

BERYLLIUM MINERALS IN THE VICTORIO MOUNTAINS, LUNA COUNTY, NEW MEXICO*

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ABSTRACT

Beryl, helvite, and beryllian idocrase occur within a small area in the Victorio Mountains, New Mexico. Beryl crystals form the selvage of a quartz-tungsten vein that cuts sharply across flat-lying limestone but which did not alter the limestone visibly. Helvite forms tetrahedral crystals that cut calcite and in turn are cut by grossularite in a nearby coarse-grained silicated marble. Idocrase containing 0.2 per cent BeO is interlayered with fluorite and garnet in tactites at the same locality. Beryllium has been found in other tactites in small amounts, but its form has not been determined.

The Victorio Mountains vein is similar in mineralogy and paragenesis to several known beryl-bearing veins that have been described from other regions.

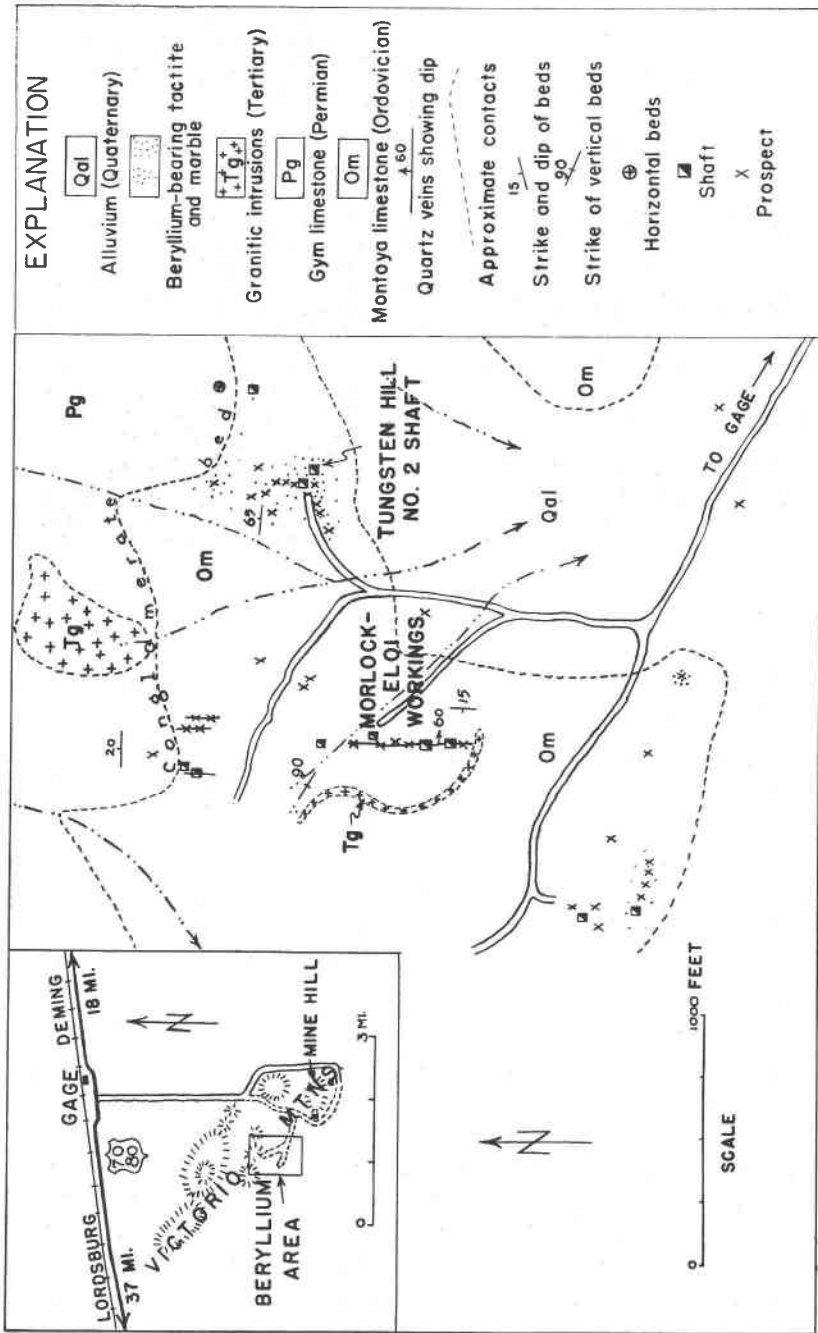
A modification of the Goldschmidt-Peters theory for the origin of these beryllium minerals is proposed: beryllium occurs as beryl in rocks rich in aluminum with relation to the sum of calcium, sodium, and potassium, and as helvite in aluminum-poor rocks. Following Shand, the aluminum ratio is applied to metamorphic as well as to igneous rocks. In the Victorio Mountains, helvite may have been formed by replacement in marble from solutions originally similar to those that deposited beryl in the open fissures, but with their aluminum content reduced by the formation of garnet in that calcium-rich environment.

