CLINTONITE AS A CONTACT-METASOMATIC PRODUCT OF THE BOULDER BATHYLITH, MONTANA

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ABSTRACT

The brittle mica clintonite occurs with grossularite, hydrogrossular, vesuvianite, blue spinel, and other minerals in a pyrometasomatically altered limestone xenolith enclosed in granodiorite of the Boulder bathylith south of Helena, Montana.

It occurs also at other places in the contact zone of the main bathylith or in those of its satellitic stocks, generally associated with black spinel. Specially fine material was found in the famous old mining camp of Elkhorn, on the east border of the bathylith, and xanthophyllite, a member of the clintonite group, has been reported by Felts (1947) to occur at the southern border of the bathylith.

CLINTONITE NEAR HELENA, MONTANA

A striking association of minerals occurs in a xenolith of limestone near the head of Dry Gulch, 5 miles south of Helena, Montana. The xenolith is enclosed in basic granodiorite ($d=2.79$) near diorite in composition, which constitutes the earliest plutonic mass in the sequence of intrusions that makes up the great composite body known as the Boulder bathylith. The xenolith is situated 300 feet from the contact with the late Mesozoic rocks that the bathylith here intrudes. The xenolith is a slab 30 or more feet long and 5 feet thick, trending N. 30° E. and dipping 70° S. It has been explored by a prospect adit, and because azure-blue spinel is a conspicuous constituent of the deposit, the prospect will here be referred to as the Blue Spinel prospect.

The deposit, or mass of tactite, is made up largely of four minerals: vesuvianite, a pale-green, nearly white grossularite, hydrogrossular, and calcite. The brittle mica clintonite, in pearly white plates, and blue spinel are the most striking constituents. Vesuvianite of pale greenish yellow color is probably the dominant mineral. Subordinately occur diopside, calcic plagioclase, scapolite, pale blue tourmaline, epidote, phlogopite, muscovite, chlorite, calcite, and stilbite. The mass manifestly represents a deposit that was formed at high temperature and was somewhat altered by retrograde changes during the stage of falling temperature.

The granodiorite is cut by narrow dikes of aplite, which is essentially a panidiomorphic aggregate of microcline and quartz, with more or less micropegmatite. Both the granodiorite and aplite adjacent to the xenolith have locally been altered; the granodiorite by epidotization and the aplite by the metasomatic introduction of diopside, epidote, and sphene. Hence the alteration of the xenolith to tactite took place after the aplite dikes had been injected.

The white grossularite, which rarely shows crystal forms, has an index of refraction of 1.739, being therefore close in composition to the ideal mineral ($n=1.734$); it is absolutely colorless in oils and is completely isotropic. On further investigation, some of the white vitreous supposed grossularite was found to have an index of refraction of approximately 1.725. This low value suggested that the mineral is hydrogrossular (Hutton, 1943). Dr. C. O. Hutton very kindly established that the mineral is hydrogrossular: 1, by determining that magnesium is absent, thereby ruling out the possibility that the low index is the result of pyrope in solid solution with the grossularite; and 2, by determining that water is present in considerable amount. An unsolved problem is whether the hydrogrossular thus found was developed by the hydration of earlier formed grossularite. The grossularite and possibly the diopside are the oldest minerals in the deposit. They were subsequently fractured, and a succession of minerals was deposited. The paragenetic sequence appears to be: 1, grossularite and diopside; 2, vesuvianite; 3, clintonite and blue spinel; 4, calcic plagioclase (bytownite); 5, scapolite; 6, epidote; 7, phlogopite; 8, muscovite; 9, chlorite; 10, calcite; and 11, stilbite. Near the end of the period of the formation of the minerals, removal of material outstripped deposition. Small open channel-ways were formed and were partly filled by spherules and radiating groups of stilbite.

The blue spinel occurs in irregular masses and sporadically as perfectly-formed octahedrons, up to 5 mm. in length. The finest of these octahedrons is embedded in vesuvianite. In oils, the spinel is colorless, and its index of refraction is 1.72, indicating nearly pure $MgAl_2O_4$($n=1.715$). The calcite in the deposit is mostly white, but some is sky blue. Under the microscope the calcite is biaxial, 2E being about 20°. Scapolite is a minor constituent of the deposit, though in places it is megascopically visible as columnar aggregates as much as 3 cm. long. It is a sodic scapolite, $\omega=1.556$ and $\epsilon=1.544$, indicating that its composition is $Ma_{70}Me_{30}$.

