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Magnesite and brucite deposits at Gabbs, Nye County, Nevada

Eugene Callaghan and Charles J. Vitaliano

INTRODUCTION

During World War II, the magnesite deposits at Gabbs in northwestern Nye County, Nev., were the source of ore for the world's largest magnesium metal plant. This Government-owned but privately operated plant at Las Vegas, Nev., near the source of power at Boulder Dam, produced 81,272 tons of metal from 920,000 tons of ore in the period from September 1942 to November 1944. Because of an oversupply of magnesium toward the end of the war, production of the metal was curtailed and finally stopped in November 1944. As of January 1947, 241,000 tons of magnesite from this area had been used in the production of refractories and oxychloride cement. Brucite deposits associated with the magnesite have been mined almost continuously since 1935 and through January 1945 have yielded 246,000 tons for use in the refractories industry of Ohio.

The U. S. Geological Survey in cooperation with the Nevada State Bureau of Mines mapped most of the above-mentioned deposits in 1931 and 1933. Preliminary estimates of reserves of both magnesite and brucite were published and provided the initial basis for the establishment of the wartime industry.

The magnesite and brucite deposits are in secs. 26, 35, and 36, T. 12 N., R. 36 E., in the extreme northwest corner of Nye County, Nev. The mining area is served by a paved highway which leads 349 miles to Las Vegas and 29 miles to Luning, a shipping point on a branch of the Southern Pacific Railroad.

The deposits are on the rugged western side of the Paradise Range which rises abruptly from the desert valley at an altitude of 4,600 feet to a maximum altitude at Sherman Peak of 8,657 feet. The deposits themselves range in altitude from 5,000 to 6,500 feet.

Six quarries were opened in the magnesite deposits by Basic Magnesium, Inc., which supplied the ore for the metal plant. Selectively mined ore was crushed, hand sorted, and treated in flotation circuits in the large mill on the property to eliminate the greater part of siliceous and dolomitic impurities. During early operations roughly half of the finely ground mill product was calcined at the mill, and both calcined and uncalcined material were shipped to the metal plant. Improved metallurgical techniques eliminated the need for shipping uncalcined magnesite to the Las Vegas plant after May 1944. The Sierra Magnesite Co., a subsidiary of Westvaco Chlorine Products Corp. and Permanente Metals Corp., opened two quarries from which magnesite was selectively mined and shipped untreated to plants in California. In 1946 the Sierra Magnesite Co. started underground mining on its lease.

Two quarries were opened in the brucite deposits by Basic Refractories, Inc., although the bulk of the yield has been from one large quarry. Brucite was shipped directly to Ohio where it was calcined and mixed with other materials for specialized refractories.

The brucite deposits were discovered by Harry Springer in 1927 and were explored by diamond drilling by the U. S. Brucite Corporation in 1930-31. Analyses of cores revealed the presence of magnesite adjacent to brucite. Under the cooperative auspices of the U. S. Geological Survey and the Nevada State Bureau of Mines, the brucite deposits and the adjoining area were mapped by Eugene Callaghan in 1931._/ Chip samples taken during this investigation revealed the great extent of magnesite, and a more thorough sampling in 1933 served to delineate roughly the major bodies of magnesite. An estimate of 71 million tons of magnesitised material of all grades in the Gabbs area was published in 1936._/

_/ Callaghan, Eugene, Brucite deposit, Paradise Range, Nevada. A preliminary report: Nevada Univ. Bull., vol.27, no. 1, 34 pp., 1933.

_/ Rubey, W. W., and Callaghan, Eugene, in Hewett, D. F., and others, Mineral resources of the region around Boulder Dam: U. S. Geol. Survey Bull. 871, pp. 142-143, 1936.

In 1942, concurrently with development and exploitation, the Geological Survey started the detailed mapping of the area containing the magnesite and brucite deposits, on a scale of 1 inch to 100 feet. The work was carried on, with only short interruptions, chiefly by Charles J. Vitaliano and assistants until it was completed in July 1946. The geologic map which accompanies this report covers an area of approximately one square mile.

The delineation of various grades of magnesite was made on the basis of microscopic examination of more than 18,000 chip samples which were correlated with chemical analyses provided by the mining companies. The companies also made available vast amounts of quantitative chemical data which, in part, represented logging and analysis of over 100,000 feet of diamond drill core, and provided access to all data on the results of exploration, mining, and milling. Their courtesy and helpfulness is gratefully acknowledged.

