PENCATITE FROM THE ORGAN MOUNTAINS, NEW MEXICO

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Introduction

The geological process known as dolomitization, or the conversion of limestone to dolomite, is recognized as of common occurrence and some of the methods by which this change is thought to have been brought about are fairly well understood. But, the reversal of this process, namely the dedolomitization of dolomites and magnesium limestones by thermal metamorphism with the formation of periclase and other accompanying minerals is quite uncommon, judging from the comparatively few occurrences, especially in the United States, reported thus far in the literature.[1]

In November 1931 several rock specimens were received from a prospector in El Paso, Texas, who sent them in for identification. A very brief statement accompanied the shipment to the effect that the specimens were collected from the south end of the Organ Mountains, New Mexico, about eighteen miles north of the Texas border. The following March a brief description was given before the Michigan Academy of Science, Arts and Letters.[2] Since then additional microscopic data have been secured, the rock has been analyzed, and a recent Bulletin on the Geology of the Organ Mountains issued by the New Mexico School of Mines[3] now makes it possible to establish the locality from which the specimens came, if not definitely, still within narrow limits.

In brief, according to Dunham[4] dolomites of Lower Paleozoic age outcrop at the southern end of the Organ Mountains and have been invaded by a batholith of quartz monzonite. Large xenoliths of dolomite found in the quartz monzonite in the vicinity of South Canyon have been completely altered, also at Target Range (head of Target Range Canyon) silication of impure beds extends to 400 feet while recrystallization has

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[1] A. F. Rogers has reported previously on four other occurrences in the United States: at Crestmore and Riverside, California; at the Mountain Lake mine, about twenty-five miles south east of Salt Lake City, Utah; and in the Phillipsburg quadrangle, Montana. *Am. Jour. Sci.* vol. **46**, pp. 581–586, 1918; *Am. Mineral.*, vol. **14**, pp. 462–469, 1929.

[2] Hunt, W. F., *Proc. Mich. Acad. Sci., Arts, and Letters*, 34th and 35th Annual Reports, Paper No. 15, Section of Geology & Mineralogy, **1932.**

[3] *Bull.* **11,** *New Mexico School of Mines*, 1935. The Geology of the Organ Mountains by Kingsley Charles Dunham. Also *Am. Mineral.*, vol. **21**, pp. 312–318, 1936.

[4] *Idem.*, p. 93.

been traced for a distance of over 2500 ft. from the igneous intrusion (Fig. 1).

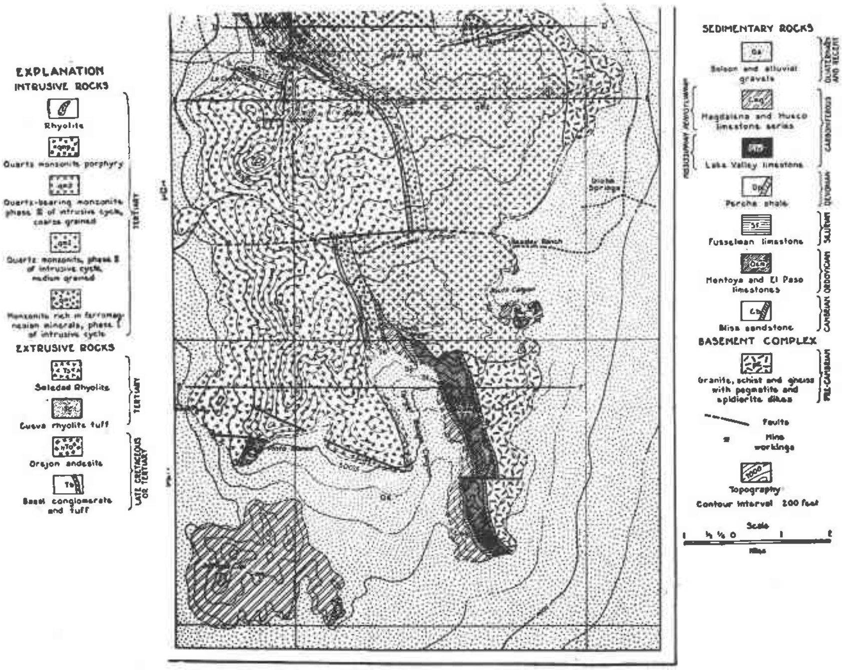

FIG. 1. Geology of lower portions of the Organ Mountains, according to K. C. Dunham, *Bull.*. **11,** *New Mexico School of Mines,* showing invasion of dolomite by batholith of quartz monzonite.

