MISCELLANEOUS.

LATE DEVELOPMENTS OF MAGNESITE DEPOSITS IN CALIFORNIA AND NEVADA.

By Hoyt S. Gale.

INTRODUCTION.

By far the greater part of the magnesite occurring in the United States is found in California, where numerous deposits are widely distributed throughout the Coast Ranges and on the western slopes of the Sierra Nevada. Recently reports of deposits at two localities in Nevada have been received. It is said that some deposits of this material are also known in Arizona and western Texas, and small veins, described as chiefly of mineralogic interest, have been found in North Carolina, Pennsylvania, Maryland, and Massachusetts. A number of these deposits, especially in California, are of considerable size and yield magnesite of excellent quality, which is probably excelled by few if any of the foreign deposits and is superior in purity to much of that mined abroad.

Bulletin 355 of the United States Geological Survey, entitled "Magnesite deposits of California," by Frank L. Hess, was based on field examinations of the California deposits made in 1905 and during the winter of 1906–7. Since that time new deposits have been opened, consumption has increased, and inquiries are constantly being received at the Survey for information relating to the occurrence and utilization of this material. The present paper has therefore been prepared to supplement the earlier publication.

PRODUCTION AND CONSUMPTION OF MAGNESITE.

The accompanying diagram (fig. 44) represents the production of magnesite in this country in terms of the raw rock as mined. The figures for production are those given in the annual volume of Mineral Resources of the United States compiled and published by the Geological Survey.

Conditions governing the production and consumption of domestic magnesite have not changed in any marked degree in recent years. The presence of many good deposits of this material in California must continue to furnish the impetus which will tend to put our own product on the market as soon as natural conditions will allow. At present by far the largest part of the magnesite used in the United

States is imported and is consumed in the Eastern States, largely for making refractory products. In 1912 the quantity of crude and calcined magnesite imported, exclusive of the refined magnesia salts imported for medicinal or other purposes, was, when reduced to terms equivalent to the calcined rock, approximately 20 times the domestic production. It is reported, doubtless correctly, that the magnesite mined in Greece, Austria, Norway, and elsewhere, where labor is cheaper than in this country and where port facilities are possibly better, has a considerable commercial advantage over our own product. An ocean rate of perhaps only $1.50 or $2 a ton, coupled with the other advantages of foreign magnesite, overbalances even inferiority in grade of some of the imported product.

Like some other nonmetallic mineral products, magnesite occurs in California and other States in numerous deposits that undoubtedly

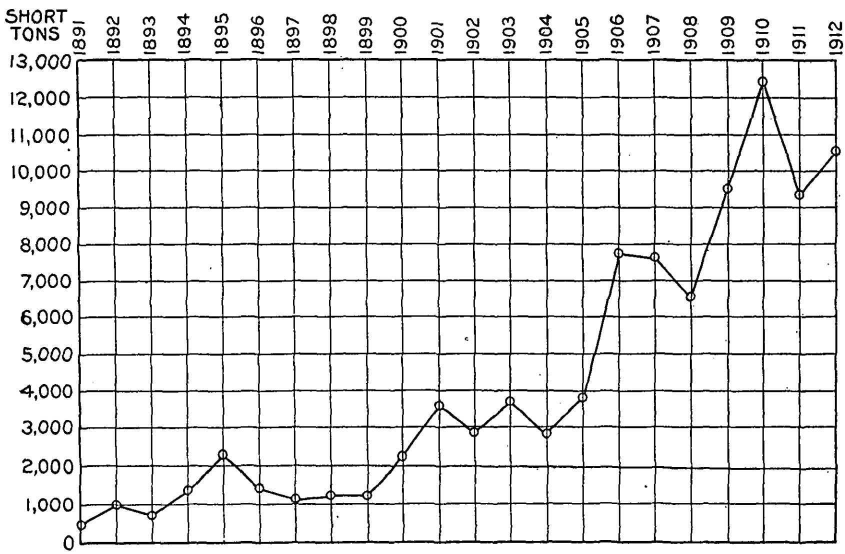


FIGURE 44.—Production of crude magnesite in the United States, 1891-1912.

have considerable potential value, but until conditions in this country will justify a steady, continuous production on a scale to permit efficient mining operations, the foreign product will probably continue to be largely used. Nearly all the California magnesite is consumed on the west coast, the greater part being used in paper manufacture. Overland freight rates to the Eastern States amounting to $10 a ton or more for the present effectually preclude the western magnesite from competing with the imported product in these States.

Considerable interest in the home production of magnesite has been aroused of late in anticipation of the possible advantages that may accrue with the opening of the Panama Canal, in the hope that this new route may enable California producers to reach the eastern ports at sufficiently low freight rates to allow them to place their product on the eastern market.

During 1912, however, foreign magnesite was received at California ports to the amount of about 400 tons of raw rock and nearly 600 tons of calcined, where the calcined (dead burned) rock has been quoted at $23 to $25 or more a ton. Sporadic demands for a few hundred tons of the domestic magnesite are said to have been at times difficult to fill. This condition is not the result of lack of material, but is due to the present limitation and uncertainty of the market, which permits few home properties to operate continuously or on a scale to promote the economy of production which would place the home product in a position to meet competition.

The following statistics concerning imports of magnesite have been obtained from the Bureau of Foreign and Domestic Commerce, Department of Commerce. They include two statements relative to the imports of magnesite "calcined not purified"—one showing the countries of shipment or nominal origin and the other the ports and customs districts into which the material was imported. Data as to the countries from which the crude magnesite was imported are not available.

Imports of magnesite showing ports of receipt during the year ending June 30, 1912.

Customs district.	Crude.	Calcined.
	Short tons.	*Short tons.*
New York, N. Y.	13,864	111
Boston and Charlestown, Mass.	65	3,028
Newark, N. J.	25	
Champlain, N. Y.	276	27
Buffalo Creek, N. Y.	56	56
Chicago, Ill.		27
Memphremagog, Vt.		90
Vermont.	3	61
Philadelphia, Pa.		76,171
New Orleans, La.		22,805
Puget Sound, Wash.	1	23
Los Angeles, Cal.		248
San Diego, Cal.	96	96
San Francisco, Cal.	321	195
	14,707	102,938

Imports of magnesite calcined, not purified, in short tons, for the years ending June 30, 1910–1912, showing countries of shipment or nominal origin.

	1910	1911	1912
Europe:			
Austria-Hungary	101,751	143,392	99,104
Belgium		33	25
Germany	2,719	1,426	689
Greece	927		114
Italy		28	
Netherlands	1,712	2,974	2,410
Norway	28	121	163
United Kingdom (England)	409	2	61
North America:			
Canada	13	296	234
Mexico			81
Asia: East Indies, British			57
	107,560	148,272	102,938

GENERAL CHARACTER AND DISTRIBUTION OF MAGNESITE DEPOSITS.

The mineral magnesite is essentially the normal carbonate of magnesium, expressed chemically by the formula $MgCO_3$. It usually occurs as a dense white massive mineral, rarely showing any crystalline structure, and in its most common massive form it is entirely devoid of cleavage or regular partings. It has conchoidal fracture, showing a smooth white opaque surface resembling broken porcelain. Less pure varieties may be stained and colored or have a coarser granular structure.

According to Dana magnesite has a specific gravity of 3 to 3.12. Therefore a cubic foot of the solid mineral weighs about 190 pounds. It is rated as 3½ to 4½ in the scale of hardness. The theoretically pure mineral contains 52.4 per cent of carbon dioxide (CO_2) and 47.6 per cent of magnesia (MgO). As the mineral occurs in nature it includes various proportions of silica, clay, or serpentine and to a greater or less extent the oxides of iron.

Most of the deposits of magnesite known are associated with intrusive igneous rocks such as peridotite and allied basic rocks, which are composed essentially of minerals rich in magnesia, like olivine and the pyroxenes. As the magnesite occurs in veins and lodes, in part replacing the igneous rock, it seems quite clear that it is derived mainly from the alteration of the intrusive magnesian rock. In the original rock the magnesia is present principally in the form of silicates. By alteration of the silicates to the carbonate, magnesite, the silica is set free. The magnesite veins commonly occur in zones of more intensive alteration in the magnesian silicate country rocks, and these zones are most conspicuously characterized by secondary silica, as opal, chalcedony, or quartz. One of the most common products of the decomposition by hydration or weathering of magnesia-rich silicate rocks is the green mineral serpentine, a magnesian silicate, with water in combination, and this alteration takes place so extensively over the surface areas of the exposures of the basic intrusive rocks here described that the whole mass is commonly referred to as "serpentine," although that term strictly signifies a specific mineral rather than a rock that is more or less diverse in composition.

"Serpentine" rock is widely distributed throughout the Coast Range and also in the Sierra Nevada of California. Reports of magnesite occurrences elsewhere indicate that similar rocks also exist in Nevada and outside of the areas concerning which definite geologic data are now available.

USES OF MAGNESITE.

The principal uses of magnesite are summarized below. The data on this subject have been of necessity compiled from published returns and from hearsay, but care has been exercised to make this statement as accurate as possible.

1. In refractory products, such as brick, furnace hearths, and crucibles.
2. As magnesium sulphite for the digestion and whitening of wood-pulp for paper.
3. In crude form for the manufacture of carbon dioxide.
4. Calcined and ground for oxychloride or Sorel cement.
5. In crude or calcined form for miscellaneous applications.
6. As refined magnesia salts for medicinal and other uses.

Refractory products.—The uses of magnesite for refractory products constitute perhaps its most important application in the industries. Made into refractory bricks it is used as linings for basic steel furnaces. In "dead burnt" calcined form as originally burned or as brick, the magnesia is used as a refractory lining for open-hearth furnaces and converters in the steel industry, for rotary kiln linings in Portland cement manufacture, for furnace hearths, crucibles, cupels, etc.

It is commonly believed that the most refractory magnesite is the "dead burnt" product derived from magnesite containing little or no lime, silica, oxide of iron, or alumina. The presence of lime in magnesite bricks used at high temperatures is said to cause them to disintegrate more readily, and in basic steel furnaces the lime is believed to cause the phosphorus to pass into the hearth instead of the slag, the hearth thereby becoming rotten. Silica, oxide of iron, and alumina are supposed to be objectionable because they have a tendency to lower the fusing point. On the other hand, analyses of the imported magnesite, which constitutes by far the greater part of the product consumed in this country and is assumed to represent a standard of desirable composition for practical purposes in the metallurgical industry, generally show 3 to 4 per cent of silica, 6 to 8 per cent of iron, and 4 per cent of lime. The percentage of alumina usually found is said to be so small that it need not be considered.

Apparently there is some divergence of opinion as to the most desirable composition of magnesites to be adopted for metallurgical refractory uses.

Paper manufacturing.—The availability of magnesite in the deposits in California has led to the considerable use of magnesium bisulphite in the manufacture of wood-pulp paper in that State.

In the sulphite process of paper making [1] the wood (mostly coniferous wood) is boiled with a disintegrating agent so that it breaks

[1] Thorp, F. H., Outlines of industrial chemistry, 1909, pp. 522-523.

down into a mass of pulp, which is afterward rolled into paper. The disintegrating agent is sulphurous acid or common bisulphite of calcium or magnesium. Magnesium bisulphite is more stable than calcium bisulphite, it dissolves the noncellulose matter more completely, and it has an additional advantage in that the residues left in the stock when it is used are not afterward injurious to sizing agents. Sodium bisulphite gives a better product than either the magnesium or the calcium salt, and strong liquors can be made from it, but it is too expensive for general use.

It is estimated that the greater part of the California magnesite is now used in the manufacture of paper by this process. The deposits near Porterville, which have been for years the largest producers, have been worked primarily for this purpose.