INTRODUCTION

A unique association of helvite and beryl occurs in the Victorio Mountains, 5 miles south of Gage, Luna County, New Mexico. The area was visited in September 1949, during a survey of nonpegmatite beryllium resources, to investigate a reported occurrence of vein beryl. Most of the day and a half spent in the area was devoted to sampling the prospects and sketching the geology in the vicinity of the known beryllium deposits.

The northern half of the Victorio Mountains, which are 600 feet above the plain, is a gently dipping series of the Tertiary andesite and rhyolite flows that are common in the region. The southern half is composed of flatlying limestones of Paleozoic age that are intruded by small bodies of granitic rock (Darton, 1916, pp. 83-85). Mine Hill, the site of a silver-lead deposit that has been described by Lindgren and others (1910, pp. 290-292), is topped by fossiliferous Fusselman limestone (Silurian). About a mile northwest of Mine Hill, where the beryllium minerals occur (Fig. 1), Gym limestone (Permian) apparently directly overlies Montoya limestone (Ordovician); "while some Fusselman limestone may intervene, no direct evidence of its existence was obtained, and it

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EXPLANATION

- Qal Alluvium (Quaternary)
- Beryllium-bearing tactite and marble
- Tg+ Granitic intrusions (Tertiary)
- Pg Gym limestone (Permian)
- Om Montoya limestone (Ordovician)
- Quartz veins showing dip
- Approximate contacts
- Strike and dip of beds (15, 90)
- Strike of vertical beds
- Horizontal beds
- Shaft
- Prospect

Strotigraphy after Darton (1916, p 84)

Base from Claim Map by D.S. Tedford

Fig. 1. Sketch map of the Beryllium Area, Victoria Mountains, Luna County, New Mexico.

