MAGNETITE METACRYSTS

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Introduction

The occurrence of abundant and even conspicuous metacrysts of magnetite in the iron formation of the Nemo region of the Black Hills attracted the writer's attention to magnetite as a metacryst in metamorphic rocks. Magnetite is well known to have a strong crystallizing power and it corresponds well with Becke's[1] statement that minerals in schists with compact molecular arrangement are most likely to take on crystal form, but Becke did not list magnetite in his series of form development. Grubenmann omitted magnetite in 1904, but Grubenmann and Niggli[2] in 1924 give it last in a list of porphyroblastic minerals. Magnetite is not given by Leith and Mead[3] among the common idiomorphic minerals in schists but their list is indicated as not complete. Grout[4] lists magnetite among the minerals common as metacrysts.

The writer studied available material and presents the following descriptions as typical of the occurrence of magnetite metacrysts and their relations to other minerals in porphyroblastic rocks. Magnetite does not form metacrysts as commonly as garnet but it is more common than some of the minerals usually emphasized.

Description of Magnetite Metacrysts

In the iron ores of the Lake Superior district magnetite crystals are not infrequently larger than most other minerals in the ores and protores. Gruner[5] shows an euhedral crystal of magnetite replacing hematite and gangue, and a somewhat similar occurrence has been shown for the coarser magnetites of the eastern part of the Mesabi,[6] where metamorphism has been more intense due to the proximity to the Duluth gabbro (Fig. 1).

Small magnetite metacrysts are also abundant in the somewhat schistose Soudan formation of the Vermilion Range as shown by Gruner.[7]

[1] Becke, F., *Compt. Rend., IX Cong. Geol. Internat. Vienna*, p. 553, **1903.**

[2] Grubenmann, V., and Niggli, P., *Die Gesteinsmetamorphose*, p. 437, **1924.**

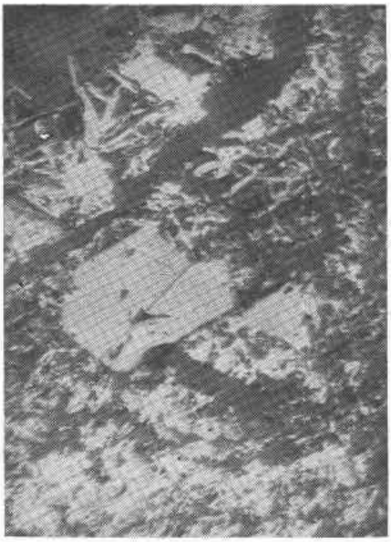
[3] Leith, C. K., and Mead, W. J., *Metamorphic Geology*, p. 111, **1915.**

[4] Grout, F. F., *Petrography and Petrology*, p. 364, **1932.**

[5] Gruner, J. W., Parageneses of the martite ore bodies and magnetites of the Mesabi range: *Econ. Geol.*, vol. **17,** Plate Id, 1922.

[6] Schwartz, G. M., New ore of the east Mesabi range: *Eng. and Min. Jour.*, vol. **116,** p. 412, fig. 8, 1923.

[7] Gruner, J. W., The Soudan formation and a new suggestion as to the origin of the Vermilion iron ores: *Econ. Geol.*, vol. **21,** figs. 2 and 3, 1926.



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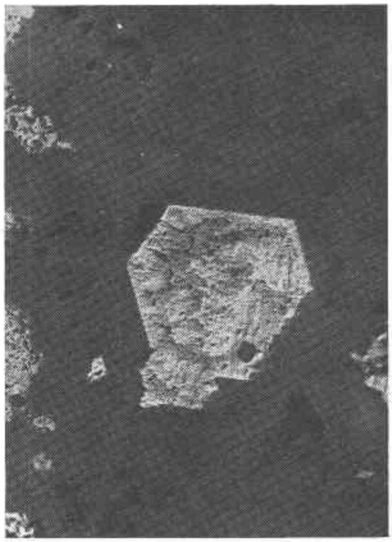