Manufacture of carbon dioxide.—The manufacture of carbon dioxide from raw magnesite consists in the decomposition of the magnesium carbonate by ordinary calcination, the carbon dioxide being recovered, purified, and compressed, and the residual magnesia being also available as a by-product. The operation of this process is described by Hess,[1] who gives a diagram showing details of one of the plants. It is understood that the use of magnesite for this purpose has now been largely or wholly abandoned on the Pacific coast, as carbon dioxide can be produced more cheaply as a by-product in other processes; for instance, it is now made as one of the products of fermentation in a distillery.

Cement.—The use of magnesite for the manufacture of oxychloride or Sorel cement is apparently a promising field. This product consists of a mixture of finely ground calcined magnesite with magnesium chloride and when it has been wet sets in an exceedingly strong, somewhat elastic cement. The material for this cement is marketed under many trade names, being especially referred to as a sanitary flooring. For flooring, wainscoting, and similar uses the cement is mixed with wood flour, sawdust, cork dust, or some similar material. When well and successfully laid, magnesite cement has some important advantages over other cements for this purpose. It produces a smooth, even floor, which may be laid in thin sheets over large surfaces without cracking. It takes colors readily, and is susceptible of a good polish with oiling or waxing. It is laid in a plastic state on wood or concrete. Its surface seems to have a resilience not apparent in ordinary cement, and it does not pulverize or grind to dust. This cement is said to have been very extensively used abroad for flooring and to be gradually coming into wider use in this country. It is also reported to have found a use in the manufacture of artificial marble and fine tiles.

There are, however, practical difficulties to be encountered in the manipulation of magnesia cements, which are not yet wholly under-

[1] Bull. U. S. Geol. Survey No. 355, 1908, pp. 8, 9.

stood and have at times led to some dissatisfaction with the material and to criticism, possibly not always merited. It would seem to be desirable that a competent investigation of the technology of this subject should be undertaken in the interest of a potentially very useful product.

Other uses.—Magnesite in both crude and calcined form finds numerous miscellaneous applications, among which may be mentioned its use as heat-insulating pipe covering. For this purpose it is commonly mixed with asbestos fiber, and the artificial magnesia alba levis seems to be best. Magnetite is said to be used as an absorbent in the manufacture of dynamite, as an adulterant in paint, and as a preventive of scale in boilers in which sulphurous waters are used. It has been tried with some success as a binder for briquetting coal, where it has the disadvantage common to all inorganic binding materials, namely, that they increase the ash without adding to the combustible portion of the fuel.

The use of magnesite in a fireproof or fire-retarding paint is also reported to be increasing. Wood and burlap coated with a paint made of magnesite are said to resist fire so that while they can be burned by the direct application of heat and flame, the fire will not spread beyond the area actually exposed to the flame.

Refined magnesia salts are used for medicinal and toilet purposes. The commercial preparation known as magnesia alba is a basic carbonate of slightly varying composition, according to the conditions of production. It is usually prepared by precipitation of either the commercial sulphate or chloride of magnesium with sodium carbonate. Epsom salts (magnesium sulphate) is derived from the deposits at Stassfurt, Germany, and is imported on a considerable scale but is also manufactured by the chemical treatment of magnesite. A considerable quantity of magnesia quoted as "medical, calcined" is imported annually, probably representing a purified product for medicinal or other uses.

DEPOSITS IN CALIFORNIA AND NEVADA.

SUMMARY.

A number of recent developments in reference to new deposits or deposits in which interest has been revived have led to a partial review of the magnesite industry of the West by the writer. Some field examinations were made in 1912, and the resulting descriptions and records are given in the following pages. In general it is designed that these accounts shall supplement rather than duplicate the matter contained in Hess's report, already cited.

The deposits visited are here described by counties, beginning with the more northerly and proceeding toward the south. A few of these descriptions have already been published with the statistical summary in the annual volume of Mineral Resources of the United States.

CALIFORNIA DEPOSITS.

SONOMA COUNTY.

EAST FORK OF AUSTIN CREEK OR RED SLIDE.

The occurrences of magnesite in the Coast Range belt, Sonoma County, Cal., have been described by Hess,[1] and the following notes are added mainly because of late activity looking to the further development of the deposits on East Fork of Austin Creek. These deposits were examined by the writer, by courtesy of Mr. A. B. Davis, September 16, 1912. At that time the most convenient means of access was to go on horseback by road and trail about 8½ miles north from Cazadero, the route crossing the steep divide between the branches of West and East forks of Austin Creek and descending at the Heider ranch, on East Fork. There is a wagon road from Guerneville to the deposits, but it is steep and difficult as well as long. A new road has been surveyed for the development of the magnesite properties, following down East Fork of Austin Creek to its junction with West Fork, a distance of about 10 miles, there meeting the railroad at Watson's, 2 or 3 miles above the junction of the forks of Austin Creek and Russian River. According to statements made by Mr. Davis this route offers no unusual difficulties for transportation, is of uniform and light grade, and when a road is built will afford a ready

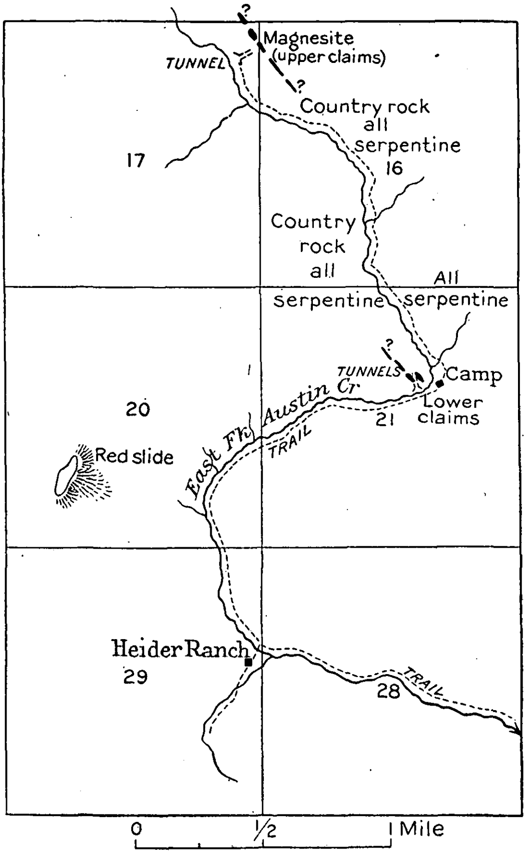


FIGURE 45.—Map showing magnesite deposits on East Fork of Austin Creek, Sonoma County, Cal.

[1] Op. cit., pp. 26–28.

means of getting the ore down to the railroad shipping point, at a relatively favorable distance from San Francisco or the Pacific coast.

The deposits are located in T. 9 N., R. 11 W., and consist of two groups of claims, which are referred to as the upper and lower claims. The lower claims lie on the north and west side of East Fork of Austin Creek in a bend of the main stream, a little over a mile northeast of the Heider ranch. Just above the prospects of the lower claims the main creek flows from the north or northwest. The tunnel on the upper claims is situated on the east bank of the creek 1½ miles N. 30° W. from the lower tunnels. A wagon trail runs between the two properties and continues downstream past the Heider ranch.

The alignment and level line of a new road survey extends as far upstream as the tunnels on the lower claims. Several large outcrops of magnesite show on the northwest bank of the creek, not far above water level, and large blocks or masses of magnesite are to be found in natural slide rock at the base of the slope and also in the creek bed.

As stated by Hess [1] large areas of serpentine, whose limits have not been defined, occur in this portion of the country, and it is in this serpentine that the magnesite veins occur. The Red Slide, a prominent landmark near the crest of the high ridge southwest of the magnesite claims, is probably a part of the same serpentine area, and the rock exposures in the canyon between the upper and lower claims consist almost entirely of serpentine.

So far as has been determined the magnesite veins of both groups of claims lie in a fairly well defined belt that trends N. 30° W. from the lower claims. This trend is approximately parallel to the upper course of East Austin Creek, crossing it, however, so that the croppings of the southern or lower group of claims are west of the creek and those of the upper claims lie east of it. It is not supposed that the veins are continuous throughout this belt, but it appears likely that there may be a more or less well defined zone of brecciation along which deposits or traces of deposits may be found at intervals. The serpentine in the road-cut between the two groups of claims was noted to be a mass of much-shattered rock containing magnesite stringer veins as much as an inch or so in thickness. No attempt was made during the writer's brief visit to trace this zone, even within the limits of the located claims.

The developments on the lower claims were apparently in much the same condition as when they were examined by Hess.[2] The accompanying diagram (fig. 46) represents roughly the sections exposed by the two main tunnels of this lower group of claims, and also the site from which the portion represented in the sample analyzed was taken. The lower of the two tunnels (*a*, fig. 46) was somewhat more than 200

[1] Op. cit., p. 26.

[2] Idem, pp. 26, 27; Pl. V, *B*.

feet in, starting on the outcrop of a vein 6 to 9 feet in width. This tunnel is driven on the vein N. 10° W. for about 50 feet, then turns diagonally off into country rock, extending about 180 feet in a northeasterly course. One other small vein of magnesite, step-faulted, trending N. 20° W., was encountered near the end of this drift. The upper tunnel (*b*, fig. 46), which is supposed to cut about the same rocks as the lower tunnel at an elevation 50 feet higher, is only a little over 100 feet in length, but shows a much larger cross section of magnesite veins. None of the veins have been followed by drifting for any considerable distance, and their continuity or extent is very uncertain. Like the lower tunnel this working is driven in at the outcrop of a large ledge exposing about 12 feet of magnesite, but apparently the entry does not follow the trend of the ore body. The west wall of the vein is distinct, stands nearly vertical, and trends N. 40° W., while the tunnel starts in at about N. 5° W. Magnesite can be seen in the serpentine at the west of the entrance, and for the first 50 feet the tunnel runs diagonally into a more easterly vein, which shows a good 5-foot face at the end of this portion of the tunnel. From this face was taken the sample whose analysis is given below in column 2.

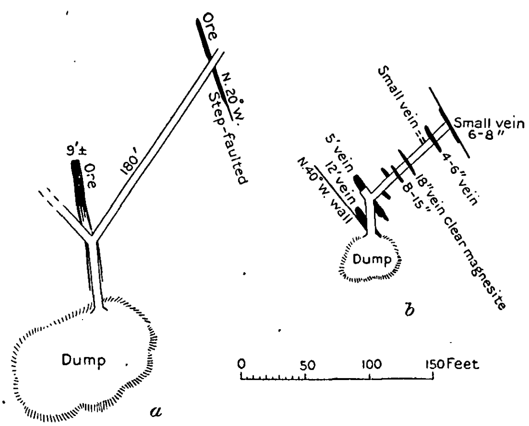


FIGURE 46.—Sections of two main tunnels on lower magnesite claims on East Fork of Austin Creek, Sonoma County, Cal.

At this point a crosscut was started, running off to the northeast about 90 feet farther. There is much minor faulting, but the general trend of the veins is N. 30°–40° W. Besides the larger bodies of magnesite near the entrance, there is another vein about 4 feet thick, faulted and somewhat offset across the course of the tunnel. At several other points veins ranging in thickness from 4 to 18 inches or more have been encountered. At one place a shallow drift has been run to follow a group of several smaller veins, but without much success. Besides the displacement due to minor faulting there is much that indicates lack of continuity of the veins for long distances. The property may, of course, contain other deposits that are not developed in the present workings. It appears that further prospecting on the larger ore bodies themselves is needed to determine the extent of the commercial reserve on this property.