Geology

Sedimentary rocks

The magnesite and brucite deposits at Gabbs are in the Upper Triassic /

/ Muller, S. W., and Ferguson, H. G., Mesozoic stratigraphy of the Hawthorne and Tonopah quadrangles, Nevada: Geol. Soc. America Bull., vol. 50, no. 10, pp. 1573-1624, 1939.

Luning formation, which consists of regionally metamorphosed shales, limestones, and dolomites.

The uppermost of the three members of the Luning formation is a dense, dark-gray to black, fine-grained dolomite in the Gabbs area. The sedimentary and metamorphic units shown on the accompanying geologic maps are alteration facies of this member. The minute dolomite grains are elongated and have parallel orientation. Minor amounts of sporadically distributed silicate minerals, mainly tremolite and talc, are associated with the dolomite. The relative amount of silicate impurities is shown by analysis 7 in table 1.

Table 1. Analyses of magnesite, dolomite, and brucite from Gabbs area, Nye County, Nevada. W. W. Brannock, analyst, U. S. Geological Survey.

	1	2	3	4	5	6	7	8	9	10
SiO_2.....	0.37	0.65	0.46	0.76	0.49	0.11	0.70	0.10	1.54	1.28
Al_2O_3.....	.17	.15	.11	.13	.13	.12	.09	.13	.30	.05
Fe_2O_3	.21	.34	.29	.31	.57	.19	.21	.35	.49	.42
FeO........	...	...	...	...	...	...	...	...	...	.40
MgO	46.97	47.35	46.87	45.06	44.26	47.14	21.54	21.75	21.61	65.91
CaO	.79	.36	1.05	2.99	3.69	.19	30.41	30.36	30.55	1.31
H_2O	...	...	...	...	...	} 1.33	...	...	...	.50
H_2O+.......	...	...	...	...	...		...	...	...	28.88
TiO	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
CO_2.......	51.52	51.04	51.48	50.86	51.02	51.14	47.06	47.26	45.42	1.27
MnO........	...	...	...	...	...	...	...	...	...	.04
	100.03	99.90	100.26	100.11	100.16	100.22	100.02	99.95	99.92	100.07
Sp.Gr.....	3.01	2.99	3.01	2.99	3.01	2.82	2.89	2.91	2.89	2.34

1 Fine-grained, white magnesite, Capella Hill quarry, Capella claim, sec. 26, T. 12 N., R. 36 E.

2 Magnesite, dark gray, from Bluestone quarry of Sierra Magnesite Co., sec. 36, T. 12 N., R. 36 E.

3 Magnesite, fine-grained, light gray, from June 2 quarry of Basic Magnesium, Inc., sec. 26, T. 12 N., R. 36E.

4 Dense light-gray magnesite with dolomite veinlets, Capella Hill quarry, sec. 26, T. 12 N., R. 36 E.

5 Magnesite, dark gray, veined, coarse- and fine-grained, June 2 quarry, sec. 26, T. 12 N., R. 36 E.

6 "Bone" magnesite, dense, clean, from west side of Lower Brucite quarry, sec. 35, T. 12 N., R. 36 E.

7 Black dolomite--not recrystallized--Betty O'Neal No. 2 claim at machine shop, sec. 36, T. 12 N., R. 36 E.

8 Coarse recrystallized dolomite June 2 quarry, sec. 26, T. 12 N., R. 36 E.

9 Gray, fine-grained recrystallized dolomite at the southwest entrance to the Lower Brucite quarry, sec. 35, T. 12 N., R. 36 E.

10 Brucite with grains of dolomite and possibly a small amount of silicate minerals, Lower Brucite quarry, Gloria Extension claim, sec. 35, T. 12 N., R. 36 E.

Igneous rocks

Intrusive igneous rocks occur in the mineralized area as a stock of granodiorite, and dikes and sills of different compositions. The granodiorite is a typical medium-grained gray granitoid rock. The outcrop pattern of the stock is irregular with many apophyses projecting into the magnesite and other adjacent rocks. The dike rocks are granophyre, andesite aplite, malchite, and rhyolite. _/ The granophyre dikes are older than the

_/ Callaghan, Eugene, Pre-granodiorite dikes in granodiorite, Paradise Range, Nevada: Am. Geophys. Union Trans. 16th Ann. Mtg. Pt. 1, pp. 302-307, Nat. Research Council, 1935

granodiorite which transects and follows them for some distance beyond the main mass of granodiorite. Andesite dikes were intruded before the final consolidation of the granodiorite so that they are locally fractured and injected by the granodiorite. Locally small aplite dikes fill joints in the granodiorite. Swarms of green to gray malchite dikes transect all earlier rocks but are themselves cut by a number of dense white rhyolite dikes.

