NOTISER

A Note on the Distribution of Ferrides in Accumulative Titaniferous Iron Ores.

BY

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A titaniferous iron ore deposit in the West-Norwegian gneiss area has recently been described by the author (1). The origin of the ore was considered due to the accumulation of magnetite during a stage of the crystallization period when appreciable amounts of titaniferous magnetite separated from the magma as a primary precipitate.

Similar ores are known to occur at Taberg and Ulvön in Sweden (2) (3), and on Rhode Island, U.S.A. (4). As the Ulvön deposit seemed to be especially favourable for a study of the trace element distribution due to the non-coronitic texture of the ore, thus rendering a clean separation of the mineral constituents possible, some analyses have been carried out at Statens råstofflaboratorium, Trondheim. Samples of the Ulvön ore were collected during a short visit to the island in 1956.

The ore horizon and the adjacent wall rock at Grunna on Ulvön are of a troctolitic composition as revealed by the modes on p. 580 in MOGENSON's paper (3). The difference between the high grade ore and the lean wall rocks is due to a variation in the proportions of olivine, plagioclase and magnetite, the latter being strongly enriched in the ore.

The texture of the ore is visualized in fig. 1. The plagioclase shows a well preferred orientation, 010 being paralell to the ore boundaries. The long direction of the olivine crystals, elongated parallel to the c-axis, as a rule also lie in that plane. A very distinct planar structure is consequently produced in the rock. The idiomorphic habit of the magnetite is demonstrated by the figure, and thus all the main constituents of the ore – magnetite, olivine and plagioclase – indicate according to texture that they arrived early at the place of consolidation.

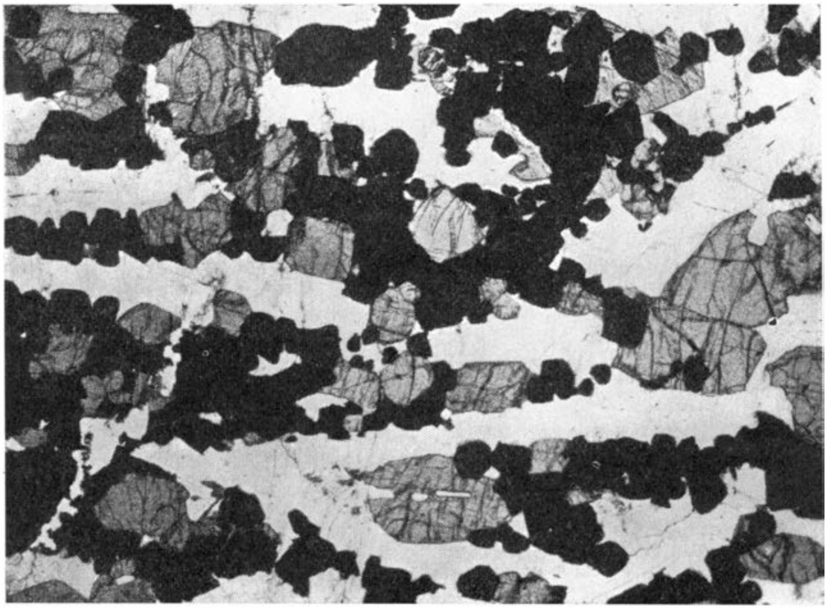

Fig. 1. Magnetite-troctolite (high grade ore), Ulvön. 11 x.

The augite, when present, has an ophitic relation to the plagioclase (the texture is coron-ophitic according to WELLS (5), as a core of olivine usually is enclosed in the augite). Small inclusions of magnetite and plagioclase may occur in the olivine.

The texture is interpreted as follows (fig. 2). Olivine and magnetite accumulated in a part of the magma in which phenocrysts of plagioclase already existed. A small amount of interstitial liquid crystallized to give plagioclase, augite, biotite and apatite. Due to the continued growth of plagioclase from the rims of the existing phenocrysts, the idiomorphic habit of the magnetite and the olivine against the outer part of the plagioclase was developed.