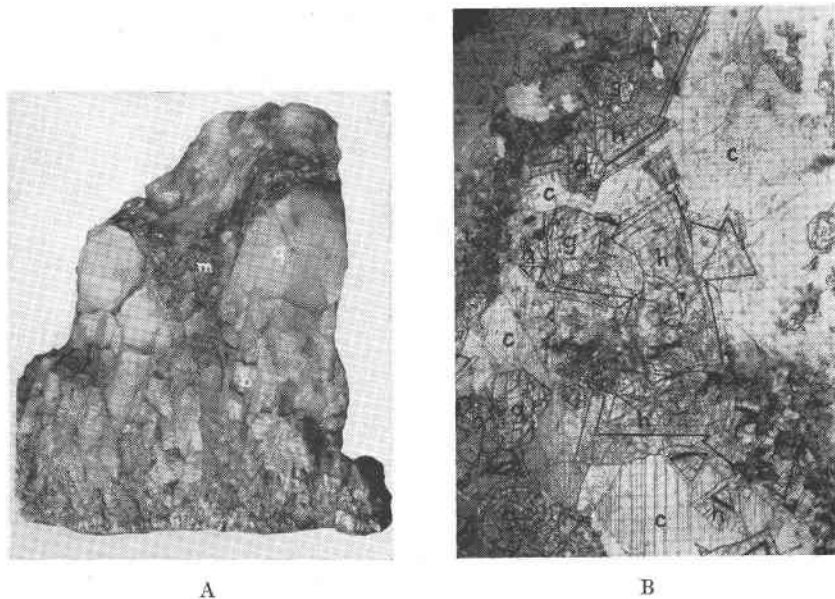


FIG. 2. Beryllium minerals. *A.* Hand specimen of quartz vein, $\times 0.35$. Crystals of beryl, *b*, are more or less perpendicular to the contact, which forms the base of the specimen (the contact plane is nearly vertical in outcrop). The beryl crystals are overgrown by crystals of milky quartz, *q*, and the spaces are filled with fine-grained muscovite, *m*. *B.* Photomicrograph of thin section of helvite-bearing marble, $\times 3.5$, ordinary light. Single and twinned tetrahedra of helvite, *h*, nearly enclose rough dodecahedra of grossularite, *g*, in a groundmass of coarsely crystalline calcite, *c*. The dark fibrous material is tremolite, replacing all other minerals.

appears to be cut out either by faulting or unconformable overlap." (Darton, 1916, p. 85). Mine Hill and the beryllium area are apparently separated by a fault, although only minor faults may be seen in the beryllium area.

BERYL DEPOSIT

Lindgren (Lindgren et al., 1910, p. 293) noted a quartz vein containing huebnerite and scheelite on the present Eloï and Morlock unpatented claims, formerly called the Brinkman, Irish Rose, or Kimmick claims. Since his visit, the vein has been irregularly mined for tungsten along part of its 600-foot length. The 1- to 2-foot thick fissure vein has knife-sharp plane contacts against dolomitic Montoya limestone, which has been only slightly altered. The limestone generally retains its fine grain and gray color except locally, where it has been slightly replaced by quartz and grossularite.

Beryl was first recognized at this locality in 1948 by W. P. Johnston of the New Jersey Zinc Exploration Co., Hanover, N. Mexico. Prismatic crystals of beryl are oriented perpendicular to the wall (Fig. 2A) in a hanging-wall selvage. The beryl crystals, as much as 5 cm. long and 1 cm. in diameter, are invariably bounded by $(10\bar{1}0)$ and (0001) forms. The beryl is very pale green (5G9/2; Munsell Book of Color, Baltimore) to colorless. It has an ordinary refractive index of 1.5740 ± 0.001 , corresponding to a composition of about 13.5 per cent BeO .¹

Quartz and some fine-grained muscovite make up most of the vein. The tungsten mineral for which the deposits were mined is wolframite; it was not present in sufficient amounts in the material available to determine its relations with the other minerals. Fluorite is rare, and galena, pyrite, wulfenite, lead carbonates, and scheelite have been reported (Hess, 1908). A beryl-bearing selvage is not evident along much of the length of the vein; nevertheless the whole vein averages 0.06 per cent BeO , 0.09 per cent tungsten, and 0.00X per cent molybdenum. The variations of beryllium and tungsten are not correlative in the analyzed material from various parts of the vein.

HELVITE DEPOSIT

Helvite occurs a few hundred feet east of the quartz vein on the Morlock and Eloi claims, in irregular lenses and bands of marble and tactite surrounded by unaltered Montoya limestone. The bands apparently are parallel to the bedding. The tactite is not near any exposed intrusion, although a small mass of granite porphyry crops out on the hill north of the altered rock (Fig. 1). The alteration, which is generally most intense in the more steeply dipping parts of the beds, may be related to a fault a mile to the east mapped by Darton (1916, p. 84). One of the veins at the top of the outcrop of the Montoya, north of the Morlock-Eloi workings (Fig. 1) is bordered by a small amount of tactite (L. R. Page, personal communication).