The developments at the upper claims, 1½ miles northwest of the lower claims, consist principally of a tunnel about 100 feet long, driven in on a course N. 48° E., on the east side of the creek about 50 feet above the water and 230 feet below large outcroppings of magnesite which form prominent ledges on the steep slope above. This tunnel has been directed with the intention of crosscutting the magnesite veins but at the time of the writer's visit had not reached them.

The exposure higher on the slope consists of a large projecting ledge of white magnesite, which makes a conspicuous feature in the thickly forested and brush-covered hillside. The thickness and attitude of the ledge are difficult to determine from the present exposure, as an apparent vein-banded structure dipping 40° NE. is most evident in the ledge, and yet the attitude of the extension of this massive ledge to the southeast, as viewed from a distance, is that of a rather steep dip toward the creek, or southwest. For this reason the section measured on the outcrop, giving a thickness of 30 to 35 feet across the banded structure, very likely does not represent the true cross-section of the vein. Magnesite constitutes a very large part of the mass, however, as is indicated by surface exposures, and further underground exploration of the deposit will be necessary before its limits can be more positively defined. The extent of this deposit in either direction is also a matter of much uncertainty. A ledge similar to the magnesite outcrop was observed to the northwest, and evidently the ledge extends about S. 30° E. from the outcrop that was examined above the tunnel. According to report the ledge has been traced 300 feet to the north and 400 feet to the south, but the deposit is supposed to be thickest near the center.

The magnesite of both the upper and the lower claims appears to be of similar character, although no samples for analysis were taken from the upper claims. The outcrop consists of rough and weather-stained rock which it was thought not worth while to sample for analysis, as a sample from such rock probably would not be representative of the deposit as a whole. Where the rock is broken off, the magnesite shows a chalky white surface, in patches having the typical white china-like fracture, but the mass is irregularly broken or jointed and filled with seams and cavities lined with silica. This gives to the deposit the appearance of being unusually high in silica, although this does not seem to be entirely borne out by the analyses of the selected samples taken at the lower claims. Siliceous bands throughout the outcrop stand out on the weathered surfaces, probably making them more conspicuous than they would be in freshly quarried parts of the deposit.

In the following table the first analysis is one made by A. J. Peters on a sample collected by Frank L. Hess, selected to represent the deposit at the time of his examination at the lower claims, and the second is a recent analysis made by Walter C. Wheeler, of the Geological Survey, on an average sample from a working face in one of the tunnels on the lower claims, collected by the writer during his recent examination. This sample represents 60 inches of magnesite cut from the vein of that width exposed in the upper tunnel on the lower claims at the end of the first portion of the tunnel, about 25 feet from the entrance. The sample was chipped, after some preliminary cleaning, across the section of vein exposed in the tunnel and was afterward crushed and quartered. This 5-foot cross-section was the best looking portion of the veins exposed in the tunnels.

Analyses of magnesite from lower claims on East Fork of Austin Creek.

	1	2
SiO_2	7.67	3.66
Al_2O_3	.26	.75
Fe_2O_3	.29	.44
CaO	.04	.20
MgO	43.42	44.90
CO_2	48.08	49.20
Undetermined	.24	.85
	100.00	100.00

Probably the silica in the deposit as a whole would average higher than that shown by the second analysis, and for this reason the writer is of the opinion that the first analysis may be more truly representative of the whole deposit. There is no reason to doubt the representative character of the samples with reference to the other constituents. The magnesite apparently lacks the beautiful white, even-grained texture so characteristic of the better part of other deposits in the State. Lime, commonly considered one of the most detrimental constituents if present in amounts over 1 or 2 per cent, is low or practically absent in the samples analyzed. Iron and alumina are also low, and for refractory purposes at least the silica in the form of quartz or chalcedony is probably not a serious detriment, except that it is an unnecessary constituent and increases the weight for shipment. So far as may be judged by analysis alone the product would also be entirely satisfactory for use in cement, though this inference should be corroborated by practical tests. The quality of the magnesite, as shown by samples from the lower claims alone, is therefore judged to be generally satisfactory.

Prospective development of these deposits is now being pushed. Success in the undertaking naturally will depend on many factors, including skillful management, correct estimates concerning market for the product, moderate costs of production and transportation, and adequate mining facilities, but other considerations that are vital to the success of such an enterprise relate to the quality of the magnesite that can be obtained from the deposit and to the question whether or not the veins are in fact large and persistent or merely erratic deposits.

A glance at the map (fig. 45) will show that important bodies of magnesite have been found at only two localities in this district, and these are known chiefly from the natural outcrops, which are not of very unusual size or character. Some shallow development work has been done, with results that are not entirely satisfactory, so far as affording proof of the size or extent of the deposits is concerned. It is true that certain parts of the deposits are shown by analyses to be magnesite of good quality, but little is known of the continuity of the deposits underground. In fact, such evidence as has been obtained tends to justify the assumption that the ore bodies are of very irregular and uncertain extent, a characteristic that is common to most known magnesite deposits. Large bodies of magnesite have been developed elsewhere and may be developed here. Other conditions being favorable, the deposit undoubtedly warrants a thorough test to determine what may be reasonably counted on as a magnesite reserve.

GILLIAM CREEK.

The deposits of magnesite on Gilliam Creek have been described as some of the most extensive surface exposures in the State. For this reason they were visited by the writer. There has probably been no further development since the property was visited by Hess in December, 1906, and therefore about the only new contributions are the sketch map (fig. 47) and the analysis given below, which by comparison with the former analysis may give some further basis for estimating the quality of the magnesite available.

The deposits are described as including in part lots 3, 4, and 5, sec. 6, T. 8 N., R. 10 W., Mount Diablo meridian, said to be patented and owned by the Western Carbonic Acid Gas Co., of Agnew, Cal. The road leading to the deposits, reported by Hess as under construction in 1906, had at the time of the later visit been long disused and had fallen out of repair so that it was in places impassable with a wagon. From the appearance of the property it is doubtful if any considerable quantity of magnesite has ever been shipped from this place.

The magnesite occurs, as usual, in the form of veins in basic rock partly altered to serpentine. The serpentinous rock is evidently intrusive and is exposed in masses irregularly distributed through the general country rock of sandstones and shales. During the writer's hurried visit, the geologic relations were not worked out in detail, only the fragmentary notes given below and the data presented on the accompanying sketch map being obtained.

The magnesite ledges occur in the more siliceous or more resistant zones of the serpentinous country rock, illustrating the general vein origin of the deposits. Thus the deposits in general lie on or near the summits of ridges, where they have more effectively withstood decomposition and erosion. At this locality the veins may bear some relation to the contacts of the serpentine and sedimentary rocks. It is uncertain whether they are simple vein fillings following shear zones in the serpentine, in which case it might be difficult to account for the large mass of some of the deposits, or fillings of

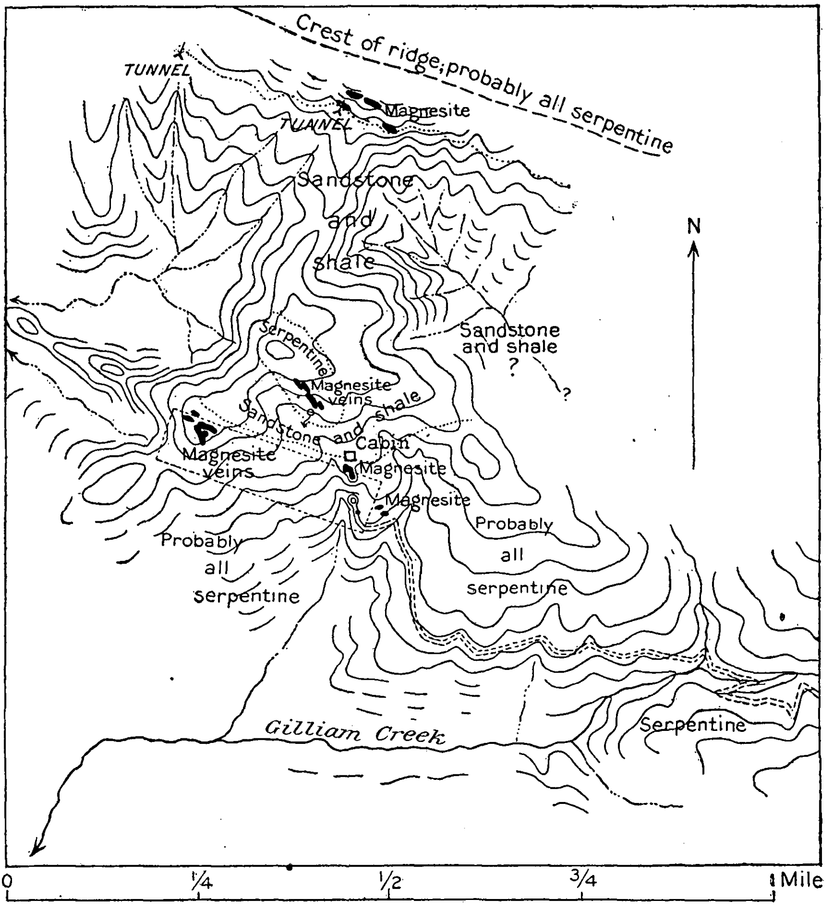


FIGURE 47.—Sketch contour map of the Gilliam Creek magnesite deposits, Sonoma County, Cal.

contraction cracks in the original mass of the serpentine, although it seems more likely that they are in part replacement deposits originating in fissured zones in the serpentinous country rock.

The principal group of claims noted lies just beyond the end of the wagon road built to the property from Gilliam Creek. Here, as in the claims farther north, the principal trend of the deposits is somewhat north of west, although the more prominent outcrops are decidedly discontinuous. Large masses of magnesite, both in outcrop and as float, were observed on the hillside near the end of the road and on the west side of the ridge to the northwest. The stack of material from which the sample for analysis was taken was evidently composed of this float that had been collected for possible shipment. It is not known how far this lode has been traced to the northwest, as no one familiar with the property was there when the visit was made, and time to make a thorough examination of the property was not available. Large blocks of float near the road to the southeast and the sharp, narrow ridge extending to the northwest indicate an extension of the zone of silicification with which the magnesite ledge may also be associated.

The following analyses of magnesite from this deposit include (1) one made by A. J. Peters [1] from a sample selected to be as nearly representative of the rock as possible, and (2) one recently made by Walter C. Wheeler, in the Geological Survey laboratory, representing an average of samples collected by the writer from many parts of the pile below the cabin at the end of the wagon trail.

Analyses of magnesite from Gilliam Creek, Sonoma County, Cal.

	1	2
SiO_2	3.51	10.21
Al_2O_3	1.10	.31
Fe_2O_3	.80	.74
CaO	1.46	.59
MgO	43.65	41.06
CO_2	49.16	44.76
Undetermined	.32	2.33
	100.00	100.00

It will be noted by comparison of these analyses that there is some variation in the two samples, both intended to be representative of the same property. In analysis 2 the silica is much higher than in the earlier analysis. From the general appearance of the rock it is thought that the higher silica content is more nearly representative of the deposit. Silica in a magnesite rock may usually be regarded, for many purposes for which this material is used, as an inert impurity. The low percentage of lime is considered favorable, and iron and alumina are not high.

Nearly parallel to the lodes described, half a mile to the north or northeast, prospects on magnesite ledges were observed in the flank of a somewhat higher and wooded ridge. This locality was not explored in detail, and the work done on the prospects was old and the tunnels caved, so that little accurate information concerning these deposits was obtained. Most of the magnesite seen was float on the hill slope. Some was seen in large masses along the ridge, but it appeared much seamed and banded with silica or foreign matter.

[1] Hess, F. L., op. cit., p. 25.

ECKERT RANCH.