As a result of this thermal treatment the dolomite has been changed in the following manner. The calcium carbonate portion has been recrystallized forming an interlocking mosaic of irregular grains which serve as a host for a number of other minerals. The magnesium carbonate component of the original dolomite is broken down to the oxide, periclase. This mineral is very unstable and has largely dissappeared as such from the rock. Most of the magnesium oxide has changed to the hydrated oxide, brucite, which in turn has altered, in part, to magnesite. Occasionally, however, fragments of unaltered isotropic periclase may still be observed either in the calcite, but more generally as a residual core in the brucite. This would seem to indicate that the hydrothermal solutions had been insufficient in amount to hydrate all the periclase.

A small amount of silica was either present in the original dolomite or was introduced by the solutions that brought about hydration as some of the magnesium has combined with it to form forsterite. This mineral in turn has likewise been hydrated, in part, producing the antigorite variety of serpentine. Other minerals present in still smaller amounts include pyrite, limonite and occasional small reddish-brown grains of rutile. No lime silicate minerals were observed in any of the slides examined.

DESCRIPTION OF THE MINERALS

MEGASCOPIC

In general appearance the rock resembles a dull white marble. A freshly broken surface presents a granular texture and possesses a distinct white color. An alteration, noted on the surface of some of the specimens, consists of a white powdery substance, probably hydromagnesite. Distributed throughout the specimens are small, dull-white areas with circular or elliptical outlines which represent the mineral brucite, $Mg(OH)_2$. The exposed surface is somewhat pitted due to the leaching of this fairly soluble constituent. A few specks of pyrite and occasional brownish stains of iron oxide were also noted.

FIG. 2. The broad polysynthetic twinning lamellae of calcite are sometimes continuous through the elliptical patches of brucite. The remaining grains are dusty calcite with mosaic texture in various orientations.

MICROSCOPIC

An examination of six thin sections reveals a typically mosaic texture. The following minerals were identified.

Calcite. This mineral is by far the most important constituent of the rock and constitutes, together with magnesite, about 70% of the entire area. The interlocking grains are quite irregular in outline and many possess a dusty appearance. Some of the larger grains are biaxial in character with a small axial angle. A number of grains exhibit two sets of broad polysynthetic twinning lamellae which intersect and give rise to rhombic outlines. The average size of the calcite grains as measured on one section was about 0.4 mm. The calcite serves as the host for the accessory minerals which include brucite, periclase and forsterite.

Figure 2, which represents a drawing of an observation under crossed nicols, shows that the twinning lamellae are sometimes continuous through the brucite. The twinning may have developed from strains resulting from the hydration of periclase to brucite, since this change involves an increase in volume of approximately 117%.

Brucite. This mineral constitutes, on an average, 26% of the area of the thin sections. It occurs in typically circular to elliptical aggregates. In plane polarized light the patches are colorless, and their complex, delicate foliated structure is revealed to best advantage under crossed nicols. Each circular area consists of a series of concentric swirls of fibrous or foliated aggregates. Some of the brucite masses enclose areas of calcite or small grains of unaltered isotropic periclase. (Figs. 3 and 4.)

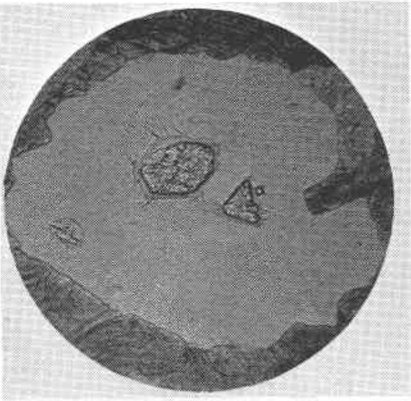

FIG. 3

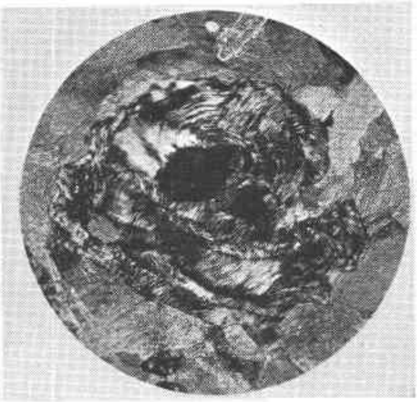

FIG. 4

FIG. 3. Brucite aggregate enclosing fragments of unaltered periclase. Plane polarized light. ×70. Note the high relief of the periclase.