The helvite was discovered in dump material from the Tungsten Hill No. 2 shaft by W. I. Finch of the U. S. Geological Survey. The shaft was inaccessible, and helvite could not be found in rocks at the surface near the shaft. The helvite is in a coarse-grained massive silicate marble, composed of about 30 per cent calcite, 20 per cent grossularite, a maximum of 10 per cent helvite, a small amount of augite, and about 40 per cent tremolite that has irregularly replaced calcite and other minerals. The color of the helvite is moderate yellow (3Y7/8). The mineral occurs scattered through the calcite as sharp tetrahedra, 5 mm. across, with no modifying faces. Some crystals are twinned on (111) . The helvite has

¹ Unpublished chart by W. T. Schaller, U. S. Geological Survey.

a refractive index of 1.735 ± 0.005 and a specific gravity of 3.25, corresponding to a composition of about 85 per cent helvite and 15 per cent danalite (Glass et al., 1944, p. 183). In thin section (Fig. 2B), the helvite is pale yellow, isotropic, and shows some dark peripheral zones of very fine grained inclusions, similar to the helvite from Casa La Plata, Cordoba Province, Argentina, and Schwartzberg, Germany (Fischer, 1925, p. 146). Helvite is most easily recognized in the Victorio Mountains by its tetrahedral form. The color is distinctive, yet similar to that of the grossularite, vanadinite-mimetite, and serpentine in this district.

Yellow or brown grossularite, in small rough dodecahedra, is a common associate of helvite. It has the peripheral anisotropic zoning and dodecahedral twinning characteristic of garnet from some limestone replacements (Holser, 1950, pp. 1082-1083). Some peripheral zones have been replaced by calcite, which is euhedral to subhedral where it is in contact with helvite (Fig. 2B).

Closely associated with the helvite-bearing marble is a tactite in which bands of idocrase and fluorite alternate with bands of garnet and tremolite that have been largely altered to talc. The idocrase occurs as radiating clusters about 3 mm. in diameter. It is anomalously biaxial negative, with a very small $2V$ and very low birefringence. The index of refraction N_x or N_y is 1.701 ± 0.002 . Spectrographic analysis of hand-picked grains showed 0.2 per cent BeO.

Spectrographic analyses of 12 samples of tactite and marble from various parts of the area showed 0.002 to 0.1 per cent BeO. These samples include metamorphosed limestone from the pediment south of the quartz vein, from one locality west of the vein, and from the slightly metamorphosed wall rock of the vein (Fig. 1). Near the north end of the vein, where it contained 0.2 per cent BeO over a width of 2 feet, a 2-foot layer of rock in the hanging wall contained 0.02 per cent BeO. Several samples were fractionated in heavy liquid. The heavy separate (mostly grossularite and psilomelane type manganese oxides) was tested for helvite by staining (Gruner, 1944), and the light separate (mostly carbonates) was examined optically for beryl. In several thousand grains examined, no grain of either helvite or beryl was found. Grossularite was separated from the richest (0.1 per cent BeO) helvite-free tactite but was found to contain only 0.007 per cent BeO. The mode of occurrence of beryllium in these tactites is, therefore, not yet known, but in the tactite at Iron Mountain, N. Mex., comparable amounts are distributed in several silicates and an unidentified alteration product (Jahns, 1944b, p. 58).

The tactites contain scheelite; analyses show a range in tungsten content from less than 0.01 to 0.06 per cent. Lead, zinc, and silver are also present in local concentrations.

