

Iron-boracite from the English Zechstein

IRON-BORACITE, $(\text{Fe, Mg, Mn})_3\text{B}_7\text{O}_{13}\text{Cl}$, has been found in nodules in an anhydritic shale that overlies the sylvinite (sylvine-halite rock) of the third Zechstein Evaporite Cycle at the Boulby Mine, Loftus, Saltburn, Cleveland. This is the first record of the mineral in this country. The succession in the type roadway is:

Anhydritic shale with the iron-boracite nodule bed near its base; the Shale and Nodule Beds are cross-cut by red sylvine-halite veins from the sylvinite below: 2 m.

Pink-grey sylvinite with red and pink sub-horizontal colour bands; 2 m.

Coarse-grained red and white halite with streaked-out fragments of anhydrite at its top; 3 m.

Iron-boracite is an orthorhombic variety of boracite ($\text{Mg}_3\text{B}_7\text{O}_{13}\text{Cl}$) in which divalent iron is the predominant cation (Dr. R. Kühn, personal communication). The iron-boracites from Boulby contain minor Mn in the cation sites. Boracite has been recorded in the U.K. in insoluble residues from the E2 boring, near Aislaby, Yorkshire, by Guppy (1944) and Stewart (1951).

Above 265 °C, boracite is cubic but below this temperature it is orthorhombic due to differences in the positions of the magnesium and chlorine atoms. This inversion results in the crystals becoming twinned by a rotation of 120° about [111]. The inversion temperatures of ferroan boracites are higher than 265 °C and rise with increasing iron and manganese content (Heide, Walker, and Urlau, 1961). Heide, however, in a personal communication to Braitsch (1962, p. 167), said that he had synthesized pseudocubic boracite crystals well below 265 °C. The rocks of the English Zechstein almost certainly were never heated to 265 °C.

The iron-boracite nodules are ellipsoidal in shape with major axes varying in length from 1 to 15 cm and minor axes being approximately half the major ones. The nodules are frequently tightly packed within the Nodule bed.

Individual grains and clusters of iron-boracite are found in the nodules together with sylvine, halite, magnesite, talc, and hematite. Some nodules are composed entirely of iron-boracite whilst in others sylvine and magnesite predominate.

Iron-boracite crystals in the nodules are either large euhedral blue-green pseudocubic crystals (up to 3 mm edges) with well-developed faces of the form {100} and subsidiary faces of the form {111}, or anhedral brown-purple grains up to 0.5 mm in width.

Both types of iron-boracite crystals are turbid although occasional pseudocubic crystals show remnant sector twinning characteristic of the boracite group of minerals. Large pseudocubic crystals are seen to have broken down and recrystallized to form the small anhedral grains. When the iron-boracite occurs in clusters the large euhedral crystals tend to be found around the rim whilst the anhedral grains occur in the centre. It has been difficult to determine the exact optical properties of the crystals owing to their turbid nature. The maximum refractive index is 1.727 and $2V_\gamma = 80-90^\circ$.

The substitution of iron and manganese into the magnesium site of boracite results in an expansion of the unit-cell parameters (Kühn and Schaacke, 1955). Many crystals from different nodules were X-rayed and shown to have unit cell parameters in the range of iron-boracite (Table I). The small anhedral grains have larger unit-cell parameters and greater MnO and

FeO contents compared with the pseudocubic crystals. In each case the unit-cell parameters were determined from a group of crystals and probably represent averages. The lines on the X-ray films were frequently sharp.

The inversion temperatures for the iron-boracites were determined using a Du Pont differential thermal analyser (Table I). The large pseudocubic crystals (lower FeO and MnO) have an inversion temperature of 297 °C whilst the small grains (with higher FeO and MnO) show a range from 287 °C upwards.

TABLE I. Comparison of the properties of English and German boracites and iron-boracites

Type and locality	Wt. %			Cations, %			a	b	c	T †
	MgO*	FeO	MnO	Mg ²⁺	Fe ²⁺	Mn ²⁺				
Small anhedral grains from Boulby ‡	12.44	28.38	4.34	40.34	51.65	8.00	8.63	8.63	12.19 Å	287 °C
Large crystals from Boulby ‡	16.82	22.11	2.85	54.53	40.21	5.25	8.59	8.59	12.15	297
Riedel, Hänigsen	8.55	38.69	0.46	28.71	70.44	0.85	8.58	8.69	12.17	310-315
Niedersachsen, Wathlingen	29.90	1.68	—	96.94	3.06	—	8.53	8.60	12.15	—
Segeberg	30.84	—	—	100	—	—	8.53	8.53	12.12	265
Stassfurt **	30.84	—	—	100	—	—	8.54	8.54	12.07	265
E2 borehole, Yorkshire ††	31.00	—	—	100	—	—	8.56	8.56	12.10	272