FIG. 4. Same as Fig. 3 but with crossed nicols. Brucite occurring as a series of concentric swirls of foliated aggregates. The two black enclosed grains are isotropic periclase. ×70.

It would seem that the brucite masses, developed from the periclase through hydration, were not formed during a single operation; rather, the reaction proceeded in successive stages gradually eliminating the MgO, although in some instances a small residual grain or two still remains. Also, the direction and amount of water causing the hydration varied from time to time as the widths and number of concentric rims of brucite are not constant in any single area.

The average diameter of the brucite aggregates was found to be 0.98 mm., while the largest single area noted measured 1.48 mm. The optical properties were measured on fragments taken from the lenticular masses. The fragments are composed of bent foliae with wavy extinction and exhibit low yellow-gray anomalous interference colors. The indices were: $\omega = 1.565 \pm 0.002$; $\epsilon = 1.585 \pm 0.002$. Elongation (−). These values are slightly higher than those given by Larsen and Berman, but agree well with those reported by Watanabe and Rogers as shown in the accompanying table.

TABLE 1. OPTICAL PROPERTIES OF BRUCITE.

Observer	Hunt & Faust	Larsen & Berman[5]	Watanabe[6]	Watanabe[6]	Rogers[7]
Locality	Organ Mts., New Mexico	None given	Nantei, Japan	Keikansan, Japan	Riverside, California
ω	1.565	1.559	1.566	1.565	1.567
	±0.002		±0.002	±0.002	±0.003
ϵ	1.585	1.580	1.584	1.584	1.583
	±0.002		±0.002	±0.002	±0.003
$\epsilon-\omega$	0.020	0.021	0.018	0.019	0.016
Elongation	(−)		(−)	(−)	(−)

The higher values recorded by Watanabe, Rogers, and the writers may be due to the presence of a small amount of iron oxide in solid solution in the brucite, for in the literature two types of ferriferous brucites are mentioned. Nemalite is defined by Dana[8] as "a fibrous variety containing 4 to 5 per cent of iron protoxide." Berman[9] reports a nemalite from Quebec with negative elongation and $\epsilon = 1.586$, and containing 9 per cent FeO. The term ferrobrucite has also been applied to iron-bearing brucites.

Antigorite. This mineral has developed from the forsterite as remnants of former forsterite grains are often still observed. A noteworthy feature of this antigorite is the absence of any concentration of iron oxides within it. The antigorite is easily distinguished from the brucite under crossed nicols because of differences in structure, interference colors and type of extinction. The indices of refraction of brucite are also higher than those of antigorite and the Becke line test can be used to advantage. The average of a number of measurements revealed a grain size of about 0.10 mm. The interference colors are a very low blue-gray, almost isotropic.

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[5] Larsen, E. S., and Berman, H., *Bull.* **848,** *U. S. Geol. Survey,* p. 70, 1934.

[6] Watanabe, Takeo, *Jour. Fac. Sci. Hokkaido, Imperial Univ.,* Ser. 4, vol. **3,** No. 1, p. 55, 1935.

[7] Rogers, A. F., *Am. Jour. Sci.,* vol. **46,** p. 582, 1918.

[8] Dana, *System of Mineralogy,* 6th edition, p. 252.

[9] Berman, H., *Am. Mineral.,* vol. **17,** pp. 313–314, 1932.

Forsterite. The forsterite grains are distributed throughout the calcite and are occasionally enclosed in the brucite swirls. They reveal in various degrees the usual alteration to antigorite (Fig. 5). A grain size determination made on a number of fragments gave an average reading of 0.04 mm.

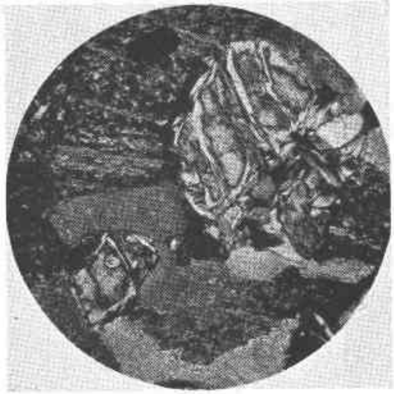

FIG. 5. Forsterite grains in upper right portion showing alteration to antigorite.