It has been reported that in 1912 two carloads of magnesite were shipped from one of the deposits on the Eckert ranch, 2 miles east of Cloverdale, Sonoma County. It is said that this material was collected from the surface and no attempt is now being made to develop a regular production from this property.

SANTA CLARA COUNTY.

Large deposits of magnesite of great purity at Red Mountain, in T. 6 S., R. 5 E., in the northeast corner of Santa Clara County, along the Stanislaus County line, are said to have been known for a long time, and several attempts have been made to put the property on a producing basis. Red Mountain is one of the higher crests in the Coast Ranges about 60 miles southeast of San Francisco, near the corner of Stanislaus, San Joaquin, Alameda, and Santa Clara counties. The deposits are probably among the best in California.

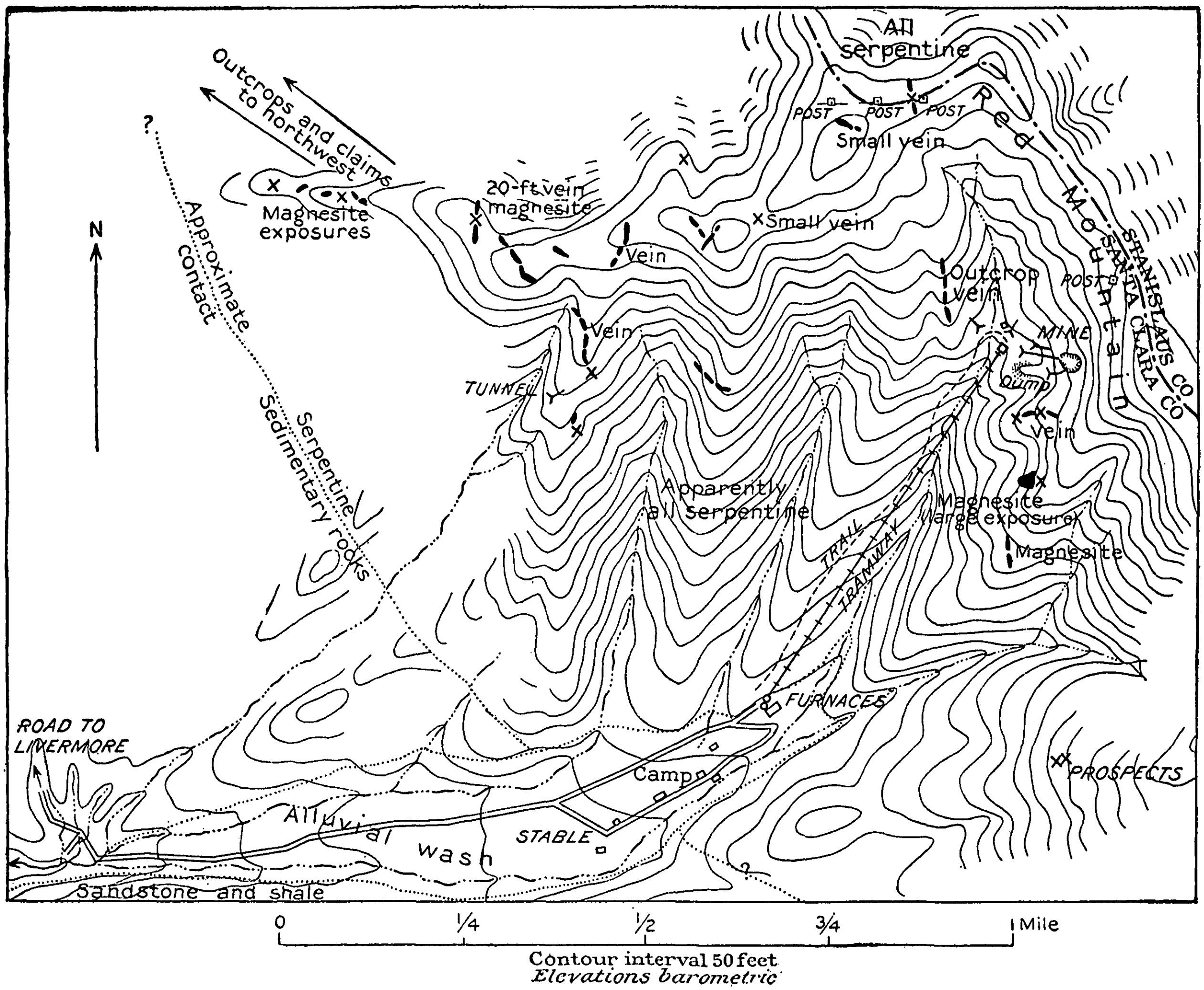
Livermore, the present shipping station, is about 32 miles distant over an excellent graded road that follows the valley of Arroyo Mocho southeast from Livermore, rising from an elevation of 487 feet at the Livermore station to a summit of nearly 2,700 feet, thence descends and crosses Colorado Creek at the head of Arroyo del Valle, and passes over another summit into the basin in which the deposits are situated.

It is stated that the deposits were first worked in 1905. A well-equipped plant, including two furnaces of the stack type, a warehouse, and camp buildings are situated in the valley below the mine and prospects and are connected with the main workings by a 3,000-foot tram which has a vertical drop of about 550 feet. The camp has a good water supply, which is derived from springs and which, though small, seems to be ample to meet the requirements.

At the time of the writer's visit (September 13 and 14, 1912) the property was being worked in a small way, magnesite being extracted to be shipped to San Francisco for the manufacture of a waterproofing paint for concrete and brick.

The deposits are covered by a group of 12 or more lode claims, but one of which, it is understood, had been patented. The outcrops prospected or mined lie on the southern and western slopes of Red Mountain. The ledges of the chalky-white magnesite stand out conspicuously as viewed from the valley, forming a contrast against the dark reddish-brown soil which covers most of Red Mountain and from which it probably takes its name. The whole mountain area is more or less thickly covered with scrubby brush, chiefly manzanita.

The general area containing the magnesite outcrops is occupied by serpentine without evidence of much variation in character or of



SKETCH CONTOUR MAP OF MAGNESITE DEPOSITS AT RED MOUNTAIN, SANTA CLARA COUNTY, CAL.

inclusions of other rocks. The serpentine is bordered on the west by sedimentary sandstones and shales which form a distinctly different topography. The other limits of the mass of serpentinous rock have not been defined. The original country rock from which the serpentine is derived is described by Hess [1] as lherzolite and peridotite, in some places remarkably fresh. Lherzolite is a variety of peridotite and is composed essentially of the minerals olivine, diopside, and an orthorhombic pyroxene. The mineral serpentine is a natural alteration product from such rocks. The original country rocks are composed principally of silicates of magnesia (silica 40+ per cent; magnesia 25 to 40 per cent; alumina and iron variable, usually 5 per cent or more; and a small percentage of alkalies). It is natural to assume that magnesite might be derived by the decomposition or alteration of these silicates being deposited as veins along fissured zones or by replacing the country rock. As a whole, however, the serpentine of this area does not show the excessive amount of shearing to be seen at many of the other magnesite localities.

Throughout the dark-red soil that covers the area of serpentine country rock, especially in the zones that contain the magnesite veins, silica is present in various forms. It occurs in part as a white and rosiny opal, scattered fragments of which are strewn about on the surface, or it may be observed as chalcedonic veins or coatings in the joints of the country rock. The silica associated with the purer mass of magnesite in the larger pit was in the form of a pale-greenish granular quartz.

The magnesite veins are very irregularly distributed and appear to trend in all directions. The larger developed masses are of most unusual size, and even the great bodies that have been removed by mining have been taken out in large open caves or chambers, so as to give little evidence of the real extent or size of the deposits underground beyond that which has been taken out. It appears that the amount of magnesite available must be very large, and as it is situated under favorable conditions for mining it should constitute, if properly handled, one of the most profitable deposits in the State whenever the market can be developed to support a steady domestic production.

The accompanying map (Pl. X) was made by pacings, with the use of a pocket compass, the elevations being obtained from an aneroid barometer. It is therefore not exact, nor is it supposed to represent all the outcrops of the magnesite or all the prospects. It indicates the distribution and irregular trend of the larger veins observed and shows the situation of the mine and camp and the approximate contact of serpentine and sedimentary rocks on the southwest side of the deposits.

[1] Op. cit., p. 34.

In general the magnesite veins seem to be distributed through a belt having a northwest-southeast trend. Claims and prospects on the magnesite some distance to the northwest beyond the limits of the area mapped could be distinctly seen but were not visited.

A number of the large outcrops of magnesite are situated on the higher slopes of Red Mountain, facing west and south on the headwaters of streams draining toward the south and southwest, so that the material from nearly all the deposits may be very conveniently carried by trams or otherwise as far as the valley flat in which the camp is situated. The main workings consist of a number of tunnels and an open cut near the head of the tram. From this place the magnesite that has been shipped was taken out. The principal tunnels run in on two levels, encountering a large body of pure white magnesite, from which a considerable amount has been removed. A large stope in the underground workings measures about 30 by 30 by 60 feet, all in magnesite of almost unusual whiteness and apparent purity, and this vein is also represented at the surface by a large open pit or "glory hole" 40 yards or more in length and 25 to 30 yards wide in its widest part, with a cavelike excavation beyond. Much of the pit has been excavated in thoroughly shattered and decomposed serpentine, but the area has contained large bodies of good magnesite, portions of which show on the sides of the pit and in the cavelike excavation at its southeast end. The magnesite includes some seams and bands of silica, in part a greenish granular quartz or chalcedony and in part a clear whitish opal, but it is a very minor constituent of the mass. Toward the borders of the large masses that have been removed the magnesite becomes more and more mixed with the serpentinized country rock, so that it is difficult to define the limits either of the magnesite body or of the purer part. The serpentine adjoining the large magnesite masses is softened, almost earthy, and of a dull yellow-greenish color and is filled with thin seams which contain magnesite and silica. The coarser joints that traverse the country rock are commonly stained a deep red, as if by iron derived from the soil above. The roofs of the large stopes or cavelike openings cut in solid massive magnesite stand without timbers or other support.

There are a number of other prospect pits, shafts, and exploratory tunnels on the different exposures about the property. These are partly indicated on the accompanying map (Pl. X), but it is difficult to give much detailed information about unopened deposits in the absence of careful sampling and analytical data. Many large veins are exposed at the surface, apparently containing a considerable reserve of magnesite of the excellent quality similar to that shown in the body that has been worked. Several ledges expose veins 10 to 20 feet or more in width at the surface. There seems to be little doubt that the property contains large resources in magnesite, even though comparatively little is known about the underground extension of the deposits.

The following analysis of the magnesite from Red Mountain is quoted from Hess[1] and was made on a single specimen selected to be representative of the average of good material taken from the deposit. No samples for analysis were collected by the writer.

Analysis of magnesite from Alameda claim, Santa Clara County, Cal.

[A. J. Peters, analyst.]

SiO_2	0.73
Al_2O_3	.14
Fe_2O_3	.21
CaO	.40
MgO	46.61
CO_2	51.52
Undetermined	.39
	100.00

PLACER COUNTY.

Deposits of magnesite have long been known in Placer County, and newspaper notices have from time to time been published, presumably in the effort to draw attention to them. These notices refer more particularly to some outcrops that have been located in claims described as situated in sec. 18, T. 15 N., R. 11 E., on the upland south of the American River canyon about midway between Iowa Hill and Damascus. The report received to the effect that one new mine had been opened at Iowa Hill in 1911 and a few hundred tons of magnesite extracted, none of the product being shipped or calcined, has not been substantiated.