TABLE 1. MINERAL ASSOCIATIONS OF VEIN BERYL

| Area | Locality | Mineral associations* | | | | | | | | | | Remarks | References | | | |
|---|--|-----------------------|----------------|----------------|----------------|----------------|----------------|--------|----------------|----------------|--------------------|-----------------|------------|--------------|--|---|
| | | Beryl | Wolframite | Scheelite | Cassiterite | Molybdenite | Other sulfides | Quartz | Muscovite | Fluorite | Tourmaline | | | Other gangue | | |
| Victoria Mts., N. M., Little Dragoon Mts., N. M. | Eloi claim | R ¹ | R ² | V | | | | | R | R | | | | | | First report Galbraith, 1947, p. 83 |
| | Bluebird mine | V | R | R | | | | | C | C | | | | | | |
| Hualpai Mts., Ariz. Lone Pine, Calif. | Tungsten King mine | R ¹⁷ | C ² | R ³ | | | | | C ³ | C ⁴ | | | | | | First report† Hobbs, 1944, pp. 254-255 |
| | Boriana mine | R | | C ³ | | | | | C ⁴ | A ⁵ | | | | | | Murdoch and Webb, 1948, p. 70 |
| Chaffee Co., Colo. | 1½ miles southeast | | | | | | | | | | | | | | | Landes, 1934; Adams (in prep.) |
| | California mine | C ¹ | | | | C ³ | | | | A ¹ | C ² | R ⁴ | | | | Page, et al (in prep.) |
| Hill City, S. D. | Cowboy mine, Mohawk mine, and others | C ¹ | | R ¹ | | | | | | A ² | C ¹ | | | | | First report†† Koschman, et. al., 1942, pp. 279-282 |
| | Pine Crow claim | R ² | | | | | | | | A ¹ | A ^{2,3} | A ³ | | | | Oppenheim, 1948, pp. 35- .36 |
| Irish Creek, Va. | Irish Creek mine | C ² | V ² | | R ² | | | | | R | A | | | | | Kittl, 1930 |
| | Muzo mine and others | C ² | | C | | | | | | R | A | | | | | Smith and Gonzales, 1947, p. 8 |
| San Luis Province, Ar- gentina | Loma Blanca mine | C | | C | | | | | | V | A | C | | | | Smith and Gonzales, 1947, p. 31 |
| | Cerro Morro mine | V | C | | | | | | | | A | | | | | Smith and Gonzales, 1947, p. 31 |
| Catamarca Province, Ar- gentina | San Antonio mine | V | | | | | | | | | A | | | | | Hallmond, 1939 |
| | Chungch'on Ch'ongyang mine | R ¹² | | | | | | | | | A ¹ | A ¹ | | | | Plemister, 1940 |
| Cornwall, England‡ | South Crofty mine, Illogan Beam mine, St. Austell | R | | | | | | | | | A | | | | | Smolynov, 1940 |
| | Dzhidim mine ? | R | | | | | | | | | A | | | | | Sushchinsky, 1916 |
| Buryat-Mongolia, USSR. Boevska, Cheliabinskia, USSR. | Akchatau mine | R ² | C ⁴ | R ⁷ | | | | | | | A ⁴ | C ⁴ | | | | Pinus, 1940 |
| | Schorl Mtn. Alman' | A ² | C ³ | C | | | | | | | A | | | | | Teyayev, 1918 |
| Kazakhstan, USSR. Onon, Chitinska, USSR. | Golshtoy Suktuy Pervonachalny mine | R | | | | | | | | | A | | | | | Fermin, 1940, pp. 120- 121, 369-370 |
| | Taemy'ong mine | V | C | | | | | | | | A | | | | | Gallagher, et al, 1946 |
| Chungch'ong-pakto, Korea | Naeson-Puyong mine | R | | | | | | | | | A | | | | | |
| | Chungch'on Ch'ongyang mine | R | | | | | | | | | A | | | | | |
| Central Honshu, Japan Yumishan district, Kiangsi, China | Ebisu-Takane mines | R | A ³ | | | | | | | | A | | | | | Takimoto, 1944 |
| | Wat'i mine | R | C ¹ | | | | | | | | A | | | | | Hsu and Ting, 1943b, p. 67, 1943a, p. 272 |
| Southern Shan States, Burma | Shuashan mine | R ⁷ | C ⁵ | R ⁵ | | | | | | | A ^{10,11} | C ¹¹ | | | | —, 1943a, p. 192 —, 1943a, p. 198 |
| | Shunglungkou mine Tungping mine MT. Iyngti | R | C | | | | | | | | A | | | | | Brown and Heron, 1909, p. 102 |

* Approximate proportions of minerals as inferred from published descriptions; A—abundant; C—common; R—rare; V—very rare. Superscripts indicate paragenesis where known.