Most of the magnesite is north of the granodiorite stock and is transected by all of the igneous rocks mentioned above. The brucite, however, is distributed as both large and small bodies along or near the granodiorite contact. Many dikes and lenses of modified granodiorite as well as subsequent dikes occur in the brucite bodies.

Rock alteration

Alteration of the regionally metamorphosed Triassic dolomite has yielded recrystallized dolomite, magnesite, brucite, and silicate minerals. Most of the recrystallized dolomite is distinguished from regionally metamorphosed dolomite by its larger grain size, massive structure, and brown-weathering surface. Some recrystallized dolomite is white, very fine grained and a fresh fracture surface has an almost vitreous appearance. Both dolomite and magnesite have been recrystallized in the vicinity of the granodiorite stock. Coarse-grained dolomite also replaces magnesite and brucite. The relationships of magnesite to both types of dolomite indicate that both magnesitization and recrystallization of dolomite are parts of the same general process. The formation of brucite, although a part of the same general process, is later than the magnesitization, as magnesite and recrystallized dolomite are invaded and replaced by brucite. Silicate minerals seem to be closely related in origin to igneous intrusion and have formed in or replaced dolomite, magnesite, and brucite. Segregations of silicate minerals are shown as tactite on the map.

Structure

All the rocks represented on the geologic map are in the over-riding plate above a thrust fault. Within the Paradise Peak quadrangle but outside the magnesite area, the thrust fault brings the upper dolomite of the Luning formation in contact with the upper limestone of the formation. Within the thrust plate the thin-bedded regionally metamorphosed dolomite dips regionally about 60° west but is broken by minor faults and is folded locally. Clastic layers in the dolomite in or near the mineralized area are isoclinally folded so that fold axes are parallel to the regional dip. Nearly all the faulting and folding within the mineralized area took place prior to mineralization and igneous invasion. The igneous intrusions follow a pattern of fractures that trends dominantly northwest, although some dikes and fractures trend nearly north and some trend west. Joints and fractures in the original dolomite influenced the distribution of magnesite only slightly. These structures in magnesite are filled with both brucite and silicate minerals, and fractures in both magnesite and brucite are filled with later dolomite.

Minor faults later than igneous intrusion and mineralization are relatively rare in the map area. The basin range fault system along the front of the Paradise Range west of the deposits is, however, much later in age. Movement on faults within the valley segment southwest of the Gabbs area took place as recently as 1932. _/

_/ Gianella, V. P., and Callaghan, Eugene, The Cedar Mountain, Nevada, earthquake of December 20, 1932: Seismol. Soc. America Bull., vol. 24, no. 4, pp. 345-384, 1934.

Gianella, V. P., and Callaghan, Eugene, The earthquake of December 20, 1932, at Cedar Mountain, Nevada, and its bearing on the genesis of Basin Range structure: Jour. Geology, vol. 42, no. 1, pp. 1-22, 1934.

MINERAL DEPOSITS

Size and shape of bodies

Magnesite (28.8 percent Mg) and brucite (41.6 percent Mg), the two minerals of economic importance in the area, are associated with dolomite and many other minerals. The assemblage of minerals other than magnesite and brucite and the igneous rocks constitute the wallrocks and impurities of the deposits. The magnesite deposits of commercial grade are north and northwest of the stock of granodiorite in an area of about one square mile. The largest area of magnesite, approximately 5,000 feet long and 3,000 feet wide, is east and north of a prong of granodiorite projecting northwest from the main part of the stock. Material ranging from nearly pure magnesite to nearly pure dolomite, occurs in varying proportions in this area. The areas containing different grades of magnesite are too complex to describe and are shown on the map as less than 5 percent CaO and between 5 percent and 26 percent CaO. Diamond drilling and excavation revealed that the distribution of different grades is as complex in depth as in plan. Magnesite extends to the greatest depth (600 feet) reached in drilling, and its maximum depth is unknown. With the exception of one quarry, all the commercial development has been in the eastern area. Magnesite bodies west of the granodiorite prong are relatively small, and only one quarry was opened in this area.