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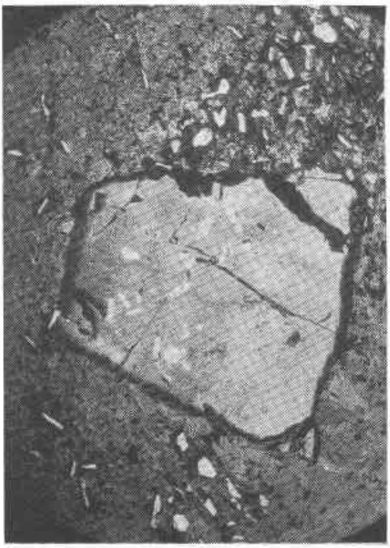

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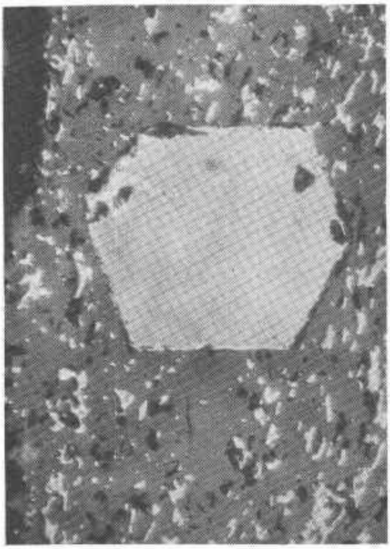

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Fig. 1. Metacryst of magnetite in taconite. Hematite needle-like forms are abundant but are cut off sharply at the contact with magnetite. East end of the Mesabi Range, Minnesota. ×200.

Fig. 2. Magnetite metacryst partly replaced by hematite (white). Holman Pit, Mesabi Range. ×134.

Fig. 3. Magnetite metacryst in garnet-chlorite schist. Small white crystals are hematite which occur equally within and without the metacryst. Michigamme Lake, Marquette district, Michigan. ×68.

Fig. 4. Magnetite metacryst in jasper. Gray is quartz and white is hematite. The orientation of the hematite indicates the schistosity. Magnetite is slightly replaced around the edge by hematite. Near Nemo, Black Hills, South Dakota. ×80.

In both the Mesabi and Vermilion districts the occurrences are usually microscopic but nevertheless magnetite forms euhedral crystals which are larger than the surrounding mineral grains.

In the Marquette iron district of Michigan near Michigamme Lake a mine dump is a classic location for collecting chlorite schist with very large garnet (andradite) metacrysts. The maximum size of the garnets is about five centimeters in diameter. This same rock shows smaller metacrysts of magnetite. These may be best observed on polished surfaces where their relations to other minerals and to each other stand out clearly. Some of the magnetite crystals are in groups or clusters and are subhedral. Others are isolated in the chlorite schist matrix and are distinctly euhedral. There are in addition to the magnetite crystals numerous lath-shaped hematite crystals. When the highly polished magnetite metacrysts are examined with the focus slightly raised shadows of the original hematite crystals may be seen as inclusions in the magnetite. Etching with concentrated HCl brings out these inclusions as shown in Fig. 3. That the iron of the metacrysts was not derived from the hematite is indicated by the fact that hematite crystals are equally abundant in and around the magnetite as elsewhere. Some of the magnetite may contain titanium, as hot concentrated HCl has a variable effect on the crystals, some being scarcely affected while others turn brown and black.

Martite octahedra up to 3 mm. have been reported in the ores near dikes in the Marquette district by Gruner.[8] It is suggested that iron for the magnetite was either introduced by solutions or gases, or was extracted by them from the basic dike material. The example cited above suggests the first explanation as more likely.

It is of interest to note that magnetite metacrysts occur included in the large garnet metacrysts with about the same distribution as in the chlorite schist portion of the rock. This suggests that the magnetite crystallized before the garnet and was included, as were the hematite crystals in the magnetite. Thus metacrysts occur within metacrysts. Specimens of chlorite schist with magnetite but lacking garnet also occur at Michigamme.

Metacrysts of magnetite seem a common feature of many ores and associated rocks in the Marquette district. A specimen of ore from Ishpeming shows good euhedral to subhedral martite metacrysts in a soft red hematite matrix. The size and distribution of the magnetite crystals indicate that the hematite may be a result of alteration of chlorite, like that described above.