Periclase. This constituent is present as residual cores in some of the brucite aggregates and occasionally as unaltered grains in the calcite. It rarely occurs in the antigorite areas. The fragments in cross section often show square, rectangular or trigonal outlines. The average grain size is 0.07 mm. but there is considerable variation, from 0.02 to 0.16 mm.

Iron Oxides. These occur in irregular patches and veinlets, the borders of which are unmatched and are controlled principally by the contours of the brucite and calcite grains. Iron oxide flakes and stringers occasionally cut across the brucite swirls or calcite grains.

Rutile. Rutile was found very sparingly occurring in reddish-brown prismatic crystals or rounded grains in the calcite groundmass. The grains have an average size of 0.08 mm.

Pyrite. A few minute specks of pyrite were noted in the hand specimen, but no particles were encountered in the traverses with the recording micrometer.

MICROMETRIC MEASUREMENTS

A micrometric survey of three thin sections was made using the improved Wentworth recording micrometer described by Hunt.[10] As recommended by Larsen and Miller[11] the measurements were carried out

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[10] Hunt, W. F., *Am. Mineral.*, vol. **9**, pp. 190–194, 1924.

[11] Larsen, E. S., and Miller, F. S., *Am. Mineral.*, vol. **20**, pp. 260–274, 1935.

by making fifteen traverses across the slide, one millimeter apart. A Leitz No 3X objective and No. III ocular were employed, giving a magnification of 82 diameters. The results are given in Table 2.

TABLE 2. AREAL ANALYSES.

Mineral	Section No. 1	Section No. 2	Section No. 3	Average
Brucite	27.5%	26.8%	23.8%	26.1%
Calcite (and Magnesite)	69.6	68.5	71.9	70.0
Antigorite	2.0	3.8	3.7	3.1
Forsterite	0.7	0.4	0.3	0.5
Periclase	0.1	0.3	0.2	0.2
Rutile (and iron oxides)	0.1	0.2	0.1	0.1
Totals	100.0	100.0	100.0	100.0
Aggregate units traversed	48,221	49,484	50,965	49,557
Distance traversed in mm.	241	247	255	244

CHEMICAL ANALYSES

QUALITATIVE

The rock powder effervesces freely with cold dilute HCl acid. Strong tests were obtained for both calcium and magnesium; also considerable water was evolved in a closed tube.

QUANTITATIVE

Carefully selected fresh fragments were broken up in a "Geophysical Laboratory mortar and pestle" and a 22-gram sample was prepared for the analysis. The powder was exposed to a magnet to make sure that no particles of the crushing apparatus were included.

The carbon dioxide was determined gravimetrically. To make sure that the absorption train was in proper condition, a check run on a pure sample of calcium carbonate was made before and after each carbon dioxide determination on the rock sample. This demonstrated the absence of leaks and the active character of the absorbent (ascarite). One gram samples of the rock were treated with sixty cc. of perchloric acid (1:5 dilution of 72 % strength) containing 0.5 gram of sodium chromate. The addition of sodium chromate to the perchloric acid solution oxidizes the sulphide to sulphuric acid, thus eliminating the use of a

$CuSO_4 \cdot 5\ H_2O$ tube to remove the H_2S otherwise generated in the reaction.[12] Two determinations gave values of 31.10 and 31.13% CO_2. The main analysis for SiO_2, R_2O_3 group, CaO and MgO was conducted according to standard methods. The water was determined by absorption in "dehydrite" (anhydrous $MgClO_4$). The results are recorded in Analysis 1, Table 3. For comparison, a partial analysis, Analysis 2, on material from Target Range Canyon, Organ Mountains, given in a report by Dunham[13] is likewise listed. The agreement of the main constituents in the two analyses is very close.

TABLE 3. CHEMICAL ANALYSES OF THE ROCK

	Analysis 1		Analysis 2
SiO_2	2.07		1.60
Al_2O_3	0.64		0.35
Fe_2O_3			0.73
MgO	23.48		23.01
CaO	34.62		34.04
H_2O	8.53	Ignition loss	40.27
CO_2	31.12		
MnO	tr.		
Total	100.46		100.00

Analyst: George T. Faust

Analyst: H. C. Lee

As a matter of interest, and as an aid in planning the analysis, a spectroscopic examination of two samples of the powder was kindly made by Dr. Kenneth B. Thomson, research spectroscopist in the department of physics. He reported as follows:

"Main constituents: Mg, Ca, Si
Minor constituent: Fe
Traces: Mn, Sr, Al, Cu

NOTES: Lead and nickel appear in one spectrum but not in the other and are almost certainly due to contamination from the arc holders. No lines due to titanium or vanadium were observed. Barium is there only as a small trace. The carbon band falls in the position of the most sensitive barium line."