The geology of the area as a whole is described by Lindgren.[2] The area lies within the great forest zone of the Sierra Nevada. The upland surfaces constitute in general form a gradual westward slope from the crest of the Sierra, which is deeply intrenched by stream canyons that form a rugged and picturesque topography but render much of the area difficult of access. The magnesite claims west of Iowa Hill are thus unfavorably situated for the transportation of any bulky or heavy material like magnesite, as it is at present necessary to descend into and cross the canyon of American River to reach them from the railroad. Colfax is now the most favorable point of access and from it the Iowa Hill road descends to American River, a drop of 1,300 feet in about 2 miles, and rises on the east side in an even shorter distance. The distance by road from Colfax to the deposit is about 12 miles, and it would probably take five hours with a light buggy and good team to make the trip.

[1] Op. cit., p. 36.
[2] Lingren, Waldemar, Colfax folio (No. 66), Geol. Atlas U. S., U. S. Geol. Survey, 1900.

The occurrence is, however, of interest and the possibility that the magnesite in this vicinity may at some time become of commercial importance must be recognized. The magnesite veins are, as usual, associated with a country rock of serpentine, a large area of which lies between Iowa Hill and Damascus. This belongs to the great serpentine belt described by Lindgren as follows:

Through the center of the Colfax quadrangle, from north to south, extends a broad belt of igneous rock surrounded by Carboniferous sedimentary rocks. It consists very largely of serpentine, from which feature the miners have called it the great serpentine belt. It is, however, a very complex area, made up of many basic rocks rich in magnesia, the most prominent of which are gabbro, peridotite, and diorite. Partly

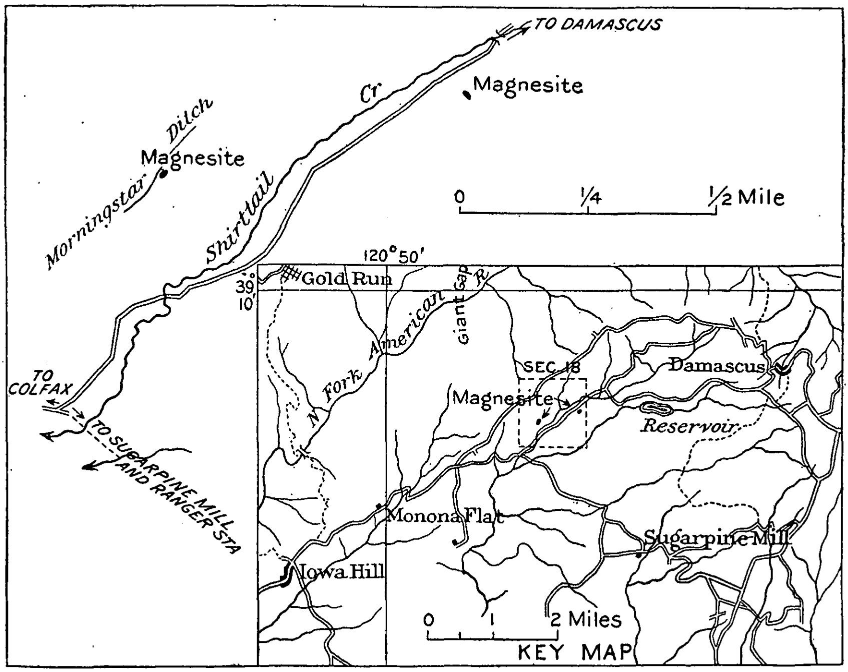


FIGURE 48.—Map showing relative location of the magnesite veins examined in the vicinity of Iowa Hill, Placer County, Cal. (Adjustment of sec. 18 approximate only.)

serpentinized peridotite has so often been found in the serpentine as to justify the belief that most of the latter rock has resulted from the alteration of peridotite, though it would perhaps be going too far to say that all of the serpentine had this origin. * * *

The great serpentine belt, extending through the Placerville, Colfax, and Downieville quadrangles, is apparently a continuous dike intruded in the Carboniferous sedimentary rocks, sometimes following, sometimes cutting across their strike.

The location of the deposits visited is shown by the accompanying map (fig. 48). By comparison with the description of the deposit quoted by Hess[1] the veins found by the writer are evidently the ones referred to in that description, except that no single body 30 by 100 feet was seen.

[1] Op. cit., p. 52.

Outcrops of magnesite at two localities were visited. The western occurrence is near and below a large ditch on the north side of the reservoir road to Damascus, east of the fork to the Sugarpine mill. The outcrop appeared to represent lenses and small veins, none of those examined exposing any considerable body of ore. The area is thickly timbered, and it is possible that not all the known outcrops were found. There was an old pit but no evidence of recent work. The veins in places measure a foot or more in width and the magnesite is largely mixed with serpentine, which is the country rock. All the veins appear discontinuous. Some portions of the veins contain clear-white magnesite with conchoidal fracture.

The other exposure examined lies south of the road, a little over half a mile somewhat north of east from the outcrop just described. At this place there was no evidence that any work had been done. The ledges are on the timbered hill slope and contain some good clear-white magnesite, with china-like fracture. The country rock is all serpentine and so far as observed is continuous between the two deposits. From one of the ledges 2 feet thick a sample was collected by chipping fragments on a freshly broken surface across the accessible part of the vein. The sample represents about 1 foot of the 2 feet or more exposed and evidently contains material of good quality. The analysis is as follows:

Analysis of magnesite from Placer County, Cal.

[R. C. Wells, analyst.]

SiO_2 $(Al, Fe)_2O_3$	0.2
CaO	None.
MgO	47.3
CO_2	51.6
H_2O	0.6
Undetermined	0.3
	100.00

In both localities the exposures are comparatively small, covering probably not over 20 or 30 square feet of rock in place, and while such outcrops might lead to larger bodies underneath, the few and scattered veins that are known do not offer much encouragement. The present cost of hauling from such a locality would prohibit the shipment of material of the value of magnesite, and it seems doubtful if much can be done with these deposits until better transportation facilities are offered.

SAN BENITO COUNTY.

In 1911 new deposits of magnesite on Larious Creek, in San Benito County, Cal., were reported to C. G. Yale, in the San Francisco office of the Geological Survey, by Hugo Fischl. In February, 1912, through the courtesy of Mr. Fischl, the writer was enabled to make a brief visit to these deposits and a short account of them was published in the annual statistical chapter on magnesite.[1] Later in the year (September, 1912) a second visit was made to the same deposit, which resulted in some hasty traverse sketch mapping and the collection of further specimens for analysis and study.

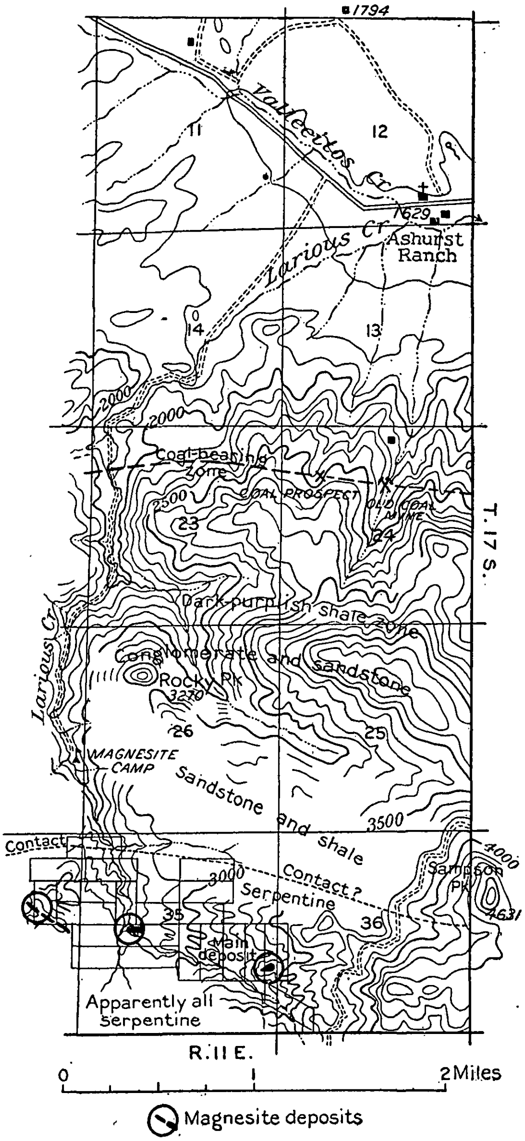


FIGURE 49.—Incomplete contour map showing location of Sampson magnesite lode claims, San Benito County, Cal.

The deposits on Larious Creek are mostly covered by a group of 21 claims known as the Sampson magnesite lode claims, owned by R. H. Moore and Hugo Fischl. The principal exposure, supposed to contain the largest body of the best ore at present revealed in the district, lies on the east side of Larious Creek. There are a number of other veins or deposits ranging from those carrying magnesite of the better quality to silicified shear zones containing magnesite mixed with the serpentine country rock. The exposures as a whole are extensive.

The location of the deposits is given as secs. 34, 35, and 36, T. 17 S., R. 11 E. Mount Diablo meridian. The approximate location of the claim group is shown on the map (fig. 49). The deposits are situated a little over a mile west of Sampson Peak and about 2½ miles west of the New Idria quicksilver mine, in the steep slopes of the Diablo Range. Most of the outcrops lie on the slopes in the upper valley of Larious Creek, a tributary of Vallecitos Creek.

[1] Mineral Resources U. S. for 1911, pt. 2, U. S. Geol. Survey, 1912, pp. 1113-1127.

The deposit is 35 to 40 miles from the nearest railroad station, Mendota, in the San Joaquin Valley.

The geology of this district is discussed in some detail in a bulletin by Anderson and Pack,[1] which deals primarily with the oil prospects in the region. The large area of serpentine exposed along the high parts of the Diablo Range in this vicinity is believed to be an intrusive mass of batholithic form, which occupies the crest of a major anticlinal axis in the sedimentary strata within which it is included. The original rock has now been so largely altered to serpentine that the whole mass is commonly referred to as serpentine. This is the type of rock with which California magnesite deposits are generally associated, and evidently it bears a genetic relation to the magnesite.

An excellent section of the sedimentary strata associated with the serpentine at this place, ranging from the sandstones and shales of the Franciscan formation to the later Tertiary formations, is exposed in the valley of Larious Creek, but details of the geology of those beds are not supposed to have any bearing on the magnesite or the matter of its commercial exploitation. It is possible that the occurrence of a bed of coal not far distant might ultimately have some effect upon the reduction or transportation of the magnesite, but there is probably greater likelihood that oil as fuel would replace the light subbituminous coals found in this vicinity. The locations of some of the coal prospects are shown on the map (fig. 49), together with an indication of the approximate tracing of the outcrop of the coal-bearing zone.

The outcrop of the principal magnesite ledge is a broad exposure about 500 feet in length and covering 2.6 acres (survey by E. Halloran for the magnesite company). (See fig. 50.) The main deposit, as shown on figure 49, is situated on the summit of a high spur that extends west from Sampson Peak, between two forks of Larious Creek. The main crest of the ridge is on the surface composed entirely of white massive magnesite, and on the west end the deposit has the appearance of being a steeply dipping vein in the serpentine country rock, trending about N. 70° E. The eastern part of the summit flattens out so that the outcrop ledges of magnesite on the top appear to be possibly in horizontal or "blanket ledge" form. If the deposit continues in depth with horizontal dimensions corresponding to those at the surface, it is of immense size. A report received since the last visit by the writer states that a prospect tunnel has been driven from the south to undercut the deposit on the broad east end of the deposit, and the approximate location of this tunnel is plotted in figure 50 from the description of

[1] Anderson, Robert, and Pack, R. W., Geology and possible oil resources of the western border of the San Joaquin Valley, Cal., between Coalinga and Livermore Pass: Bull. U. S. Geol. Survey (in preparation).

locations given in the report. Statements of the results obtained in driving this tunnel seem to indicate that the ledge is of blanket form on the east end of the deposit, but that the body of magnesite has considerable thickness there. Details of the working are not now available. Of those now known this deposit contains the greater part of the highest-grade magnesite on the property, and there is a possibility that further work will show that some of the smaller supposed outcrops farther down the hill slope are but broken masses slid down from this deposit.

