MINERALOGICAL MAGAZINE, SEPTEMBER 1974, VOL. 39, PP. 811–15

The mineralogy and paragenesis of a fluorspar flat at Masson Hill, Matlock, Derbyshire

ROBERT A. IXER

Department of Geological Sciences, University of Aston in Birmingham

SUMMARY. Investigation of the mineralogy and paragenesis of the fluorspar flat at Masson Hill, Matlock, Derbyshire, shows the mineralization to be a combination of void infilling and metasomatic replacement. The main paragenesis is of the non-sulphides, fluorite, baryte, and calcite accompanied by a sequence of sulphides, bravoite, pyrite, marcasite, chalcopyrite, sphalerite, and galena. A wide range of secondary minerals occur in the oxidation zone.

THE presence of an intermittent fluorspar flat, within the bioclastic Matlock Lower Limestones, along the summit of Masson Hill has long been known, and the presence of fluorite, baryte, quartz, and galena recorded (Dunham, 1952; Smith *et al.*, 1967; Ford, 1967, 1969). The distribution of the mineralization was largely controlled by minor lithological variations, and by small-scale faulting and jointing, both within the limestones and the largely barren dolomites that overlay it.

Surface and underground mapping of the central and north-eastern area of the flat showed that the main paragenetic sequence was most clearly developed at three localities: Masson opencast (SK 2845 5913), Jughole mine (SK 2793 5971), and Oxclose mine (SK 2753 5994). Many of the specimens from the last locality were collected from spoil-heaps.

From the field evidence the mineralization is believed to have formed during one extended phase of migrating fluids followed by oxidation of some of the primary phases. Although small-scale fracturing and repetition of any phase are seen, it is so limited that it is best interpreted as localized movements during mineralization. Elsewhere in Derbyshire, notably at Long Rake (SK 216 653), there is evidence of polyphase mineralization; brecciation and fracturing of earlier mineralization are seen to have accompanied later influxes of mineralizing fluids (Ineson and Al-Kufaishi, 1970). This difference may reflect the greater sensitivity of rake deposits to minor earth movements.

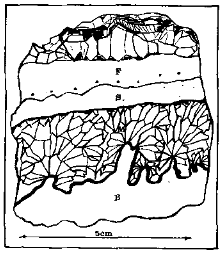
Textural classification

Using both petrographic and field evidence two distinct ore-types can be recognized (figs. 1 and 2):

a. A mixed mineral rock resulting from metasomatic replacement and showing relict sedimentary calcite (to 40 μm), dolomite rhombs (120 μm), and prismatic quartz (120 μm). At Masson and Jughole the ore has a restricted occurrence being confined to the junctions between limestone and dolomite. It consists of fluorite and quartz, with subordinate baryte, calcite, and galena. Locally a mixed sulphide layer occurs, containing galena, bravoite, pyrite, marcasite, plus traces of chalcopyrite and sphalerite. At Oxclose the mineralization is of bravoite, pyrite, marcasite, chalcopyrite, sphalerite, and galena within fluorite or smithsonite. The ore is friable and secondary copper and zinc minerals are common.

b. A rhythmic layered ore showing euhedral upper faces. The lack of any relict sedimentary fabric and its occurrence within joints and premineralization solution cavities suggests the result of void infilling. At Masson and Jughole the ore consists of fluorite, baryte, and galena, whilst at Oxclose the layers comprise marcasite, sphalerite, galena, baryte, and fluorite. Alteration of the primary minerals is rare.

Field evidence indicates that the two types are contemporaneous and often grade into each other.



FIGS. 1 and 2: FIG. 1 (left). Type *a* ore. Subhedral to anhedral bravoite (B) showing alteration to goethite (Go) and surrounded by pyrite (P). Associated chalcopyrite (Cp) with alteration along cleavage and margins, galena (G), marcasite (M), and sphalerite (Sph) occur in a mixed fluorite and smithsonite matrix. FIG. 2 (right). Type *b* ore. Banded baryte (B), marcasite (M) with an oxidized base, sphalerite (S), and fluorite (F) indicating euhedral upper faces. Zones of bravoite inclusions occur in the fluorite.

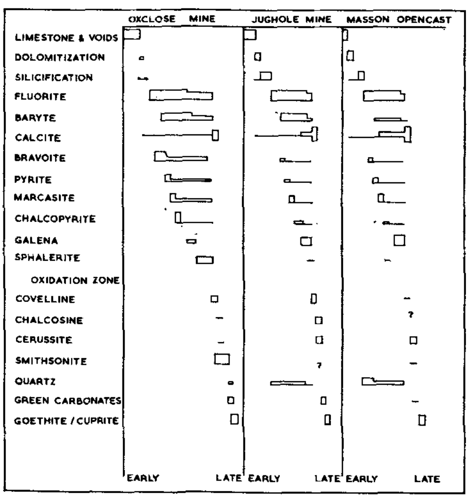


FIG. 3. The paragenesis for the mineralization between Oxclose Mine and Masson Hill Opencast.

Mineralogy

The mineralogy is discussed in order of its deduced paragenetic sequence (Fig. 3). Modal proportions are also given for five specimens of type *a* ore from Oxclose Mine (Table I), which illustrate the local importance of bravoite.

Fluorite is the most common and the earliest mineral, and occurs throughout the primary mineralization. Normally it is colourless to pale yellow, but less often it is blue, green, or purple, the last colour being especially common at the crystal edges or surfaces near to other minerals, especially baryte and smithsonite. Cubic crystals are common, often exhibiting {210} faces.