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[12] Method suggested by Professor H. H. Willard of the Dept. of Chemistry in a personal communication.

[13] Dunham, K. C., *Bull.* **11**, *New Mexico School of Mines*, The Geology of the Organ Mountains, p. 104, 1935.

CALCULATIONS

Using the average volumetric analysis and the following values for the specific gravities: calcite 2.72, brucite 2.40, antigorite 2.60, forsterite 3.21, periclase 3.6, rutile 4.2, iron oxide 3.8, the weight percentage was calculated and is given in column 1 of Table 4. In column 2 are the weight percentages by Dunham[14] on an unanalyzed brucite marble from South Cayon, Organ Mountains.

TABLE 4. WEIGHT PERCENTAGE CALCULATED FROM AREAL MEASUREMENTS

Mineral	1	2
Brucite	23.7	36.2
Calcite and magnesite	72.1	62.3
Antigorite	3.1	1.5
Forsterite	0.6	
Periclase	0.3	
Rutile and iron oxides	0.2	
Total	100.0	100.0

The chemical analysis was then recast in terms of mineral components in order to compare the results with the gravimetric micrometric measurements. In order to carry out this comparison the CaO was calculated to calcite and the remaining CO_2 was assigned to magnesite. The SiO_2 with the necessary amounts of MgO and H_2O were computed to antigorite. The remaining MgO and H_2O were present in the proper proportion to form brucite. The computations involved are shown in Table 5.

TABLE 5. RECALCULATION OF CHEMICAL ANALYSIS

Chemical Analysis (Minus Al_2O_3 and Fe_2O_3)		Recal. to 100%	Combining ratios	Calcite $CaO \cdot CO_2$	Magnesite $MgO \cdot CO_2$	Antigorite $3MgO \cdot 2SiO_2 \cdot 2H_2O$	Brucite $MgO \cdot H_2O$
SiO_2	2.07	2.07	.0344	....	....	0344	
MgO	23.48	23.52	.5833	....	....0902..	....0516..	4415
CaO	34.62	34.68	.6184	.6184			
H_2O	8.53	8.55	.4746	....	....	....0344..	4402
CO_2	31.12	31.18	.7086	.6184	.0902		
	99.82	100.00		Calcite 61.9%	Magnesite 7.6%	Antigorite 4.8%	Brucite 25.7%

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[14] Loc. cit., p. 103.

Table 6 shows the results of the comparison of recast chemical analysis with the gravimetric micrometric measurements. It will be noted that the deviation is in each case quite small, varying from less than 1% in the case of the antigorite-forsterite-periclase group to 2.0% in brucite.

TABLE 6. COMPARISON OF RECAST CHEMICAL ANALYSIS WITH THE GRAVIMETRIC MICROMETRIC MEASUREMENTS

Calculated from Analysis			Measured with Micrometer	
Calcite	61.9	69.5%	72.1%	
Magnesite	7.6			
Brucite	25.7		23.7	
Antigorite	4.8	4.8	3.1	4.0
Forsterite	0.0		0.6	
Periclase	0.0		0.3	

NOMENCLATURE

The question of the nomenclature of this rock can now be considered in the light of the preceding analyses. Two rock names appear in the literature for dedolomitized dolomites and magnesium limestones, pencatite and predazzite, depending upon the amounts of brucite and calcite developed, which in turn depend upon the magnesium and calcium contents of the original rock. Harker[15] has defined in a quantitative manner the meaning of the terms pencatite and predazzite as follows:

"It is most in accordance with the original usage to employ the name pencatite for an aggregate of calcite and brucite in equal molecular proportions, i.e. with the percentage composition of 63.3 calcite to 36.7 brucite, reserving the predazzite for varieties richer in calcite."

The rock here described contains 62% calcite and while the amount of brucite is less than that theoretically demanded, all of the magnesium was not converted to brucite as other magnesium minerals have formed instead, so that the term pencatite seems the more appropriate one to use.

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[15] Harker, A., The Tertiary igneous rocks of skye: *Mem. Geol. Surv. United Kingdom*, pp. 144–151, **1904**; Metamorphism, p. 77, **1932**.