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ILVAITE: A LATE MAGMATIC OCCURRENCE IN GABBRO OF MISSOURI

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Ilvaite occurs in Precambrian intrusive gabbroic rocks which are exposed in Madison and Iron Counties of southeastern Missouri. The rocks are principally gabbro, olivine gabbro and olivine diabase; plagioclase and augite, with or without olivine are the major silicates. About 35 polished surfaces and 35 companion thin sections of the basic rock have been studied.

Ilvaite is present in 8 of 13 fresh gabbroic rocks collected from various localities 5 to 15 miles apart. Identification of ilvaite is based on: (1) *x*-ray powder patterns, (2) the observed (apparent) angle of rotation, which is more than 9° for a section showing maximum bireflectance (Cameron, 1959, p. 56), (3) polarization colors, and (4) dispersion properties. Vonsenite, a mineral recently described by Leonard and Vlisidis (1960), has several characteristics similar to ilvaite, but the latter has a larger angle of rotation in reflected light. *X*-ray powder patterns of ilvaite from the Hanover Mine, Hanover, New Mexico were prepared and found to be essentially identical to the patterns given by the ilvaite of the Missouri gabbroic rocks.

Point counts (1500 per 530 sq. mm. surface) of ore minerals revealed that where ilvaite is present, it ranges in amount from less than 0.1% to about 2% of the rock. Percentages of ilvaite are comparable to those of pyrrhotite and exceed those of chalcopyrite. Other ore minerals in the fresh rock include ilmenite, magnetite with ulvöspinel cloth texture and and traces of pentlandite in pyrrhotite.

Ramdohr (1960, p. 1001) cited two occurrences of ilvaite in olivine gabbros, one in Elfdalen, Sweden and another in the Skaergaard intrusion of East Greenland. He (1960, p. 1001) states that ilvaite is a reaction product of plagioclase and iron-rich olivine at these localities. Other than these, no other occurrences of ilvaite in gabbroic rocks were found in reviewing the literature.

The most frequent occurrence of ilvaite is with the skarn minerals of contact metamorphic deposits and particularly those rich in copper and iron sulfides and minor iron oxides. Gorbunov and Kornilov (1954) report the presence of disseminated ilvaite in pyrrhotite-pentlandite-chalcopyrite ore (locality not given); ilvaite replaces magnetite and is

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replaced by epidote and zoisite. Baker (1953) observed ilvaite in a micropegmatite diorite in New Guinea where it is associated with ilmenite near veins of prehnite and replaces some of the pyroxenes in the diorite. He considers that ilvaite (and prehnite) are the products of hydrothermal alteration, that ilvaite formed later than ilmenite, and that locally ilvaite hydrothermally replaces pyroxene. Ramdohr (1960, p. 1001) doubts the strictly hydrothermal origin of ilvaite which has been suggested for some localities. In view of the fact that prehnite may be an alteration product in intermediate and basic rocks, ilvaite in the diorite described by Baker (1953) may have been derived from the late volatiles expelled from the intrusion as he suggested (p. 842). However the relationships described by Baker (1953, p. 840) do not indicate that ilvaite and prehnite were necessarily contemporaneous and of the same origin.

In the gabbroic rocks of Missouri ilvaite is not a hydrothermal mineral. Quartz and calcite veins locally cut the gabbro and are probably of hydrothermal origin, but thin sections and polished surfaces of the gabbro cut by these veins contain no ilvaite.

Deuterically altered gabbroic rocks of the area are considered as those showing the following alterations: olivine to minerals commonly identified as iddingsite, bowlingite and serpentine; plagioclase to saussurite; augite to amphibole or a chlorite-like mineral; titaniferous magnetite to a turbid mass of sphene and leucoxene; pyrrhotite to pyrite. Ilmenite is unaffected. Carbonate and quartz are common and more mesostatsis is present than in the unaltered rocks. The altered rocks are apparently more abundant than those which are unaltered. Two gabbro specimens from the same exposure (one of which is deuterically altered and the other is not), less than one foot apart vertically, clearly show ilvaite in the unaltered specimen while it is lacking in the altered one. Eighteen specimens systematically collected from a gabbroic sill less than 300 feet thick show the same relationships as above. Unaltered gabbro contains ilvaite and altered gabbroic rocks do not.

Ilvaite is present in olivine diabase, olivine gabbro, and gabbro which have not been affected by deuteric or hydrothermal solutions. Ilvaite is not necessarily associated with plagioclase or olivine and iron-rich olivine is lacking in the rocks examined. It is most abundant in specimens without olivine. According to the paragenetic sequence ilvaite was the last magmatic mineral to crystallize; it is most closely associated with pyrrhotite, ilmenite and magnetite and occurs as minute grains in small aggregates. Ilvaite also incipiently replaces the pyroxene component of ilmenite-pyroxene micrographic (myrmekitic) intergrowths in which ilmenite shows optical continuity.

Baker (1953) observed ilvaite incipiently replacing pyroxene of ilmenite-pyroxene micrographic intergrowths and implied the ilvaite was of hydrothermal replacement origin. In the Missouri rocks the presence of ilvaite in unaltered gabbros and its absence in the deuterically altered and hydrothermally altered gabbros indicates it is of magmatic origin. If pyrrhotite and chalcopyrite may be considered as late magmatic minerals in the gabbroic rocks of Missouri, then ilvaite must also be placed in this category. The association of ilvaite with pyrrhotite, chalcopyrite, ilmenite and magnetite is consistent with mineralogical assemblages found in ore deposits like those of Hanover, New Mexico, those described by Gorbunov and Kornilov (1954) and some contact metamorphic deposits.

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