Brucite is distributed in bodies of variable size along the contact of the north side of the granodiorite stock with adjacent magnesite and dolomite. There are two main bodies of brucite- one on the east side of the granodiorite prong noted above, and the other on the west wide. Quarries were opened in both of these bodies but the eastern deposit, 1,000 feet long and 200 feet wide, has been the source of most of the production. In 1948 nearly all the brucite recoverable by open pit methods had been removed. Diamond drilling has shown that brucite continues below the present floor of the quarry. The western deposit, triangular in shape and about 400 feet long and 250 feet wide, contains too much impurity to be utilized without beneficiation. With the exception of experimental shipments made in 1930-31 by U. S. Brucite Corporation, all the brucite has been quarried by Basic Refractories, Inc., a lessee.

The ownership of the patented claims covering the deposits of magnesite is divided. The federal government purchased claims around the outer border of the patented area from Basic Magnesium, Inc., the locator. These claims include the June 1, June 2, Capella and Margie magnesite quarries. Standard Slag Co. holds five claims in the eastern part of the area, east of the granodiorite prong. Basic Magnesium, Inc., as a lessee, opened a quarry in the Duplex claim at the northwest end of the Standard Slag property, and another lessee, Sierra Magnesite Co., opened a quarry in the Bluestone claim at the southeast end. Sierra Magnesite Co., as a lessee, opened another quarry on two claims of the Nevada Massachusetts Co., in the east part of the area. The central group of claims distributed around the granodiorite contact and containing almost all the brucite is the property of U. S. Brucite Corporation.

Composition and impurities

The composition of the magnesitic material is of utmost importance, not only in selecting the parts of the deposit to be mined but also in determining the most effective method of beneficiation and use. Analyses of selected samples are given in table 1, and a log of part of a diamond drill core with partial analyses is given in table 2.

Individual crystals of carbonate are either magnesite or dolomite. Evidently neither exists in solid solution in the other in excess of 4 percent. However, crystals of dolomite are mixed with crystals of magnesite in nearly all proportions both areally and in depth. Magnesite and recrystallized dolomite are so similar in appearance that they cannot always be distinguished by the unaided eye. Both are coarse-grained to very fine-grained, have a brown-weathering surface, and show intricate replacement structures. Both are readily distinguished by chemical analysis, by examination in index oils under the microscope, and by difference in appearance on polished surfaces as well as by other means. Iron is present as iron oxide or more rarely as iron sulfide rather than as a solid solution of iron carbonate. Alumina is present chiefly as talc. Lime, in addition to that in dolomite, is present as films of caliche on joint surfaces or as calcite or aragonite in what were probably channelways of springs long since dried up. Silica in the magnesite rock is accounted for by a variety of silicate minerals of which serpentine and forsterite are probably the most abundant. The numerous igneous rocks that have intruded the magnesite are possibly the most troublesome impurity of all, as the inclusion of only a small amount of igneous rock in the ore noticeably lowers the grade.

Table 2. Record of part of diamond drill core no. DG-K 27-g from

Greenstone Addition claim

Depth in feet From	To	Insol.	R_2O_3	CaO	
70.0	74.0	1.5	0.8	28.9	70.5 - 74.5 feet medium- and fine-grained carbonate; locally vuggy with patches of brown vuggy fine-grained
74.0	77.3	0.9	0.6	11.2	carbonate
77.3	82.8	1.3	0.5	7.1	74.5- 84.0 feet light gray blotchy friable fine-grained carbonate with
82.8	86.0	0.8	0.5	19.2	dark medium-grained carbonate veins. Shattered core at 79.0 feet. A 1½-inch, steep, very coarse grained,
86.0	91.5	1.9	0.4	12.5	carbonate vein at 82.6 feet.
91.5	97.7	1.5	0.4	3.8	84.0 - 107.5 feet medium gray, fine-grained carbonate; locally light gray;
97.7	101.0	0.0	0.7	2.9	also locally blotchy due to dark-gray veins. A few scattered spots of iron
101.0	102.1	0.7	0.5	3.5	oxide and tight iron-stained veins.
102.1	109.0	0.8	0.7	1.8	107.5 - 113.3 feet dark-gray fine grained carbonate; flat iron-stained streaks
109.0	113.5	2.0	1.0	2.8	common in lower part. Also a few prominent steep joints with silicate
113.5	117.5	0.8	0.7	1.8	coatings.
117.5	118.9	0.6	2.5	14.9	113.3 - 125.5 feet light-gray blotchy, fine-grained carbonate. A few vuggy
118.9	125.5	0.8	0.6	2.8	streaks of iron oxide. Brown fine-grained blotchy carbonate near 118.9 feet

Drilled by: Basic Magnesium, Inc.

