A REINVESTIGATION OF THE PSEUDOBROOKITE FROM HAVREDAL (BAMBLE), NORWAY

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An investigation with the electron microprobe shows that the so-called pseudobrookite from Havredal is actually a very fine grained intergrowth of rutile and hematite, with lesser amounts of quartz and sheridanite chlorite.

In the course of a study of pseudobrookites from various localities and geological environments, the well known material from Havredal (Palache, Berman & Frondel 1944, Brögger 1888, Cederström 1889) has been reinvestigated.

The material from Havredal is unusual in several respects. Instead of occurring in volcanic rocks where it is found most commonly, or in pyrometamorphic rocks where it has been recognised on several occasions recently (Agrell & Langley 1958, Smith 1965), it appears in a pegmatite associated with quartz, feldspar, ilmenite, and wagnerite ('kjerulfin') altering to apatite. Furthermore, instead of the microscopic crystals that are normally found, Brögger extracted crystals a few inches in length. The mineral was identified by Brögger (1888) on morphological grounds from the interfacial angles, striated faces etc., and was later analysed by Cederström (1889). The analysis led the latter worker to postulate the formula $2Fe_2O_3.3TiO_2$ for pseudobrookite — a composition that is of course no longer accepted.

A preliminary reflected light examination by the present writer revealed that at least 3 phases were present in a specimen of the Havredal pseudobrookite kindly provided by Professor H. Neumann of the Mineralogical and Geological Museum, Oslo. The material was then examined using an A. R. L. 'EMX' electron microprobe, and X-ray scanning pictures, and analyses obtained of the phases present. It soon became clear that none of the phases in the material was in fact pseudobrookite, and that actually the material is an extremely fine grained and complex intergrowth of rutile and hematite with lesser amounts of quartz and the sheridanite variety of chlorite. In general, the chlorite forms a rim between the quartz and the rutile-hematite intergrowth (see Fig. 1).