Outcrops of the better hard magnesite are in the main exposed in massive ledges, which are resistant to weathering and commonly stand out prominently, capping ridges that they have protected from erosion while the adjacent softer rocks have crumbled and been

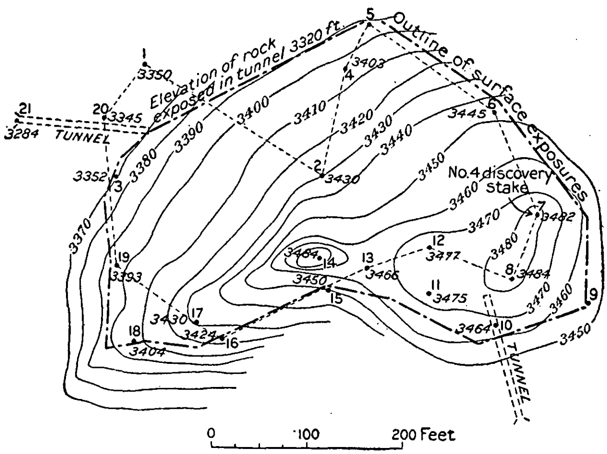


FIGURE 50.—Main deposit of Sampson magnesite lode claims, San Benito County, Cal. Elevation datum approximate. Published by permission of Mr. Hugo Fischl.

carried away. The white, weather-rounded surfaces of the magnesite show the solvent action of rain or surface waters, being in places sharply fluted, more or less covered with moss and lichens, and stained in spots with a yellowish-brown to rusty color. The inside of freshly broken pieces is generally white, but in places a pale-yellow stain extends into the rock to a depth of several inches from the exposed surface or along joints and cracks. When freshly quarried the whole mass of the rock would be characteristically white in general aspect, just as the outcrop now appears from a distance. Some cracks or cavities in the magnesite contain silica, generally in chalcedonic form, and this is usually colored a pale green, as if by some form of chromium. Much of this green chert-like material is to be found in association with other impure siliceous veins on the adjoining hillside.

A very prominent ledge of an impure siliceous and iron-stained magnesite forms the crest of a peak on the west side of Larious

Creek, approximately on the line between secs. 34 and 35. This is evidently a zone of silicification and secondary deposition, the magnesite material being included within the serpentine mass, which has a trend of N. 60° W. and an apparent northeasterly dip of about 70°. The outcrop is very yellow and iron-stained and stands out in rough crags, being evidently a vein at least 20 feet thick. Its extension to the southeast is marked by outcrop ledges which form the summit of a ridge leading off toward the upper Larious Creek valley. As a whole the impure character of the rock is supposed to render this large deposit of doubtful value, but it remains to be seen whether such a rock will find a use for refractory or other purposes. Smaller masses of purer white magnesite are included within the vein, but none of the bodies observed in outcrop were of sufficient size to be workable.

Similar iron-stained siliceous veins or silicified shear zones containing some magnesite are found in the serpentine on the slopes and ridges leading up to Sampson Peak. Most of these have not been prospected and are of doubtful value. One of the most prominent is indicated on the map east and northeast of the main magnesite deposit. At places these rusty honeycombed outcrops of silica and other rock resemble the gossan of a metalliferous lode.

Analyses of the rock from these deposits have been made as follows: A single block broken from the exposure at the main deposit at the time of the writer's first visit was analyzed in the Geological Survey laboratory by J. G. Fairchild, and the analysis is given as No. 1 in the following table. No. 2, made by W. B. Hicks in the Geological Survey laboratory, is the analysis of average material made up from twelve samples taken at points distributed over the large outcrop on the crest of the ridge. This is believed to represent the average character of the deposit as nearly as was feasible under the existing conditions. Before sampling the weathered surface was cleaned by chipping so as to eliminate if possible surface stain and alteration. No. 3, also made by W. B. Hicks, is the analysis of an outcrop sample of magnesite taken from the ledges of iron-stained siliceous rock on the west side of Larious Creek. It is doubtful whether this sample is representative of the whole deposit.

Analyses of outcrop samples of magnesite from San Benito County, Cal.

	1	2	3
SiO_2	0.14	0.81	11.08
Al_2O_3	.48	.00	.55
Fe_2O_3		.52	.61
CaO	.59	1.04	.60
MgO	47.07	46.67	41.38
CO_2	50.66	50.60	45.26
Undetermined	1.06	.36	.52
	100.00	100.00	100.00
Loss on ignition	....	51.43	46.10

Analyses 1 and 2 indicate that the magnesite of the main deposit is of somewhat exceptional purity, the silica, iron, alumina, and lime being so low that the rock is believed to be available for either cement or refractory products.

One other feature of the district deserves special comment. In the forks of Larious Creek, near the center of the W. ½ sec. 35, there are large wash banks of slide material wholly bare of vegetation, forming a striking contrast to the brushy and scrub-timbered slopes that surround them on all sides. These slides are somewhat weather-stained at the surface but have a white limy appearance in excavations or fresh breaks. The material is a much-sheared serpentine, fresh samples of which range from a dull green, earthy color to the clear green of the mineral serpentine in polished slickensided surfaces. Throughout the mass a white powdery mineral occurs in specks and in little rounded balls. These are readily effervescent and soluble in hydrochloric acid and are indicated by analysis No. 2, below, to be hydromagnesite. In the following table No. 1 is the analysis of a sample from the surface in this slide deposit as it occurs, including the sheared serpentine and some hydromagnesite, and No. 2 is an analysis of the white powdery hydromagnesite, made from a large number of the little balls picked out from the weather-decayed mass at the exposure. Both analyses were made by W. B. Hicks in the Geological Survey laboratory at Washington.

Analyses of weather-decayed serpentine and hydromagnesite from forks of Larious Creek, Cal.

	1	2
SiO_2	35.24	2.50
Al_2O_3	.38	.13
Fe_2O_3	7.08	.44
CaO	.20	.34
MgO	39.35	41.60
CO_2	2.66	34.89
Undetermined	15.09	20.10
	100.00	100.00
Loss on ignition	18.15	54.10

The main deposit, situated on the slopes of Sampson Peak, unquestionably contains a large body of high-grade magnesite, and by careful measurements of it a fair estimate of the available material in sight could readily be made. It is to be expected that eventually, when the transportation problems for this district have been solved, and when a market for high-grade domestic magnesite from California has been developed to support a continuous production from such deposits, this will prove to be one of the more valuable deposits in the State.

As to the extent and possible utilization of the hydromagnesite deposits in the forks of Larious Creek or of the siliceous deposits on the west side of Larious Creek and elsewhere near the main deposit on the slopes of Sampson Peak, it hardly seems necessary at present to venture any prediction, for these are matters to be proved by practical trial. The analyses given in the present report may serve as some basis for estimating the availability of these materials for other uses.

FRESNO COUNTY.

Magnesite has been observed in the eastern foothills of the Diablo Range in the vicinity of the deposits described above. Whether of economic importance or not, this occurrence furnishes interesting data as to the age and possibly indications as to the former distribution of such deposits. The following memorandum is quoted from a manuscript by Anderson and Pack:

In the middle of the exposed Tertiary rocks skirting the western border of the San Joaquin Valley, about 15 miles east of New Idria, there is a series of beds ranging in thickness from less than 50 feet to several hundred feet, composed almost entirely of comminuted serpentine and of serpentine bowlders. They are of lower Miocene age and probably represent a near-shore marine deposit. They go by the name of the Big Blue. The beds extend for a distance of about 20 miles along the foothills and lie directly east of the large mass of serpentine that is intrusive into the Franciscan rocks in the core of the range south of New Idria. The débris forming these beds has evidently been derived from that mass and has been carried by streams at least 10 miles.

At several places the Big Blue contains fragments of pure hard magnesite a few inches in diameter. They were noticed especially just south of Cantua Creek and between Cantua and Salt creeks, in the patches of these beds that have been left as remnants overlying the older formations. The fragments are in places scattered over the surface at intervals of a few hundred feet. They are without question of the nature of bowlders derived by erosion from the serpentine area. They are not believed to represent an accumulation in any commercial quantity, but are mentioned only because they point to the presence of magnesite in the serpentine area on the west and prove that at least some of the magnesite veins originated in or prior to the early Miocene.

TULARE COUNTY.

PORTERVILLE.

The magnesite deposits 4 miles northeast of Porterville, which had been mined continuously since 1901, were abandoned in 1909. From 1902 to 1909 these deposits were operated by the Willamette Pulp & Paper Co. They doubtless still contain much workable and valuable magnesite, but the upper parts of the larger vein have been almost completely worked out. Any further development at this place would doubtless have to be made through new entries opening the deposit on lower levels in the vertical vein. There is a considerable quantity of magnesite remaining in the flat-lying vein on this property, but this vein is difficult to work without timbering, which will make mining in this deposit more expensive than the methods formerly employed. A complete description of the Harker magnesite deposits, with a map and illustrations, is contained in Hess's report.[1] The entire equipment, including the furnace, has now been removed from the property.

SOUTH FORK OF TULE RIVER.

A hitherto undeveloped deposit on South Fork of Tule River, 9 or 10 miles east of Porterville, was opened in 1907 by the Tulare Mining Co., of which W. P. Bartlett is superintendent. The deposits were fully described as outcrops by Hess [2] before any development or even prospecting had been done on them. To this description of the outcrops there is little to be added, and the following paragraphs relate principally to the recent developments for the commercial production of the magnesite.

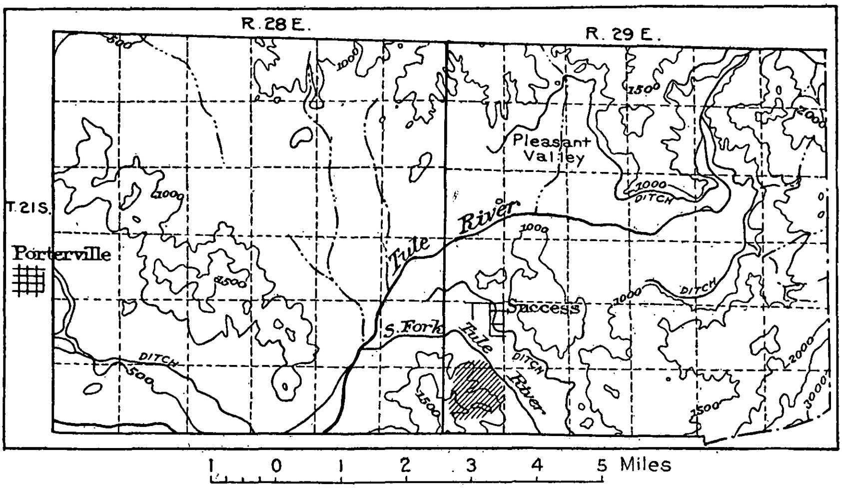


FIGURE 51.—Index map showing location of magnesite deposits on South Fork of Tule River, east of Porterville, Cal.

The magnesite veins are situated on the north face of a high hill southwest of South Fork of Tule River in secs. 30 and 31, T. 21 S., R. 29 E. (See fig. 51.) The Porterville Northeastern Railroad has now been completed along the main valley of Tule River, and a spur about 2 miles long direct to the magnesite deposits has also been built.

