
		16	1.59
15	10.25	3	1.70
		6	1.74
		14	1.62
20	7.74	3	2.15
		11	1.96
		13	2.02
30	6.95	6	1.91
		8	1.93
49	4.11	.....	.....

Potilitzin and Van't Hoff hold that "soluble anhydrite" will unite with water when exposed to ordinary air in such quantity as to form the half hydrate ($CaSO_4.\frac{1}{2}H_2O$) and that at this point the hydration will cease. Cloez determined the quantity of water absorbed by soluble anhydrite to be 8 per cent, which is slightly in excess of the amount required to form the half hydrate, viz, 6.2 per cent.

W. A. Davis[b] has shown the work of Cloez to be correct, but if the product is then exposed to dry air it will lose water to such an extent as to leave a resulting material containing water closely approximating the amount required for the half hydrate. From these data it may be concluded that for every 1 per cent of rehydration which has taken place, as shown in column headed "Water reabsorbed," 15.1 per cent of "soluble anhydrite" was present, the remainder having been there in the nonsetting condition.

Results of the same order were obtained from the sample of massive gypsum, though this was not ground so long as the selenite.

[a] Hillebrand, W. F., The influence of fine grinding on the water and ferrous-iron content of minerals and rocks: Jour. Am. Chem. Soc., vol. 30, No. 7, p. 1120.

[b] Jour. Soc. Chem. Ind., vol. 26, No. 13, p. 727.

The following table is given to show the extent to which the dehydration due to grinding might affect the results of the chemical analysis of a commercial gypsum:

TABLE 2.—*Extent to which dehydration due to grinding may affect analyses of gypsum.*

Water in coarse ground.	Water in fine ground.	Difference.
15.60	9.78	5.82
20.45	16.12	4.33
15.15	9.90	5.25
19.48	19.90	− .42
17.80	9.19	8.61
19.73	19.86	.13

The material used for the determinations contained in the first column was crushed in a mortar only to a rather coarse powder; no grinding motion was used. These figures represent the true percentages of water held by the impure gypsums. In the second column will be found the percentages of water retained after continued grinding of fresh portions of the same specimens, and in the third column the errors caused by the long grinding.

Standard methods were used for the determination of CaO, SO_3, etc., with the usual precautions. No difficulties were experienced.

As stated by Van't Hoff, if the dehydration of gypsum takes place below 107° C. anhydrite is formed without going through the half-hydrate stage. If the crude gypsums referred to in the earlier part of this bulletin were formed by the dehydration of the dihydrate by the action of the desert sun, and if Van't Hoff's conclusions are to be accepted, we might expect to find no half hydrate, but only the original dihydrate and anhydrite. W. A. Davis, however, shows by experiments that dehydration takes place in two stages, the half hydrate being an intermediate product. If this theory is accepted, all three forms may be present.

Le Chatelier[a] showed that at 155° C. the dehydration is incomplete, the half hydrate only being formed at this temperature. He states that the reduction to anhydrite requires a temperature of at least 163° C. Lacroix[b] claims that gypsum can be completely dehydrated at 80° C., while Shenstone and Cundall[b] observed that the water may be entirely driven off at 70° C.

The allotropic forms in which these compounds may occur, their relations one with another, and the contradictory results obtained by numerous experimenters, together with the unknown conditions under which the dehydration or deposition of the crude gypsums referred to took place, throw doubt on any conclusions that would be

[a] Experimental records on the constitution of hydraulic mortar.
[b] Jour. Soc. Chem. Ind., vol. 36, p. 735.

drawn from an ordinary chemical analysis as to the amount of plaster a particular specimen might yield.

In crude gypsums that have been produced by natural processes under circumstances which are not fully known, either by the dehydration of the dihydrate or by direct deposition in the partly hydrated state, we would expect to find mixtures containing the dihydrate, the half hydrate, and the anhydrite, the last being partly in the soluble and partly in the nonsetting form. From the bulk analysis of such material it is not possible to calculate the proportions of these compounds. All that can be done is to indicate the minimum quantity of plaster that might be produced by combining the entire amount of water (about 100° C.)[a] to the dihydrate, providing the material contains sufficient calcium sulphate.

Here again false conclusions may sometimes be drawn, for many crude gypsums contain admixed clay or other hydrated materials. In case impurities of this character are present the amount of plaster the sample will yield, as shown by the above calculation, will appear too high. On the other hand, if the partly dehydrated material contains a quantity of the half hydrate or soluble anhydrite, the figures will be too low, as both of these forms are capable of producing plaster.

It may be that special determinations can be made to throw light on the ratios of these forms, but time has prevented such work in connection with the foregoing analyses.

[a] See Clarke, F. W., The data of geochemistry: Bull. U. S. Geol. Survey No. 330, 1908, pp. 178, 193, 494.

SURVEY PUBLICATIONS ON GYPSUM AND PLASTERS.

The more important publications of the United States Geological Survey on gypsum and plasters are included in the following list. These publications, except those to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

ADAMS, G. I., and others. Gypsum deposits of the United States. Bulletin No. 223. 123 pp. 1904. 25c.

BOUTWELL, J. M. Rock gypsum at Nephi, Utah. In Bulletin No. 225, pp. 483–487. 1904. 35c.

BURCHARD, E. F. Gypsum and gypsum products. In Mineral Resources U. S. for 1906, pp. 1069–1078. 1907. 50c.

——— Gypsum. In Mineral Resources U. S. for 1907, pt. 2, pp. 643–650. 1908.

——— Gypsum. In Mineral Resources U. S. for 1908, pt. 2, pp. 621–628. 1909.

DARTON, N. H., and SIEBENTHAL, C. E. Geology and mineral resources of the Laramie Basin, Wyoming; a preliminary report. Bulletin No. 364. 1909.

ECKEL, E. C. Salt and gypsum deposits of southwestern Virginia. In Bulletin No. 213, pp. 406–416. 1903. 25c.

——— Gypsum and gypsum products. In Mineral Resources U. S. for 1905, pp. 1105–1115. 1906. $1.

ORTON, E. Gypsum or land plaster in Ohio. In Mineral Resources U. S. for 1887, pp. 506–601. 1888. 50c.

RICHARDSON, G. B. Salt, gypsum, and petroleum in trans-Pecos Texas. In Bulletin No. 260, pp. 573–585. 1905. 40c.

SHALER, M. K. Gypsum in northwestern New Mexico. In Bulletin No. 315, pp. 260–265. 1907.

SIEBENTHAL, C. E. Gypsum of the Uncompahgre region, Colorado. In Bulletin No. 285, pp. 401–403. 1906. 60c.

——— Gypsum deposits of the Laramie district, Wyoming. In Bulletin No. 285, pp. 404–405. 1906. 60c.

——— (See also Darton, N. H., and Siebenthal, C. E.)

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