* Calculated by difference, knowing FeO and MnO% † Orthorhombic to cubic inversion temperature

‡ Cell dimensions determined using a Haag-Guinier camera of 200 mm equivalent diameter and Cu-K α radiation.

|| Kühn and Schaacke, 1955 ** Ito, Morimoto and Sadanaga, 1951 †† Guppy, 1944

Errata: * applies to anal. 1 and 2 only; last col., line 1, for 287 °C read \geq 287 °C

Iron-boracite from a nodule in which the crystals only occurred as anhedral grains gave a chemical analysis of 3.82 MnO, 24.05 FeO, 11.75 MgO, 0.27 CaO, 0.55 SiO₂, 53.80 B₂O₃, 0.10 Na₂O, 0.01 K₂O, 0.01 % Br, and 7.38 % Cl. Total (less O \equiv Cl) = 100.07 %. It contains 49.09 mole % FeO, 42.86 mole % MgO, and 8.05 mole % MnO. The analysis gives a formula of (Mn_{0.24}Fe_{1.50}Mg_{1.30})B_{6.9}Si_{0.04}O_{13.07}Cl_{0.93} based on fourteen anions (oxygen and chlorine).

The turbidity of the crystals suggests breakdown of the structure and in some cases this has resulted in recrystallization. The variation of iron and manganese contents of these crystals suggests that the breakdown may have been caused by the influx of a solution rich in iron and manganese into nodules containing pre-existing boracite or low-Mn iron boracite.

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An occurrence of brucite at Merehead Quarry, Cranmore, Somerset

THIS note offers the first record of an occurrence of brucite in the Mendip Hills. The locality is in Merehead Quarry (grid ref. O.S. 1" map ST 698443), which is situated on the south flank of the Beacon Hill Pericline. The rocks quarried are well-bedded limestones that are referred to the Lower Carboniferous Clifton Down Limestone. A notable feature of this locality is the occurrence of a varied assemblage of rare lead and copper minerals. These have recently been described by Alabaster (1975: see references there to the no. 2 vein, at which brucite has now been discovered). The rare minerals are found within the pods of manganese oxide that occur, together with iron oxides, as replacement deposits set in faults and Trias-filled fissures developed in the Carboniferous Limestone. Doultling Stone (mid Jurassic: Upper Inferior Oolite) rests unconformably on the Carboniferous Limestone at Merehead and can be seen to truncate the mineralized fissures. The fissures occasionally contain inserted sedimentary materials ranging in age from Rhaetic to Upper Inferior Oolite.

The pods of manganese oxide contain numerous small cavities, the ore from no. 2 vein being especially cavernous. The secondary minerals occur either as simple cavity fillings or else are contained in calcite nodules, which have themselves grown in, and may in some instances have enlarged, the original cavities. The brucite has been found occupying a small central cavity in two of these calcite nodules.

Brucite occurs in each of these two cases as a compact mass of transparent, prismatic-acicular crystals, arranged in radiating groups that are intergrown with one another. The crystals are elongate \parallel [0001] and grow out from the cavity walls. In both specimens there is some degree of alteration to white hydromagnesite and pseudomorphs after brucite are seen. A thin (up to 0.5 mm) discontinuous light-brown rim occurs at the brucite/calcite interface. This light-brown material is translucent, has a vitreous-resinous lustre, and is appreciably harder than the brucite, which it invariably pseudomorphs. XRD analysis shows it to consist of a mixture of brucite and crystalline hydromagnesite. Both the brucite and the white hydromagnesite are seen to grade into this material.

In one specimen (now in two parts deposited in the Geology Museum, University of Bristol, numbered B3624 and B3625: see the former in fig. 1) brucite is associated with massive orange blixite, which shows partial alteration to hydrocerussite. Contacts between brucite and blixite are sharp. The gently undulating contact is uninfluenced by both cleavages and crystallographic orientation of the brucite crystal groups. There is no evidence to suggest that brucite is intergrown with the blixite/hydrocerussite. It seems to be the case that brucite formed before blixite in this nodule.

The two brucites are of different colours, brownish green in the nodule that has blixite and pale green in the other. Refractive indices (determined using white light) too are different in