Descriptions quoted from log by: W. P. Fuller, Jr.

Partial analyses by: Basic Magnesium, Inc.

Average core recovery 74.3 percent.

As brucite is chemically a highly reactive material, it contains even more impurities than the magnesite. Residual cores of dolomite or magnesite remain within the brucite, which is itself further altered in large patches to late dolomite. Brucite was particularly susceptible to igneous invasion and contains many dikes or lenses of igneous rock. Silicate minerals are abundant in zones surrounding these igneous masses, or they occur along fractures in the brucite. The surface outcrop of brucite has weathered to hydromagnesite and artinite, and open fractures extending to great depth in the brucite are also lined with these minerals. Dense white or "bone" magnesite is found in some fractures. All these impurities are readily recognized in brucite.

Origin

Crystalline magnesite and recrystallized dolomite were formed by replacement of regionally metamorphosed dolomite by solutions moving upward through the dolomite. This process took place at moderate to great depth prior to the emplacement of the igneous intrusions. Silicate minerals and disseminated cubic pyrite were introduced at the time of intrusion of the igneous rocks, particularly the granophyre and the granodiorite. Brucite was probably formed at the time of the intrusion of granodiorite, because all the brucite bodies occur at or very near the contact of the granodiorite with the dolomite or magnesite. Changes in the constitution of solutions caused replacement of both magnesite and brucite by later dolomite.

Magnesite reserves

The intricacy of replacement structures and boundaries of the different grades of material makes the calculation of reserves very difficult. To sample the deposits accurately diamond drill holes were spaced not more than 50 feet apart. Diamond drill holes spaced a hundred feet or more apart served only to supply a rough estimate of the ore reserves. The relation of ore to waste revealed by the quarrying operation of various companies in the district was an aid in attempting to predict the continuity of ore of a certain grade. The distribution of various grades of ore on the surface was taken into account in the areas that had been drilled in order to determine the area beyond the last drill hole that was to be included in the ore block. Ordinarily ore was not estimated beyond 50 feet from the drill hole. Estimates were carried only to the depth of drilling even though the lower limit of magnesite beyond that depth is unknown. Outside the drilled areas, estimates dependent on grade established by surface sampling were carried to a depth of only 50 feet. In other words, the estimates given in table 3 represent a high degree of assurance as far as ore of this type is concerned and are regarded as "measured" within the limits of definition by the Geological Survey and the U. S. Bureau of Mines */. A cut-off grade of 5 percent.

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*/ Measured Ore: Is ore for which tonnage is computed from dimensions revealed in outcrops, trenches, workings, and drill holes and for which the grade is computed from the results of detailed sampling. The sites for inspection, sampling, and measurement are so closely spaced and the geologic character is so well defined that the size, shape, and mineral content are well established. U. S. Geological Survey and U. S. Bureau of Mines Joint Memo., 4/14/43.

CaO was chosen as reasonable in the light of beneficiation studies and possible refractory use as well. The Sierra Magnesite Co. maintained a grade of 2 percent CaO in their quarry in the Bluestone claim. The tonnages given in the first column represent material within the measured blocks that could be selectively mined to yield ore with not more than 5 percent CaO. The second column represents material within the measured blocks that ranges between 5 and 26 percent CaO, and the third column represents dolomite so closely associated within the measured blocks that it would probably have to be handled in removing the magnesite. The estimates take into account the probable volume of igneous rocks within the ore blocks, but not the engineering details of extraction such as locations of benches, slopes of quarry walls, or practicability of removing overburden.

Table 3

Measured ore reserves of magnesite in principal ore bodies exposed at the surface in Gabbs area.

	Less than 5 percent CaO	5 percent to 26 percent CaO	More than 26 percent CaO
Total tonnages	27,000,000	18,300,000	6,700,000

RECOMMENDATIONS

The reserves of magnesite in the Gabbs area are so large that specific recommendations for further exploratory work are not presented here. Measured reserves could be increased by extending the pattern of diamond drilling in the areas that contain magnesite of the highest grades and that have the fewest dikes. Property lines are so laid out that it is difficult to plan economic and effective quarry systems in magnesite on one property without affecting other properties. Consolidation and unit operation are recommended for any attempt to quarry magnesite on a large scale.

Brucite underlying the quarry east of the granodiorite prong would have to be removed by underground mining methods, so that exploration beyond what has already been done doubtless would be necessary to justify the investment.