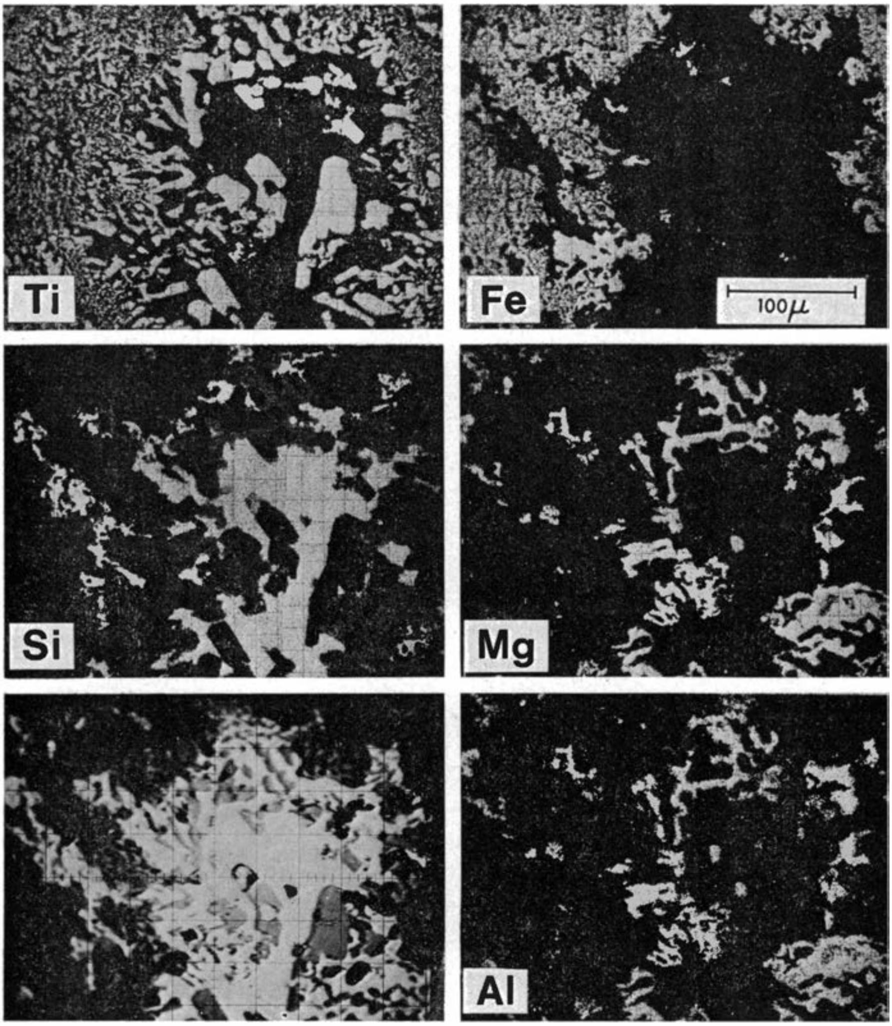

Fig. 1. Composite scanning pictures of an area of the intergrowth containing a grain of quartz. All magnifications are as indicated by the scale in the upper right photograph. Upper left: Ti X-ray picture. Centre left: Si X-ray picture. Lower left: Inverted specimen current picture. Upper right: Fe X-ray picture. Centre right: Mg X-ray picture. Bottom right: Al X-ray picture. Note that there appear to be two scales of intergrowth: Large rutile grains and a few large hematite grains are set in a very fine grained intergrowth of hematite and rutile. This suggests that the breakdown may have occurred in two stages; first a breakdown to hematite, rutile, and ilmenite, and then subsequently a breakdown of the ilmenite to give rutile and hematite by oxidation. The area showing counts for Mg, Al, and Si is the sheridanite chlorite reaction rim around the quartz.

There seems no reason to doubt the accuracy of Brögger's original crystallographic measurements and there e ore it is suggest e that the material from Havredal orig i ally crystalli s d as pseudobrookite but later broke down to the rutile-hematite intergrowth, either during cooling or perhaps during some oxidising event that postdat e the mineral's formation. Lindsley

Table 1. Electron probe analyses of the phases present in the Havredal material

	I	II	III	IV	V	VI
SiO_2	–	0.08	0.16	99.65	28.52	27.12
TiO_2	44.26	2.70	99.37	0.27	0.78	–
Al_2O_3	–	0.20	trace	trace	26.66	27.68
Fe_2O_3	56.42	94.52	0.47	0.08	0.41	0.20
FeO	–	2.43	–	–	–	1.24
MnO	–	–	–	–	–	0.54
MgO	–	0.07	n.d.	n.d.	30.72	30.96
Na_2O	–	n.d.	trace	trace	0.04	–
H_2O	–	–	–	–	12.87	12.83

I Cederström's (1889) analysis of the Havredal 'pseudobrookite'
II Hematite recalculated to 100% from 99.11%
III Rutile recalculated to 100% from 97.25%
IV Quartz recalculated to 100% from 97.26%
V Sheridanite chlorite recalculated to 100% from 96.29%
VI Sheridanite from Camberousse France, quoted by Deer et al. (1962, Vol. III, p. 140, anal. 12).
n.d. = not detected; – = not sought

(1965) has found that p eudobrookite of the composition Fe2TiOs is unstable below about 600°C, and the FeTi20s e d member below 1140 ± 10°C. It h s also be e shown that m a y naturally o curring mem b rs of the pseudobrookite family can c o tain amounts of MgTi20s and Al2TiOs in solid soluti o (Smith 1965); as yet the effects of the s components on the stability relations of the mineral have not been determined. It is therefore further suggest e that the chlorite found in the Havredal s p cim e resulted from the release of Mg and Al during the br e kdown of the pseudobr o kite to rutile, hematite, and probably ilmenite, and its reacti o with inclusions of quar t.

That Cederström's analysis d o s not corres p d to the pre s tly accept e formula of the mineral is pro b bly due to the fact that his se p ration pr o ur e r e oved the phases in which Mg and Al now occur and also, perhaps, that the material was oxidis e during decomposition. El e tron probe analyses of the phases now present are given in Table 1. These analyses were corr e ted for b ckgro u d, atomic number, absorption and fluorescence e f ects by an APL computer program written by the pres e t author and M. C. Tomlinson (to be publish e). All elem e ts were analysed using an accelerating voltage of 15 KV and a b am curr e t of 0.1 μ A against chemically analysed mine r l or pure oxide st a dards. The totals are in general a little low for go o electron probe analyses - probably r e l e ting the fine grain size and difficulty of preparing relief-free and perf e tly polished surfaces of such material.

The a alysis of the iron-rich phase shows that it is a normal h e atite with about 5 % of ilmenite i solid soluti o (assuming that all Ti02 is present as the ilmenite molecule). Very minor amounts of Al, Mg and Si are also indicated. The magnesium aluminum silicate forming the reaction rim between quartz and decomposed pseudobrookite, is apparently a chlorite of the sheridanite variety. The (OH) has been assumed on the basis of 28 oxygens in the structural formula calculated for the mineral from the corrected analysis. The composition of this mineral is interesting in that it is very low in iron and higher in Ti than any of the sheridanites reported by Deer et al. (1962). In all other respects, the analysis is very comparable to analyses 12 and 13, p. 140, given by these authors. The rutile is quite pure and contains only a small amount of Fe and an even smaller amount of Si.

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