Diopside is abundant in some thin sections, and the strong dispersion $r>v$ on the optic axis B indicates an aluminous, fassaitic pyroxene.

The clintonite occurs as fan-shaped groups of snow-white color and pearly luster. The maximum size is 1.5 cm. across. It is embedded either in vesuvianite or in calcite, and may have blue spinel associated with it. Under the microscope the clintonite is colorless. Because of the high index of refraction, basal sections show shagreened surfaces. These sections give a uniaxial or nearly uniaxial negative interference figure. Some of the clintonite is interleaved with a colorless phlogopite and partly replaced by it; and in places both the clintonite and phlogopite have been altered to white chlorite, probably leuchtenbergite.

Dr. Horace Winchell has kindly made precise determinations of some of the properties of the clintonite. The density is 3.03. The γ index of refraction, is 1.6591 for sodium light. The dispersion of that index is rather high—$F-C=0.0451$. α is probably about 1.646. The birefringence is therefore 0.013. *X*-ray patterns of the clintonite were taken at Yale University by Mr. James W. Clarke, and of seybertite from the type locality in New York (Brush Collection No. 3965) and of xanthophyllite from Crestmore, California (Brush Collection No. 5910). All three patterns are closely similar, but the clintonite from Montana corresponds most nearly with the seybertite from New York. As the type seybertite is known to contain 1.26 per cent of fluorine, it seemed desirable to test the Montana mineral for fluorine. A qualitative test by Dr. C. O. Hutton showed that fluorine is present.

In view of the present knowledge of this group of brittle micas the name clintonite appears to be the most appropriate for the Montana mineral. According to Koch (1935), who has done the most careful work on this group in recent years, in fact supplying four new analyses made on centrifuged material: "the warrant for grouping together the brittle micas clintonite [seybertite], xanthophyllite, and brandisite under the name clintonite is clear from the analyses and optical data of these minerals. The identity in crystallographic and chemical properties is so close that a single name must be considered as fully justified." Winchell and Winchell (1951) voice the same opinion: "xanthophyllite, brandisite, and seybertite are sometimes considered varieties of clintonite; they are almost identical." However, more work on the clintonite group (as used in the restricted sense of comprising xanthophyllite, brandisite, and seybertite) is clearly desirable.

When Eakle in 1916 described xanthophyllite as a product of contact metamorphism occurring at Crestmore, California, associated with blue calcite and monticellite, he commented on the fact that the two previously recorded occurrences of xanthophyllite were in schists—talc schist and chlorite schist. However, the original "clintonite" discovered by Finch, Mather, and Horton in 1828 at Amity, New York (which name became according to Dana (1892) a *nomen nudum* because of prior publication of the name seybertite by Clemson in 1832) is a contact-metamorphic mineral in limestone associated with amphibole, spinel, graphite, and leuchtenbergite (Tschermak and Sipöcz, 1879). Brandisite also is a contact-metamorphic mineral, doubtless pyrometasomatic, occurring in the Fassatal, Tyrol, in limestone in association with the aluminous pyroxene fassaite and black spinel.

The clintonite found by Laitakari (1921) at three localities in the Parainen (Pargas) district, Finland, occurs in parageneses very similar to those around the Boulder bathylith. It occurs in limestone with pargasite, sky-blue spinel, and phlogopite. In Tenby the clintonite is associated with scapolite, grossularite, vesuvianite, and diopside. The clintonite is either colorless or very pale green. The largest individual was 4 cm. in diameter.

Clintonite at Other Localities

Tactite containing clintonite occurs along the border of the granodiorite stock northwest of the trestle of the Northern Pacific Railway across Greenhorn Gulch. This stock is 1 mile north of the Boulder bathylith and is 0.4 square mile in area. It is intrusive into early Paleozoic formations ranging from the Meagher limestone of Middle Cambrian age to the Jefferson formation of late Devonian age. The tactite consists, in descending order of abundance, of diopside, serpentinized forsterite, biaxial calcite, clintonite, and phlogopite. Some of the clintonite incloses minute octahedrons of spinel. The clintonite as seen in hand specimens is vitreous with bronzy metallic reflections. In thin section it is faintly pleochroic, being brownish rose transverse to the cleavage and showing maximum absorption in that position—a feature found to be a valuable diagnostic aid in distinguishing clintonite from other minerals.

Clintonite was recognized to occur in the Marysville district (Knopf, 1950), where it replaces the diopside, in the superb scapolite-diopside hornfelses that make up Drumlummon Hill.

