

have been established. The survival of these high-temperature polymorphs in meteorites and lunar rocks can probably be ascribed to the extremely anhydrous nature of these materials; the catalytic action of water in promoting recrystallization and equilibration is well documented.

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FLUORESCENT HYDROGROSSULAR  
FROM NORDLAND, NORWAY.

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## ABSTRACT

Fluorescent hydrogrossular is reported from a vesuvianite-bearing marble from near Mosjøen, North Norway, and the modes of occurrence of the mineral are described. In the same rock non-fluorescent grossular is present in the narrow contact zone of two monzonitic dikes. The hydrogrossular formed during the second of two main crystallization episodes, probably by metasomatism asso-

ciated with intrusion of monzonite. Possible factors contributing to fluorescence in garnets are briefly considered.

During the geological mapping of an area in Helgeland, North Norway, fluorescent garnets were discovered in a banded vesuvianite-bearing limestone in a quarry on the peninsula of Halsøy, 1 km north of Mosjøen.

The host rock containing the garnets is a pale grey to white, crystalline, yellow-brown weathering limestone or marble with intercalated silicate-rich bands and lenses. Grain-size is from 0.1 to 0.5 mm. The rock is isoclinally folded with the silicate bands occasionally broken into boudin-like structures.

Under ultraviolet light the fluorescing garnet is seen to occur either in thin bands some few millimeters in thickness or as small aggregates within a 10 to 15 cm thick zone. Vesuvianite, which appears together with hydrogrossular, here gives the marble a weakly banded greenish hue.

In the zone containing the fluorescent garnet the following minerals are present: calcite, zoisite, wollastonite, vesuvianite, diopside, quartz, microcline, hydrogrossular, sphene, pyrrhotite, pyrite, and plagioclase. (Fig. 1). In thin-section all the minerals are colorless except for vesuvianite which is sometimes pale green, and sphene which displays a strong brown pleochroism. A mineral with a low  $n$ , weak birefringence and small  $2V$  (+) and which occurs in thin veinlets cutting across the silicate-mineral layering is probably a zeolite.

About 1 meter away from this zone is a 1.5 to 2 meter thick

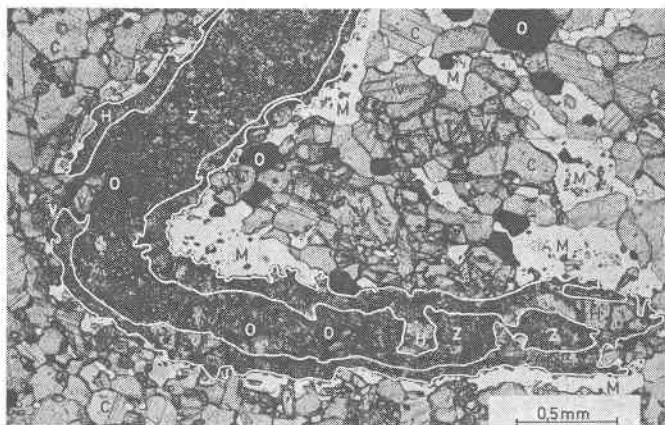


FIG. 1. A folded silicate band bordered by hydrogrossular. H—hydrogrossular, Z—zoisite, V—vesuvianite, C—calcite, M—microcline, O—opaques.

TABLE 1. SEMI-QUANTITATIVE SPECTROGRAPHIC ANALYSES OF HYDROGROSSULAR AND GROSSULAR FROM HALSØY, NORWAY.

	No. 1 fluorescent hydrogrossular	No. 2 non-fluorescent grossular
SiO <sub>2</sub>	main constituent	main constituent
TiO <sub>3</sub>	ca. 0.1%	ca. 0.2%
Al <sub>2</sub> O <sub>2</sub>	20-25%	ca. 20%
Fe <sub>2</sub> O <sub>3</sub>	ca. 1%	ca. 4-5%
MnO	ca. 0.2%	ca. 0.1%
MgO	ca. 1%	ca. 1%
CaO	ca. 30%	ca. 26%
Na <sub>2</sub> O	ca. 0.2%	n.d.
Cr <sub>2</sub> O <sub>3</sub>	0.0x%	n.d.
V <sub>2</sub> O <sub>3</sub>	trace	n.d.

monzonitic dike which is connected to a 30 m-thick quartz monzonite dike (Nissen, 1969). The monzonitic dike is subparallel to that of the layering in the host rock. A fine-grained banded rock in a zone about 10 cm wide at the contact between the dike and the marble, consists of diopside, plagioclase, and calcite with accessory clinzoisite, wollastonite, and opaques as well as garnet porphyroblasts up to 3 mm across. This garnet is a pale brown and non-fluorescent grossular with about 20 percent andradite. Pale brown, non-fluorescing grossular has also been found in the contact zone of another monzonite dike 30 m to the west, but there the garnet occurs in 0.5 mm stringers rather than individual porphyroblasts. Water has not been found in this particular garnet, a semi-quantitative spectrographic analysis of which is given in Table 1.

The hydrogrossular, which is colorless, is difficult to pick out with the naked eye, but displays a clear orange fluorescence in short-wave ultraviolet light (2000-3000 Å). No fluorescence could be detected under long-wave (3000-4000 Å) uv light.