Several specimens collected by Dr. John W. Gruner from the Mar-

[8] Gruner, J. W., Additional notes on secondary concentration of Lake Superior iron ores: *Econ. Geol.*, vol. **27**, p. 200, 1932.

quette district show varied examples of the occurrence of magnetite metacrysts. A specimen of jasper from the hanging wall of the Empire Mine, near Negaunee, shows excellent small metacrysts of magnetite in quartz. The magnetite crystals range from the size of the quartz grains to excellent euhedral forms at least ten times the diameter of the small crystals. There is slight alteration to hematite.

Samples from the 6th level of the Cliff A shaft show rather massive magnetite composed of anhedral grains varying to euhedral crystals in chlorite. So-called paint rock from the Holmes Mine shows excellent martite metacrysts, varying from subhedral to euhedral, in a hematitic and kaolinitic matrix probably derived from chloritic rock like that from the Cliff A shaft.

Ore from the contact with a dike in the Cleveland Hard Ore pit shows abundant metacrysts of magnetite in chlorite with many stages of martization. Other examples might be described but these suffice for a single district.

A chlorite-magnetite schist from Hartford County, Maryland, contains numerous metacrysts of magnetite which range up to a size with octahedral faces 5 mm. along an edge. These crystals appear perfect in a hand specimen but on polished surfaces they may be observed to vary from euhedral to subhedral, and there is much magnetite as irregular elongated masses oriented with their long dimensions parallel to the schistosity. The magnetite shows slight alteration to hematite along octahedral planes.

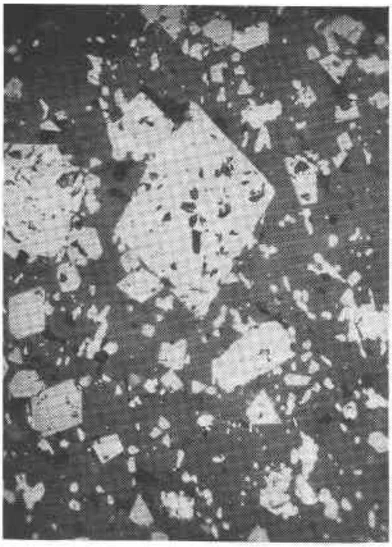
The iron formation of the Black Hills of South Dakota occurs at certain horizons in the exceedingly folded and metamorphosed beds of the pre-Cambrian series. At places they greatly resemble the iron formation of the Vermilion and Marquette districts of the Lake Superior region. The iron formations are exposed principally in the Nemo district which is in the northeastern part of the pre-Cambrian portion of the uplift. They are described by Darton and Paige,[9] and more recently by Runner.[10] The reader is referred to these papers for a discussion of stratigraphic relations. Runner believes that the iron formations are not limited to any one stratigraphic horizon. Within the upper series which is clearly younger than the earliest iron formation, pebbles of iron formation are found in the conglomerate.

The iron formation consists of alternating bands of recrystallized quartz and specular hematite, martite, and magnetite. In the coarser

[9] Darton, N. H., and Paige, Sidney, Central Black Hills folio, South Dakota: *U. S. Geol. Survey, Geol. Atlas, Folio* **219**, 1925.

[10] Runner, J. J., Pre-Cambrian geology of the Nemo district, Black Hills, South Dakota: *Am. Jour. Sci.*, vol. **28**, pp. 353–372, 1934.

recrystallized material metacrysts of magnetite are a conspicuous feature. In some bands only a few metacrysts occur, in others the rock is closely studded with them. Polished surfaces of the various phases of the



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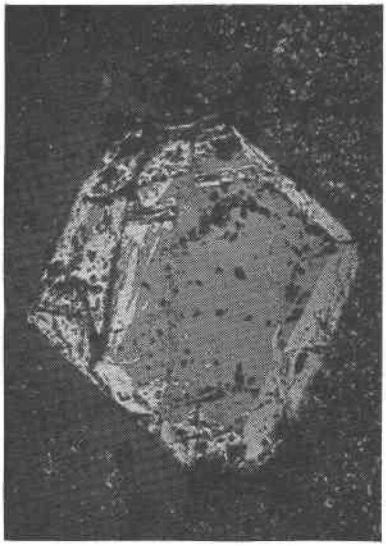

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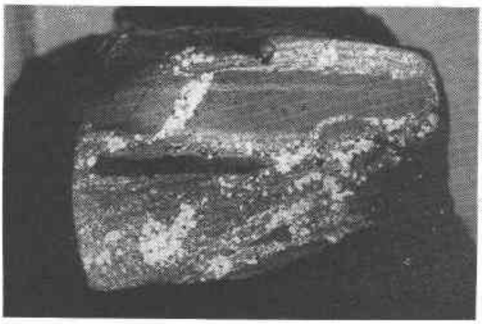

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Fig. 5. Euhedral magnetite crystals of various sizes in quartz. Near Nemo, Black Hills, South Dakota. ×80.