Recent mining developments on the deposits consist of a 1,400-foot tunnel through the point of a ridge, not far above water level, some other short tunnels, and many small and large open cuts and pits, by which the numerous other outcrops on the property have been prospected. The 1,400-foot tunnel follows an exceedingly irregular vein, which in places reaches apparently large dimensions

[1] Hess, F. L., Magnesite deposits of California: Bull. U. S. Geol. Survey No. 355, 1908, pp. 40–46.
[2] Idem, pp. 46–48.

and elsewhere is lost altogether. Crosscuts appear to reveal some large bodies of magnesite and in places these bodies are mixed with country rock or foreign matter that probably reduce the quality. At the present stage of development it is somewhat difficult to estimate the reserve on this property, but it is believed to be rather large. No samples of the raw or calcined product were obtained for analysis owing to lack of time when the examination was made.

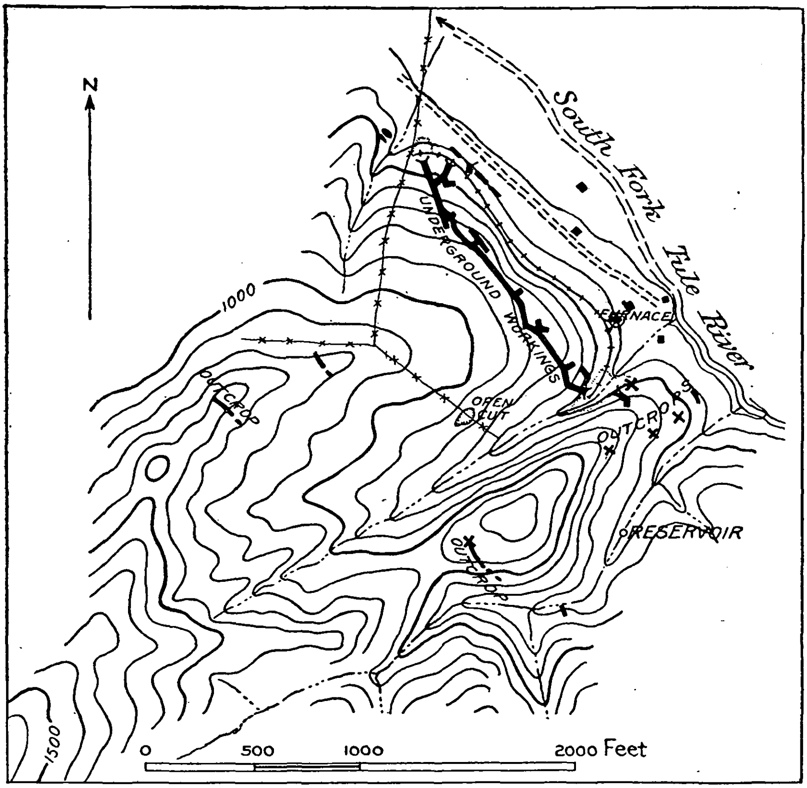


FIGURE 52.—Sketch map of magnesite deposits on South Fork of Tule River east of Porterville, Cal.

No raw rock is shipped, all the product being calcined in stack furnaces at the mine.

The accompanying plat (fig. 52) is the result of a hurried sketch traverse of the property, made February 25, 1912, and although it is not based on an accurate instrumental survey and is not complete, it will serve to indicate the character and relation of both the developments and the more prominent outcrops.

Much of the information here given concerning the production and development of the deposits was obtained through the courtesy and assistance of Mr. W. P. Bartlett, superintendent of the Tulare Mining Co., at Porterville.

KERN COUNTY.

In 1911 a new deposit of magnesite was developed near Bissell station, on the Atchison, Topeka & Santa Fe Railway 11 miles east of Mohave, Kern County, Cal. It is said to have been located in part by B. M. Denison, of Tehachapi, and D. S. Clark, of San Pedro, Cal., and in part by C. A. Williams and J. N. Conover, both of Tehachapi, Cal.

The deposit is situated about one-half to three-quarters of a mile northeast of Bissell station (fig. 53). The only developments that had been made up to March 8, 1912, consisted of a series of pits and a few shallow shafts opening the deposit through a stretch of about a quarter of a mile.

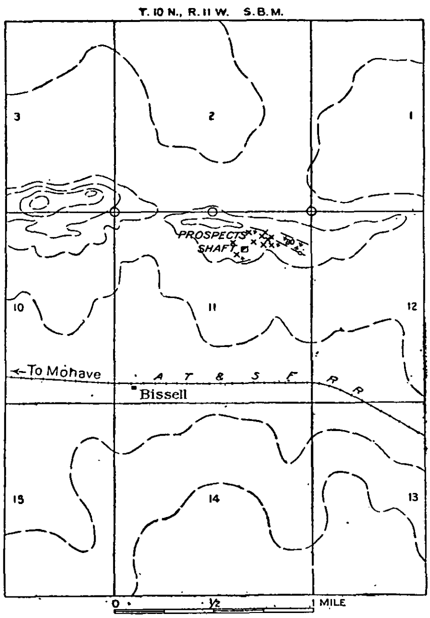


FIGURE 53.—Sketch map of magnesite deposits at Bissell station, near Mohave, Cal. By Leon J. Pepperberg, geologic department, Southern Pacific Co. Contours have only sketch value.

This deposit is unique in being the only occurrence of magnesite of evident sedimentary origin that has been reported in this country. Some deposits in Quebec are described as probably of sedimentary origin, but hitherto all the California magnesite has been described as associated with and evidently derived from altered basic intrusive igneous rocks carrying a large percentage of magnesia.

The magnesite at Bissell occurs in definitely bedded form, interstratified with clays and clay shales and evidently forming a part of the same series that shows massive ledges of limestone and cherty layers in outcrop near by. The clay beds are prevailingly dull greenish but in places consist of a very dark carbonaceous material. In the low rounded hills that characterize this part of the Mohave Desert the strata in general do not outcrop conspicuously and consequently are not readily traced. The limestone and cherty ledges are visible, however, and recent prospecting has revealed the softer magnesite-bearing beds to some extent. The outcrops prospected occur on the south slope of a low ridge.

The dip of the beds is steep and in most places is inclined to the south but in others is practically vertical. The beds are very irregular in trend and, in fact, are locally so much contorted that it was not possible to determine from the surface indications the structural relations between strata exposed in closely adjacent prospect pits.

The following sections—partly measured, partly estimated—serve to indicate the character and thickness of the beds of magnesite and associated materials. The exposures given in these sections afford what is regarded as sufficient evidence of the original bedded character of the deposits. The extreme irregularity of the beds in some of the pits is thought to be due chiefly to structural distortion, and it is not known how constant the magnesite strata may prove to be.

Section at 14-foot shaft near west end of Bissell prospects.

[Some magnesite at top not included.]	Ft.	in.
Cherty layer		6
Clay, carbonaceous, lenticular, about		4
Magnesite, white, about		5
Clay, gray, about		3
Magnesite, white, about		6
Clay, dark gray		4
Magnesite, white		4
Clay, white (magnesite?)		8
Magnesite, clear white, massive	1	6
Clay, brown		4
Magnesite, white, about	1	
Clay, greenish, about		3
Magnesite, compact white		10
Clay (considerable body).		
	7	3

A sample for analysis (No. 4 in the table below), taken at this place consisted of selected pieces of the hardest and whitest magnesite-like rock from the dump, and was intended to represent the best of this ore near the surface.

The beds exposed in this section are largely lenticular in their thicker parts. They also show slip planes and are not uniformly as distinctly bedded as at other points in these deposits. The strike at this place was recorded as N. 15° W., which is almost directly transverse to the trend of nearly all the other exposures throughout the prospected ground. The dip is 60° E.

About 300 feet west-northwest of the 14-foot shaft is a prospect hole 2 feet deep showing dark-brown carbonaceous beds interstratified with pure-white magnesite, one bed of magnesite being at least 15 inches thick. The strike here is N. 60° W. and the dip 45° S.

About 450 feet a little north of east from the same shaft is a hole 12 feet deep showing two rather thin beds of apparently good solid white magnesite. About 700 feet northeast of this shaft is a trench showing several 6 to 8 inch beds of what is supposed to be good white magnesite, interstratified with greenish clay shale.

About the same distance from the shaft and 150 to 200 feet southeast of the locality last mentioned is a prospect trench showing the following section:

Section in prospect trench near Bissell station.

	Ft.	in.
Magnesite		7
Clay, brownish		1
Magnesite	3	
	3	8

An average sample (No. 1 in the table) was cut across the entire face represented in the foregoing section except the 1-inch bed of brownish clay, which readily splits from the magnesite beds. The lower part of the 3-foot magnesite bed contains some thin clayey streaks, 3 or 4 inches to 8 inches apart, which were included in sampling. This was a shallow pit that had been dug very recently and made a very good showing of white hard magnesite in regularly bedded form. The strike here is N. 80° W. and the dip 25° S.

Sample No. 2 represents a 6-inch layer of white clay overlying the section from which sample No. 1 was taken and was saved to be tested for magnesia. The analysis shows it to be of essentially the same composition as the underlying magnesite beds.

Sample No. 3 consists of selected pieces of the best-looking magnesite from the same place as sample No. 1.

The analyses of these samples are given below. They were made in the laboratory of the Geological Survey at Washington by J. G. Fairchild.

Analyses of samples of magnesite from Bissell, Cal.

	1	2	3	4
SiO_2	9.64	8.51	6.03	4.75
$Al_2O_3 + Fe_2O_3$	2.46	2.94	1.40	.76
CaO	4.25	3.36	1.56	Trace.
MgO	37.19	38.32	42.78	44.20
CO_2	40.70	40.12	45.78	47.32
Undetermined	5.76	6.75	2.45	2.97
	100.00	100.00	100.00	100.00

In the foregoing analyses it may be seen that, except in No. 1, carbon dioxide is not present in sufficient quantity to satisfy the magnesia alone if it were all combined as normal magnesium carbonate, even neglecting the fact that the lime is as likely to be in the form of carbonate as the magnesia, and might be combined with some of the carbon dioxide. Theoretically pure magnesite is composed of 47.6 per cent of magnesia plus 52.4 per cent of carbon dioxide. It is probable that part of the silica in this sedimentary material is free and that some of it is combined with lime and magnesia to form silicates. F. W. Clarke suggests the possible presence of basic carbonates, such as hydromagnesite ($3MgCO_3Mg(OH)_2 + 3H_2O$), which would tend to compensate the proportions, by the relatively smaller amount of carbon dioxide required in its composition.

Another prospect about 750 feet a little north of east from the 14-foot shaft shows the following section:

Section at prospect near Bissell station, Cal.

	Ft.	in.
Magnesite		4
Clay, thin streak.		
Magnesite		2
Clay, thin streak.		
Magnesite		2
Clay (with thin streak of magnesite)		6
Magnesite		8
Clay, greenish	1	3
Magnesite		2
Clay, greenish	1	
	4	3

The strike of the beds at this place is N. 85° W. and the dip 75° S.

North of these prospects, within a fourth of a mile, is the crest of the low rounded east-west ridge, and here are to be found occasional outcrops of the harder strata that lie on that side of the magnesite series. These ledges consist of creamy-white limestone and sandy shale layers, the shale showing chiefly as float on the surface. Some of the limestone is exceedingly cherty, the chert occurring as compact black flint nodules, in some places strewn thickly over the surface. Similar chert is to be found south of the magnesite beds, so that it doubtless both underlies and overlies the magnesite.

Another prospect on white material said to be magnesite could be seen half a mile or more east of the property examined, but this prospect was not visited.