Hydrogrossular occurs as subhedral grains (1) in small, irregular aggregates with vesuvianite and zoisite, (2) in coronas around zoisite aggregates, or (3) in thin bands up to 2 mm in thickness, though usually much thinner (Fig. 1). The bands are generally alternating with layers of vesuvianite or zoisite, the most continuous and regular bands being of zoisite; these can also be folded. Scattered grains of hydrogrossular in the calcite-rich portions of the rock are often surrounded by a corona of vesuvianite. On cut surfaces of rock samples it is possible to see, with the aid of the uv lamp, that hydrogrossular forms a thin encompassing layer around broken-up silicate bands.

The refractive index  $n$  of the garnets was determined with sodium light, and the cell size  $a$  with an 11 cm camera (Table 2).

Because of the similarity in specific gravity between hydrogrossular and vesuvianite, separation of the minerals using heavy liquids was impracticable and the garnet grains were picked out under a binocular microscope; only the smallest grains were chosen in order to obtain as pure a fraction as possible. On two such garnet samples, one hydrogrossular and the other grossular, a semi-quantitative spectrographic analysis was carried out (Table 1).

Water in the hydrogrossular was determined by the Penfield method, but the precise quantity unfortunately could not be determined because of insufficient material. With increasing total H<sub>2</sub>O content in the hydrogrossular series,  $n$  decreases, while  $a$  increases (Flint *et al.*, 1941; Hutton, 1943; Yoder, 1950; McConnell, 1964; Deer, Howie, and Zussman, 1962, table 20, p. 105). An analysis in Deer, Howie, and Zussman (1962, no. 4) is similar to my spectrographic analysis and  $n$  and  $a$  are virtually identical. The water content of the Halsøy hydrogrossular should therefore also probably be somewhat similar to the 1.16 percent given by Deer, Howie, and Zussman's (1962) analysis no. 4.

The rocks on Halsøy were first metamorphosed and folded. During this phase the silicate bands were broken and disconnected. Coronas of hydrogrossular and vesuvianite around the separated silicate bands indicate post-tectonic metasomatism associated with the monzonite intrusion.

The occurrence of hydrogarnets and water-deficient garnets at a single locality has been reported by Heflik and Żabiński (1969), who postulated local variations in both physical and chemical conditions of metasomatic processes. Experimental studies carried out by Yoder (1950) and Pistorius and Kennedy (1960) showed the great importance

TABLE 2. REFRACTIVE INDICES AND CELL CONSTANTS OF GARNETS FROM HALSØY, NORWAY, AND BUFFELSFONTEIN, S. AFRICA

	$n$	$a(\text{Å})$	composition <sup>a</sup>	
No. 1	1.728	11.87	hydrogrossular	} Halsøy
No. 2	1.753	11.86	grossular	
No. 3	1.764	11.88	grossular	
No. 4	1.728	11.859	hydrogrossular <sup>b</sup>	Buffelsfontein <sup>c</sup>

<sup>a</sup> Determinations based on H. Winchell (1958).

<sup>b</sup> Includes Cr<sub>2</sub>O<sub>3</sub> 0.25.

<sup>c</sup> J. J. Frankel (1959).

of temperature in determining the amount of water in hydrogrossular. The water content decreases with increasing temperature at constant water pressure until one gets anhydrous grossular. This can possibly explain the present situation in which grossular occurs in the contact zone adjacent to monzonite while the hydrogrossular is present at some distance from the intrusion.

Descriptions of fluorescent garnets are few, and have not previously been recorded in Norway. Gleason (1960) remarked that garnets rarely or never fluoresce, possibly on account of the high iron content, and indeed iron-bearing minerals do appear to show a lesser tendency to fluoresce than iron-poor types (Pringsheim, 1949). Pringsheim and Vogel (1946) listed a red fluorescent uvarovite. In a study of emission and excitation spectra of yttrium-gallium garnets ( $Y_3Ga_5O_{12}$ ) activated with several rare-earths, Keller and Pettit (1961) found these artificial garnets to be luminescent; the spectra were measured at 77°K.

In all probability, quite special conditions must have obtained to account for the origin of fluorescence in naturally occurring garnets. Of possible significance in this connection is that this particular garnet is deficient in iron, the  $Fe_2O_3$  content of the hydrogrossular is ca. 1 percent, whereas that of the grossular in the monzonite contact zone is 4-5 percent.

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HORNBLLENDE-ACTINOLITE AND HORNBLLENDE-CUMMINGTONITE  
ASSOCIATIONS FROM CUYUNI RIVER, GUYANA, SOUTH AMERICA

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ABSTRACT

Fine-grained proterozoic metagreywackes from Matope Falls, Cuyuni River, contain abundant actinolite rimmed by green hornblende. Both amphiboles also coexist in the matrix—apparently due to a miscibility gap between the two. At the intrusive contact of a granodiorite the rocks have been further metamorphosed to hornblende hornfels in which hornblende has exsolved cummingtonite lamellae. Optical and unit-cell data are given.

INTRODUCTION

Parageneses of coexisting amphiboles have been frequently reported in which two amphiboles not only occur as discrete grains but also one of them is found to be rimmed by the other. The most commonly observed association is that of actinolite with hornblende rims, and the sharp demarcation of the two has been taken as an indication of a miscibility gap. Electron microprobe analyses of such amphiboles by Klein (1969) and by Cooper *et al.* (1970) lend support to this idea of immiscibility. Another feature of amphibole immiscibility is the occurrence of exsolution lamellae analogous to those in pyroxenes in calcic and Mg-Fe amphiboles. Recently, attention has been drawn to amphibole exsolution by Jaffe *et al.* (1968), Klein (1969), and Ross *et al.* (1968, 1969). Rimmed amphiboles and exsolved amphiboles