† Discovered by E. S. Larsen in 1918, according to a personal communication in 1948.

‡ Discovered by D. W. Lemmon in 1942.

§ Occurrence of beryl probably very limited, as not mentioned by Davison (1930) in his study of emerald minerals in Cornish tin veins.

COMPARISON WITH OTHER LOCALITIES

Beryl in quartz veins similar to the vein in the Victorio Mountains has been widely reported, as summarized in Table 1. In most of these localities the beryl is rare; it is usually associated with tungsten minerals, fluorite, and, to a lesser extent, cassiterite or molybdenite. Beryl occurs also in the unique carbonate veins of Muzo, Colombia. The paragenesis of beryl in many of these localities has not been recorded.

Thousands of beryl-bearing pegmatites have been described, many of them rich in quartz and tabular in shape. In compiling Table 1, a distinction between pegmatite and quartz veins was made on the basis of the presence or absence of feldspar. This follows a classic definition by Haidinger (1845, p. 585); its significance with relation to quartz-rich dikes or veins was pointed out by Tolman (1931, p. 296). Admittedly the distinction is somewhat arbitrary, as many examples of gradation between the two have been described. (See compilations by Tolman, 1931, and Furnival, 1939.) Fersman's work emphasized the genetic relation of many quartz veins to pegmatites (1940, pp. 37-39). The fracture fillings that form distinct units of many pegmatites are commonly composed of quartz, but many contain other pegmatite minerals, including beryl. Some of the quartz-rich fracture fillings are continuous and contemporaneous with the quartz core or other inner zone of the associated pegmatite (Cameron et al., 1949, pp. 70-83, 105-106). Some beryl-bearing veins in Quebec (Norman, 1945, pp. 15-16) and in New South Wales (David, 1887, pp. 112-113; Carne, 1911, pp. 58, 67) contain small amounts of feldspar and seem to be transitional between quartz veins and pegmatites. The quartz veins of Chaffee County, Colo., Hill City, S. Dak., Irish Creek, Va., San Luis Province, Argentina, Onon, U.S.S.R., and southern Kiangsi, China (Table 1) are all said to be closely related to neighboring pegmatites.

These many examples suggest that beryl-bearing quartz veins have origins similar to those of beryl-bearing pegmatites. They were probably formed at temperatures higher than those of most other mineral veins. Bodies so rich in quartz probably were deposited from aqueous solutions. (See, for example, Furnival, 1939.) (According to Jahns, 1948, they are magma-like solutions.) A late-pegmatitic to early hydrothermal stage is also favorable for the deposition of the frequently associated tungsten minerals (Kerr, 1946, pp. 38-39). Although no pegmatite was found in the Victorio Mountains area, the quartz-beryl vein is probably a high-temperature hydrothermal type.

Helvite in veins is associated with rhodonite, rhodochrosite, and quartz (Silverton, Colo.: Burbank, 1933; Butte, Mont.: Hewett, 1937; Kapnik, Hungary: Szabo, 1882), and in each vein helvite was late in

the sequence of mineral deposition. The mineralogic and paragenetic contrast of the two types of beryllium-bearing veins is evident.

The occurrence of helvite in the Victorio Mountains is superficially similar to some other occurrences of the mineral that may also be pyro-metasomatic. In most of these, however, helvite formed very late in the mineral sequence, commonly having been deposited in open spaces with fluorite and quartz (Baerum, Kjenner, Rien, and Aamot, Norway: Goldschmidt, 1911, pp. 65, 88, 101, 394-399; Schwarzenberg, Germany: Beck, 1904, p. 60; Carpenter district, N. Mex.: Weissenborn, 1948; Iron Mountain, N. Mex.: Jahns, 1944*a*, p. 195; Lupikko, Finland: Trustedt, 1907, pp. 270-271, Eskola, 1951, p. 71; Bartlett, N. H.: Huntington, 1880). Its origin is probably closely related to that of hydrothermal vein helvite. At Iron Mountain, N. Mex., much of the helvite was deposited at the same time as magnetite tactite, just prior to filling of open spaces. The paragenesis is probably similar at Lupikko, Finland, and Bartlett, N. H., where large amounts of magnetite are likewise present.