The magnesite can be obtained in very clean white masses, as it readily separates from the inclosing clay. It is pure white, very fine grained, and compact, breaking with a china-like conchoidal fracture, such as is characteristic of most magnesite. On exposure to the air, however, the material from this deposit shows a tendency to break down that has not been noted at other deposits. A rain a short time before the date of visit had wet the magnesite on the prospect dumps and the lumps were said to have cracked and broken down like lime starting to slack. It was observed that only the more freshly dug material afforded solid specimens. Disintegration by weathering may give to the surface of these deposits a somewhat coarser and more earthy texture than the porcelain-like fracture characteristic of magnesite, but the rock has nevertheless a marked similarity to the typical magnesite. It would perhaps be surprising if a sedimentary deposit of this sort should be found to carry as low a percentage of lime as is contained in many of the other California magnesites.

All other California magnesite deposits, so far as known, occur as veins in connection with serpentinized magnesian rocks, usually referred to as serpentines. No evidence of any association with serpentines was observed at the Bissell deposits.

A suggestion as to the possible origin of these deposits may be found in considering the character of the salines commonly associated with the lake-bed deposits of the desert basins. Magnesium is commonly absent from the soluble salts of the desert-lake salines, although magnesium salts are common constituents of spring waters in Tertiary and Mesozoic rocks in other parts of the Western States. Many of the lake waters now in the Great Basin area are rich in sodium carbonate, which would of course precipitate as magnesium carbonate any soluble magnesium salt introduced. Possibly, therefore, spring or other waters bearing magnesium salts, generally the sulphate, entered a lake basin containing sodium carbonate in solution, with the result that magnesium carbonate was precipitated, forming bedded deposits. The relatively greater solubility of magnesium sulphate compared with calcium sulphate would perhaps explain the predominance of magnesia over lime in the resulting precipitate. It is also suggested that if this magnesite were thus precipitated it would probably be, in part at least, laid down as hydromagnesite, and that it would have been deposited more thickly near the source of supply and thus the beds would necessarily be lenticular.

RIVERSIDE COUNTY.

Production from the deposit of magnesite now being worked near Winchester, Riverside County, Cal., has continued since the later part of 1908 with a uniform and normal growth. This deposit has been described by Hess,[1] and only a few additional notes chiefly concerning its present status will be given here. The illustrations accompanying Hess's account represent well the character of the veins.

The Winchester deposit is owned and operated by the California Magnesite Co. and the entire product of the mine at Winchester is manufactured into cement or is sintered for furnace use at the company's plant in Los Angeles. This appears to be the only output of domestic magnesite that is utilized largely for plastic purposes. A large part of the company's product as shipped consists of finely ground plaster, which is marketed in barrels and is quoted at a much higher price than the raw or roughly calcined product from other mines.

The magnesite mined at Winchester is derived from deeply decomposed serpentine rock, which is found at the crest of one of the steep peaks that form the divide between the valley in which the town of Winchester is situated and Diamond Valley, on the south. The mine is about 2 miles in an air line from the nearest point on the railroad and is 4 miles by good road from the shipping point at

[1] Op. cit., pp. 38-39.

Winchester. The broad, flat valley north of the magnesite property is largely under cultivation and the steep little hills at its margin rise abruptly 600 to 700 feet. The open cut of the magnesite mine is about 500 feet above the level of the plain at the valley margin.

The accompanying map (fig. 54) is a topographic and geologic sketch plat of the property including the magnesite mine, reaching from the margin of the valley plain to the crest of the dividing ridge. The property all lies within the NW. ¼ sec. 31, T. 5 S., R. 1 W.

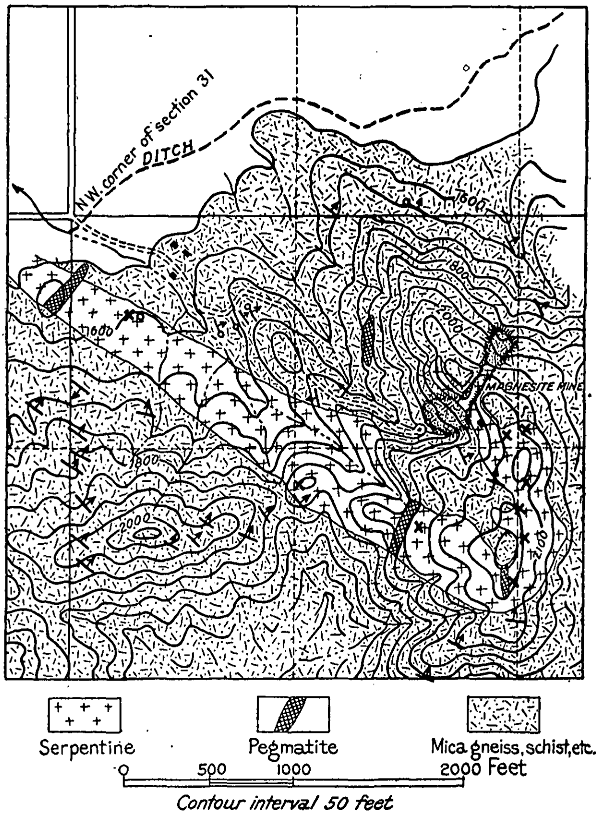


FIGURE 54.—Sketch topographic and geologic map of magnesite deposit at Winchester, Riverside County, Cal.

The area is geologically somewhat complex. It consists essentially of dark-banded micaceous gneisses and schists, in which the foliation trends in general from northwest to southeast and dips steeply to the northeast. The gneiss suggests sedimentary origin, some of the more quartzitic layers resembling conglomeratic material much distorted by shearing. Probably intrusive into the micaceous gneiss is a belt of serpentine from 200 to perhaps 400 yards wide, extending in a northwest-southeast course from a point near the northwest corner of the section. Both micaceous gneiss and serpentine are cut by pegmatite dikes, but it appears that some of the larger white pegmatitic feldspar dikes terminate within the serpentine. Crystals of black tourmaline are numerous in some of the dikes.

There are exposures of coarsely crystallized basic rock, which may be the original intrusive, now largely altered to serpentine. A very fresh specimen of this rock, when examined in thin section under the microscope, proves to be a peridotite composed essentially of olivine and enstatite. F. C. Calkins has examined a specimen of the freshest of this material from the gulch just below the mine. He reports as follows:

The chief minerals are enstatite (pale) and olivine (dark). Other original minerals revealed by the microscope in small quantity are iron oxide, probably chromite; colorless amphibole, probably tremolite; and diallage, forming a few thin laminæ intergrown with enstatite. A good deal of talc and some carbonate and pale chlorite are present. They seem to have been formed for the most part by the alteration of enstatite, although small particles are scattered through the olivine. The olivine, however, is remarkably fresh—far more so than the enstatite. The cleavage cracks of the olivine contain opaque dust, probably magnetite, and perhaps a very little serpentine, but serpentinization has no more than barely begun.

Many pits on this property expose networks of thin veins of magnesite in serpentinous rock decomposed in place. The principal deposit of this sort is that shown in a large open cut crossing the summit of the ridge at its north end and making a prominent landmark visible for miles through the valley on the north. This cut is about 85 yards long and some 25 yards wide at its widest place and is intrenched to a depth of 60 to 75 feet in the crest of the ridge. Dumps have been thrown out at both ends, and from this cut all the magnesite shipped has been taken out. The cut shows a network of magnesite veins throughout, these being fully as numerous and of as great individual thickness at the present bottom of the pit as they were near the top, or possibly the size and thickness of the veins are even increasing with depth. Shear planes within this mass are bounded by banded alteration zones of talc, chlorite, and doubtless other secondary magnesian minerals.

A sample of the magnesite at this place collected by the author was made up of 30 separate portions collected at various parts of this cut and is believed to be representative of the material as mined. The following analysis of this sample was made by J. G. Fairchild in the laboratory of the Geological Survey, at Washington:

Analysis of average sample collected from magnesite mine at Winchester, Cal.

SiO_2	6.17
$Al_2O_3+Fe_2O_3$	.80
CaO	Trace.
MgO	43.80
CO_2	45.02
Undetermined	4.14
	100.00

The following average taken from a mill run shows the composition of the product ground for plastic use, as it is barreled for shipment. The analysis was made by E. Miall Skeats, chemist for the company.

Analysis of ground magnesite.

Insoluble	14.00
Iron and alumina	.80
Calcium oxide	.61
Magnesium oxide	84.59
	100.00

The recoverable and available magnesite veins possibly constitute one-tenth of the mass, although the actual proportion of magnesite in the finer form may be considerably higher. Thus 8 to 10 or more wheelbarrow loads of waste go over the dump for 1 load of magnesite saved. There is much fine magnesite in the dump, and it has been suggested by the owners that this might be utilized directly in the manufacture of brick. Some experiments have been made with this end in view.

The deposit at Winchester presents several features that might be considered almost unique. In the first place, the rather exceptionally favorable situation of the deposit for mining and also for shipment gives to it a distinct advantage. In many other situations it would doubtless be impracticable to mine, separate, and ship magnesite occurring in a network of thin veins traversing a massive body of serpentinous rock. As stated, the whole mass is so deeply weather-decayed that it breaks down easily and is mined by open cuts with some blasting, the ore and waste being worked over by hand labor, with pick, shovel, and wheelbarrow. However, the magnesite readily separates from the much-decomposed country rock, crumbling away as dug, leaving the fragments comparatively clean to be sorted by hand. Exception has to be made when the whole is wet by rain, as the serpentine does not crumble, and this renders necessary a suspension of operations in the open pit. The situation of the deposit at the crest of a steep slope is an important factor, as it affords a ready dump for waste and convenient sites for ore chutes and loading bins. The mining methods are therefore of the simplest type.

At least some of these peculiarly favorable features are in a measure related to surficial conditions. A protecting cap of the harder gneiss at the crest of the ridge has held in place the underlying serpentine, while on the flanks of the ridge this mass has been exposed to deep surficial decomposition. This has resulted in disintegration of the country rock bearing the magnesite veins. Prospecting at greater depth may reveal a harder mass of the magnesite-bearing rock, from which it may be more difficult to separate the magnesite. At present there are no especial indications that the deposit decreases in magnesite content as depth increases.

NEVADA DEPOSITS.

NYE COUNTY.

Reports of a deposit of supposed magnesite at a locality in the southern part of the Amargosa Desert, near Ash Meadows, Nev., have been received from several sources. A recent communication from that vicinity, transmitting a specimen of the rock, described the deposit as located half a mile northeast of the spring at the Fairbanks ranch. This is in T. 17 S., R. 6 E., 7½ miles northeast of the Nevada-California line. The ranch and spring are represented on the Furnace Creek topographic map published by the United States Geological Survey.

The specimen referred to above has been submitted to analysis in the Geological Survey laboratory at Washington, showing the following composition:

Analysis of supposed magnesite from deposit near Ash Meadows, Nev.

[W. D. Hicks, analyst.]

SiO_2	0.58
Al_2O_3	.00
Fe_2O_3	.13
CaO	55.17
MgO	.19
CO_2	42.90
Undetermined	1.03
	100.00
Loss on ignition	43.85

This rock was white and fine-grained and had the conchoidal fracture and other appearance of typical magnesite. The analysis shows the specimen to be carbonate of lime, or limestone, about 98 per cent pure with relatively very minor amounts of impurities. If the specimen received is representative, the deposit is therefore not magnesite at all.

ESMERALDA COUNTY.

Several reports of deposits of magnesite near or in the Lone Mountains, near the south end of the Big Smoky Valley, and southwest of Tonopah, somewhere near the Mount Diablo base line, Rs. 39 to 41 E., have been received. Some samples and analyses purporting to represent rock from that locality have been shown by persons interested in the deposits. These exhibit typical magnesite, apparently of good grade. Much secrecy seems to have been maintained as to the situation of the deposits, which the writer has not visited, and therefore little can be said concerning them.