PHENOCRYSTS (formed *in situ*)	*Plagioclase*	
ACCUMULATED PHENOCRYSTS	*Olivine* *Magnetite*	
INTERSTITIAL LIQUID		*Plagioclase* *Augite* *Biotite* *Apatite*

Fig. 2.

Table 1. *Spectrographic analyses of the ferrides in the dolerite and the ore deposit of Ulvön.*

	TiO_2	V	Cr	Co	Ni	Mn
Magnetite, high grade ore	22.4[1]	0.66	0.20	0.022	0.025	0.30
« low grade ore	21.2[1]	0.68	0.11	0.021	0.022	0.27
« dolerite		0.24	0.005	0.011	0.005	0.40
Olivine, high grade ore	0.19	0.020	—	0.021	0.030	0.23
« low grade ore	0.11	0.029	—	0.020	0.027	0.36
Augite, dolerite	2.5	0.017	—	0.006	—	0.15
Plagioclase, high grade ore		—	—	—	—	0.004
« low grade ore		—	—	—	—	0.004
« dolerite		—	—	—	—	0.005

[1]) Determined by chemical methods.
— indicate that concentration of the element is less than 0.005 %.

The analyses are presented in the table below. It clearly shows that the contents of the ferrides, except Mn, is higher in the magnetites which crystallized early. The enrichment of Mn, in the late magnetites is expected owing to the great radius of its ion, being larger than any other of the ferrides. LUNDEGÅRDH (6) has suggested that the Ni/Co ratio may indicate the stage of fractionation, and this agrees well with the present results, cobolt and nickel being reduced with a factor of 2 and 5 respectively in the late magnetites.

Vanadium and chromium are unable to enter into the lattice of olivine in any abundance, but are rapidly removed from the magma when magnetite precipitates, V^{3+} and Cr^{3+} being camouflaged by Fe^{3+}. The low contents of vanadium and especially chromium in the augite, in which these ions easily may find a place in the structure, demonstrates the effectiveness of the vanadium – chromium removal in the early magnetites.

Nickel, on the other hand, may go into the olivine as well, there being camouflaged by Fe^{2+} or Mg^{2+} (7). The distribution of nickel between magnetite and olivine, which precipitated from the magma at the same time, depends therefore upon the ease of entry in these structures. The olivine of the Ulvön ore has a little higher content of nickel than the associated magnetite, but the reverse relation applies to the Taberg ore (2). Accordingly nickel seems to enter olivine (hyalosiderite) and magnetite with about the same ease. Nickel has been almost entirely removed from the magma at the early stage, shown by the small contents of nickel in the augite.

Plagioclase apparantly is able to incorporate some Mn in the lattice.

It is rather interesting that the ulvöspinel, found by Mogenson in this ore some years ago (3), is present in the high grade ore only. In the magnetites of the low grade ore, which have only a slightly lower TiO_2 content, ulvöspinel is entirely absent and martite appears. Lamellae of ilmenite and hercynite are present in both magnetites. VINCENT (8) has pointed out that the presence of ulvöspinel is related to a low oxidation state of the magnetite. According to FOSLIE (9), the ulvöspinel is not stable in the presence of Fe_2O_3: $Fe_2TiO_4 + Fe_2O_3 = Fe_3O_4 + FeTiO_3$. The disappearance of ulvöspinel in the hematite-bearing magnetite confirms the antipathetic relations between ulvöspinel and hematite.

VINCENT and PHILLIPS (8) suggested that oxidation by the inter-precipitate magma, being more abundant in the ulvöspinelbearing bands, was responsible for the formation of ilmenite at the expence of ulvöspinel. The study of the Dopma titanic iron ore in Norway (1), supported this conclusion. At Ulvön, however, the only difference of some importance between high and low grade ore is the proportions of the main minerals. This speaks in favour of a primary difference in the oxidation state of the magnetites. That a temperature difference might have been the controlling factor is indicated by the lower contents of the Fa-molecule in the olivine associated with the mogensenite (ulvöspinel-bearing magnetite). According to chemical analyses the composition of the olivine is Fa 36 and Fa 41 in the high and the low grade ore respectively.

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