At Hortekollen, Norway, helvite occurs both in magnetite-fluorite tactite and along fissures in silicate tactite (Goldschmidt, 1911, pp. 93, 395). The euhedral form of the helvite caused Goldschmidt to infer that it was deposited at an early stage in the metamorphism; but its place in fissures and the association with magnetite-fluorite tactite make a later deposition more probable. At both Iron Mountain and Hortekollen the helvite certainly formed later than the silicate tactite. Beryllian idocrase is among the silicates at both these localities (Jahns, 1944*b*; Goldschmidt and Peters, 1932), as at Victorio Mountains.

In contrast with the other occurrences in metamorphic rocks, the helvite of Victorio Mountains is associated neither with magnetite nor with andradite and hedenbergite. Furthermore, the silicates are euhedral against calcite, in a texture typical of contemporaneous metamorphic recrystallization (Harker, 1939, p. 38). The only mineral having a penetrative replacement texture is tremolite (Fig. 2). The Victorio Mountains helvite deposit thus shows no signs of the iron metasomatism of later lower-temperature and typical replacement form, which preceded or accompanied beryllium deposition in other localities.

The Victorio Mountains helvite occurrence resembles in some respects the helvite occurrence at Casa La Plata, Cordoba Province, Argentina (Fischer, 1925). There helvite occurs in tactite and marble associated with feldspar, fluorite, calcite, quartz, mica, garnet, and idocrase. The deposit is adjacent to an intrusion of pegmatite, however, and it is difficult to assess the relative contributions of intrusion and metamorphism (Fischer, personal communication, 1951).

RELATIONS OF HELVITE AND BERYL

Beryllium concentrations in veins and metamorphic rocks are so unusual as to suggest that the two deposits, so closely situated in the Victorio Mountains, are related in origin. Their age relations were not proved in this preliminary investigation, although the one occurrence of tactite next to the vein suggests contemporaneity. The quartz vein is cut off at its southern end by a small dike of rhyolite porphyry, but the intrusion of this and similar rocks does not seem to be directly related to the areas of tactite and marble.

In any case, the proximity of beryl and helvite in this area suggests reconsideration of the general question of their relative modes of occurrence.

Goldschmidt and Peters (1932) postulated that the beryllium in magmas with mole ratio $(\text{Na}_2\text{O} + \text{K}_2\text{O})/\text{Al}_2\text{O}_3$ less than 1 ("plumasitic magmas") will crystallize as beryl, chrysoberyl, or euclase; and in those with a ratio greater than 1 ("agpaitic magmas") it will crystallize as leucophanite or meliphanite. Helvite could form from either type of magma. Stability of complex aluminum-oxygen ions in the magma was adduced to explain this difference in mineralogy.

The influence on rock mineralogy of the proportion of aluminum in magma has long been recognized, but it is perhaps most explicitly stated in Shand's classification of igneous rocks (1947*a*, pp. 227-228). The chemical relations of the solid crystals are sufficient to explain the mineralogical differences found, without recourse to any particular ionic situation in the magma. Furthermore, as Shand points out elsewhere (1947*b*, pp. 196-197), the concept is equally applicable to equilibrium relations within metamorphic facies.

If the aluminum ratio for beryllium minerals is to be extended to metamorphic rocks, the virtual absence of beryl in metamorphosed limestone,² in contrast with the many occurrences of beryl in aluminous schists around pegmatites,³ suggests that calcium should be added to the alkalis in the ratio. As for helvite, much of it occurs in the highly calcic environment of metamorphosed limestones. These facts suggest that in an environment of low alumina ratio helvite tends to be deposited exclusive of beryl.

Beryl occurs in many veins with muscovite (Table 1), which requires a high alumina ratio for its formation. The helvite veins do not contain calcium-, sodium-, potassium-, or aluminum-bearing minerals, so the

² One occurrence of beryl in marble has been noted by Chhibber (1945).