A tactite containing clintonite occurs in the Madison limestone on the border of the Spring Hill granodiorite stock, 5 miles southwest of Helena. It is S. 30° E. of the summit of Spring Hill. The tactite consists of vesuvianite, calcite, black spinel, and clintonite. The clintonite is more or less filled with octahedrons of spinel. It is weakly pleochroic: nearly colorless parallel to Z and brownish yellow parallel to X, the maximum absorption being perpendicular to the elongation and cleavage.

In the contact zone of a small diorite stock ($d = 2.81$) west of Holmes Gulch, which is a few miles southeast of Helena, is a blackish rock containing innumerable minute octahedrons (1 mm. or less in size) of black spinel in a poikilitic matrix of calcite and clintonite. As seen under the microscope, the spinel is green, with strong central pigmentation and the borders nearly colorless. A strange feature is that countless minute octahedrons are juxtaposed around large crystals of spinel. About half the tactite consists of spinel. The clintonite, which occurs as rather large metacrysts, is crowded with euhedral spinel. The only other constituent is the white chlorite leuchtenbergite in small amount.

Clintonite, so far as now known, occurs at two localities at Elkhorn on the eastern margin of the Boulder bathylith. It was recognized by the writer to occur as a minor constituent in a specimen collected by Barrell in 1899 (Yale University Petrographic Coll. No. 3289). This tactite has a density of 3.15 and is made up chiefly of vesuvianite and clinopyroxene, with 15 per cent of calcite. The clintonite in this rock also is faintly pleochroic. Geologically, the tactite occurs in the contact zone of the gabbro mass of Black Butte.

The finest clintonite-spinel tactite was found to occur in a small prospect pit on the divide between Elkhorn and Queen gulches. The rock is nearly black because of the prevalence of closely crowded minute octahedrons of black spinel, and is more or less spangled with plates of clintonite. As found microscopically, the tactite is made up dominantly of green spinel and clintonite in lamellar-radiate groups, with subordinate colorless phlogopite and diopside, probably fassaitic, as it shows strong dispersion $r > v$ on the optic axis B.

Xanthophyllite has been reported by Felts (1947) to occur at the south end of the Boulder bathylith. It is associated with grossularite, diopside, vesuvianite, forsterite, and calcite; much of the forsterite and diopside are now serpentine.

In conclusion, clintonite has been shown to occur from the contact zone of the Marysville granodiorite stock on the north, 6 miles north of the Boulder bathylith, to the southern end of the bathylith. It generally has spinel occurring with it, in places abundantly so, an association that harmonizes with the fact that clintonite is low in silica (18 per cent) and high in alumina (40 per cent).

References

Dana, J. D. (1892), System of Mineralogy, 6th ed., 638–639.

Eakle, A. S. (1916), Xanthophyllite in crystalline limestone: *Washington Acad. Sci. Jour.*, **6**, 332–335.

——— (1917), Minerals associated with the crystalline limestone at Crestmore, Riverside County, California: *Univ. California Dept. of Geology Bull.* **10**, no. 19, 341–342.

Felts, W. M. (1947), Xanthophyllite near Butte, Montana: *Geol. Soc. Amer. Bull.* **58,** 1179 (abstract).

Forman, S. A. (1951), Xanthophyllite: *Am. Mineral.*, **36**, 450–457.

Hutton, C. O. (1943), Hydrogrossular, a new mineral of the garnet-hydrogarnet series: *Roy. Soc. New Zealand Trans. Proc.* **43**, 49–51.

Knopf, Adolph (1950), The Marysville granodiorite stock, Montana: *Am. Mineral.*, **35**, 834–844.

Koch, G. (1935), Chemische und physikalisch-optische Zusammenhänge innerhalb der Sprödglimmergruppe: *Chemie der Erde*, **9**, 458–461.

Laitakari, A. (1921), Ueber die Petrographie und Mineralogie des Kalksteinlagerstätten von Parainen (Pargas): *Comm. Geol. Finlande Bull.*, **54**, 87–89.

Stevens, R. E. (1946), A system for calculating analyses of micas and related minerals to end members: *U. S. Geol. Survey Bull.* **950**, 113.

Tschermak, G., and Sipöcz, L. (1879), Die Clintonitgruppe: *Ztschr. Krist.*, **3**, 496–515.

Winchell, A. N., and Winchell, Horace (1951), Elements of optical mineralogy, Part II, 391.