Fig. 6. Metacryst of magnetite altered around outside to hematite. Near Nemo, Black Hills, South Dakota. ×24.

Fig. 7. Polished surface of iron formation with bands broken and fractures filled with magnetite crystals (white). $\times 1\frac{1}{2}$. Near Nemo, Black Hills, South Dakota.

iron formations show many interesting relationships. As a rule the quartz is filled with minute plates of micaceous hematite which are usually well oriented in the direction of the schistosity (Fig. 4). Embedded in the quartz are innumerable crystals of magnetite varying from those just visible at a magnification of 100 to crystals with an octahedral face measuring 4 mm. on an edge (Fig. 5). In some specimens practically the whole range may be seen, others are more uniform. Along certain bands in the coarser recrystallized quartz the entire mass of iron oxide has crystallized to a coarse aggregate of anhedral magnetite grains. The magnetite shows all stages of alteration to hematite (martite). Figure 4, for example, shows very slight alteration along the borders and Fig. 6 a more advanced stage. Other examples were observed in which no remnants of magnetite could be seen at magnifications of 200 diameters.

The metacrysts, like those of the Marquette district, usually show no obvious source of the iron oxide, as disseminated hematite is neither more nor less abundant near the large metacrysts of magnetite. It seems clear that hematite was abundantly present during rock flowage, as it shows parallel orientation in practically all specimens. The magnetite is of later origin and the crystals cut across the schistosity with no evidence of deformation. In some specimens the original bands of the iron formation are broken and the fractures filled with magnetite grains (Fig. 7). As noted above, many of the magnetite crystals were altered to martite. Locally nearly pure hematite bands occur, but on polished surface these are observed to contain at least small metacrysts of magnetite. These hematite bands are usually decidedly schistose but the magnetite grains cut abruptly across the schistosity. Where magnetite grains make up the bulk of the specimens specular hematite often occurs as a matrix.

The above descriptions might lead one to the conclusion that magnetite metacrysts are limited to iron formations and chlorite schists. Dr. Frank F. Grout furnished the writer a muscovite schist specimen from Wardsboro, Vermont, which showed imperfectly developed magnetite metacrysts varying up to 4 mm. in diameter.

A diamond drill core of sericite schist shows excellent metacrysts about 1 mm. in diameter with minute hematite crystals oriented with the schistosity. A quartz-sericite schist also shows euhedral magnetite crystals larger than recognizable grains except original clastic quartz grains.

Harker[11] shows an excellent example of a magnetite-phyllite from Montherme, Ardenne. His interpretation is that the magnetite was present during deformation rather than having developed after rock flowage ceased.

Discussion

The examples cited above, while not exhaustive, are sufficient to show that magnetite not uncommonly forms metacrysts, especially in meta-

[11] Harker, A., *Metamorphism*, p. 156, London, **1932.**

morphosed iron formations and chlorite schists. The relations of these crystals to other minerals and textures in the rocks in which they occur clearly suggest their formation after orientation of hematite and chlorite in response to the forces which develop parallel orientation of minerals in metamorphic rocks.[12] The source of the iron forming some of the metacrysts is a puzzling problem. Many of the metacrysts evidently have not formed by absorbing the iron from adjacent hematite or other visible minerals. It seems rather that cases such as those illustrated by Figs. 3, 4, and 7 represent introduction of iron and oxygen. This may come from igneous emanations active during metamorphism, or equally well by transfer of iron within the rocks being metamorphosed. The latter is perhaps more difficult to explain in so far as transfer is concerned, but abundant iron is available. Magmatic solutions frequently carry iron and deposit it as magnetite as shown by the abundance of magnetite in contact metamorphic zones.

[12] Leith, C. K., *Rock Cleavage: U. S. Geol. Survey, Bull.* **239**, p. 91, 1905.