³ The best example is the emerald region of the southern Urals (Fersman, 1929).

pertinent chemistry of the solutions that formed them is unknown, aside from an evident excess of manganese.

The principal beryllium mineral of pegmatitic rocks is beryl, although chrysoberyl or phenakite occur in some beryl-bearing pegmatites. All beryl-bearing pegmatites also contain muscovite and other minerals rich in alumina, which indicates that the alumina/alkali ratio of the entire pegmatite is high and that it would be characterized as peraluminous in Shand's nomenclature. In some of these pegmatites the beryl has crystallized early in the formation of the narrow border zone, preceding or accompanying the first feldspar, which is usually perthite or albite (Cameron et al., 1949, pp. 26–27).

The scattered occurrences of beryllium minerals other than beryl in pegmatites are difficult to evaluate and reconcile with the Goldschmidt-Peters theory. It is true that leucophanite or meliphanite are found in the peralkaline nephelite syenite pegmatites of southern Norway, and this was apparently the basis of Goldschmidt and Peter's theory. However, helvite also was deposited in these dikes, and as a relatively early magmatic mineral rather than the late druse filling that is characteristic of leucophanite and meliphanite. Another beryllium mineral in this area, eudidymite, is an alteration product of leucophanite or meliphanite (Brögger, 1890, pp. 148–165, 277, 285). Inasmuch as these three minerals have not been found at any other locality, they are of little use in the general geochemistry of beryllium. Genthelvitite occurs in the peralkaline granite pegmatite of St. Peters Dome district, Colorado. (Genthelvitite: Adams, personal communication, 1951; pegmatite: Landes, 1935), and danalite in the subaluminous granite pegmatite of Rockport and Gloucester, Mass. (Warren and McKinstry, 1924). On the other hand, helvite occurs in several peraluminous granite pegmatites, even in the same pegmatite with beryl,⁴ and with corundum in what is probably a syenite pegmatite (Kityaev, 1928).

Summarizing the suggested changes to the Goldschmidt-Peters theory it is postulated that the stable beryllium mineral in alumina-rich rocks [$(\text{Na}_2\text{O} + \text{K}_2\text{O} + \text{CaO})/\text{Al}_2\text{O}_3$ less than about 1, equivalent to peraluminous rocks in Shand's nomenclature] is beryl, and in aluminum-poor rocks it is helvite. This postulate is now without reference to a magma, or to complex ions or any other condition within the magma. Otherwise stated, where more alumina is present than necessary to form feldspars or similar minerals, beryl may crystallize; where less alumina is present, beryl may

⁴ At Amelia, Va., helvite was found with spessartite as the last mineral to crystallize, beryl having formed earlier (Fontaine, 1883). At Miask, Ilmen Mountains, U.S.S.R., the very rare helvite apparently was in a granitic pegmatite, and other pegmatites in that area contain beryl (Fersman, 1940, p. 164).

not form and the beryllium may remain to crystallize as helvite. Although somewhat obscured by the discussion of magmatic ions, this idea was implicit in Goldschmidt and Peters' recognition of the association of beryl with muscovite. The occurrence of these minerals may thus be controlled by chemical conditions rather than by physical conditions such as temperature and pressure. The mechanism by which the chemical conditions control the mineralogy is not stated, although the extension of the theory to metamorphic rocks where an equilibrium situation exists casts doubt on the necessity of postulating complex ions to control the alumina content of the crystallizing magma.

In the Victorio Mountains, the beryl and helvite could have been formed from solutions originally of identical aluminum-rich composition, at the same temperature and pressure. In the open fissure the wall rock would have little effect, and beryl would have crystallized. In the tactite, permeation of the solution into limestone would have changed the composition of the system, the excess aluminum being removed to form grossularite and idocrase, causing the crystallization of helvite. Detailed study of the Victorio Mountains occurrence, not possible in the brief time available, may provide a firmer basis for general application of the theory.

ACKNOWLEDGMENTS

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