Three types of inclusions occur: the relict sedimentary carbonates and quartz within fluorites from type *a* ore; fluid inclusions occurring in fluorites from type *b* ore, and described by Mueller (1954*a*); and primary sulphides common to all fluorites. The most common inclusions are of bravoite, pyrite, marcasite, and chalcopyrite.

Baryte occurs as white to orange incrustations on fluorite, and as cockscomb crystals (1·5 cm). Although it is essentially an early phase it has a number of late stage associations, notably with marcasite or acicular goethite. The grey mammilated baryte described by Ford and Sarjeant (1964) forms one of these late associations.

Both *quartz* and *calcite* occur throughout the primary mineralization, and calcite in the oxidation zone. Both carry sulphide inclusions and both are far less significant at Oxclose than in the more central areas of the flat.

TABLE I. *Modal proportions for type* a *ore from Oxclose Mine*

	OC1	OC2	OC3	6·1	OC5
Fluorite	44·24	41·68	52·20	41·72	21·85
Calcite	< 0·01	< 0·01	< 0·01	< 0·01	< 0·01
Bravoite	6·29	8·20	5·29	13·13	0·98
Pyrite	2·35	3·34	2·05	4·28	1·57
Marcasite	1·21	1·09	0·32	1·17	0·98
Chalcopyrite	0·12	0·49	0·86	1·05	0·33
Galena	< 0·01	< 0·01	< 0·01	< 0·01	< 0·01
Sphalerite	1·33	1·22	1·84	7·43	0·45
Covelline	0·12	0·50	0·22	0·94	0·06
Cerussite	< 0·01	< 0·01	< 0·01	< 0·01	< 0·01
Smithsonite	39·50	37·46	33·44	27·79	72·24
Green carbonates	0·12	0·12	0·27	0·90	0·02
Quartz	0·26	0·52	0·16	0·08	0·39
Goethite	4·46	5·38	3·35	1·51	1·13
Total	100·00	100·00	100·00	100·00	100·00

Bravoite is the earliest hydrothermal sulphide, occurring as inclusions in all the non-sulphide phases. The inclusions are generally 10–30 μm in size showing a pentagon dodecahedral habit. They show zoning and pyrite and marcasite overgrowths.

At Oxclose two types of bravoite occur: A brown euhedral to subhedral, faintly zoned bravoite (50 to 300 μm) with average reflectivity in air in plane polarized light of 41·9 to 42·5 %. This is typical of type *a* ore. And a rarer, euhedral, lilac-brown, zoned bravoite (20 μm) with an average reflectivity of 38·0 to 38·5 %. This bravoite occurs within the centre of large pyrite masses (100 to 200 μm) or as inclusions in fluorite. These reflectivities are similar to those determined by Vaughan (1969) for bravoites from Millclose Mine.

The bravoite inclusions within fluorite occur within 500 μm wide zones, both as individual grains and as long stringers (40 to 100 μm $\times$ 2 μm) lying perpendicular to the crystal edges. Although the spectral reflectivity within a given zone is uniform, adjacent zones show differing reflectivities indicating a change in the iron to nickel ratio of the mineralizing fluids.

Microprobe analysis of bravoites from Oxclose Mine (Table II) show the nickel content to be similar to the 'type 1' bravoite analysed by Hey (in Bannister, 1940) and to the bravoites analysed by Vaughan (1969), both from Millclose Mine. The presence of a second type of bravoite containing 28% nickel found by Bannister at

Millclose could not be confirmed at Oxclose Mine although the primary mineralization is similar in both mines.

Fracturing of bravoite occurs; early fractures are cemented by fluorite, later ones by smithsonite. Oxidation of bravoite is widespread, commonly with goethite pseudomorphs that still show the original zoning.

Bravoites with essentially similar parageneses have also been recognized in Derbyshire at Ball Eye Mine (SK 286 574), Hucklow Rake (SK 1750 7790), and Dirtlow Rake, Castleton (SK 1500 8190) suggesting that it may occur throughout the pyrite–fluorite zone (Mueller, 1945*b*) and not just in the Matlock area (Ford and Ineson, 1971).

TABLE II. *Microprobe analyses of bravoites from Oxclose Mine*

Fe	28·52	32·91	34·61	27·20
Ni	16·47	12·13	13·03	18·92
S	52·44	52·37	52·78	53·36
Co	1·22	0·83	0·92	1·22
Total	98·65	98·24	101·34	100·70

Pyrite and marcasite generally occur as overgrowths on bravoite inclusions, characteristically on the faces away from the direction of growth of the host mineral. In addition a late-stage marcasite occurs as bladed crystals associated with baryte and calcite.

Small anhedra of *chalcopyrite* occur, often showing extensive and variable alteration. Successive rims of covelline, chalcosine, cuprite, and malachite are common, due to later oxidation. Some chalcopyrite occurs as exsolved lamella (100×20 μm) within sphalerite.

Large subhedral to euhedral cubes of *galena* are typical throughout the flat, occurring in both ore types. Occasionally, octahedral galena is associated with calcite scalenohedra at Masson Opencast. Oxidation to cerussite is very common.

Sphalerite. Semi-quantitative microprobe analysis and single crystal diffraction confirmed the sphalerite as an iron-poor honey-blende with an average 4·3 mol % Fe. In addition to the typical internal reflections of this type of sphalerite, deep-purple reflections are common, often along twins and growth zones. The colour is not due to the inclusion of purple fluorite but its origin is undetermined. Alteration to smithsonite is extensive, accompanied locally by rosasite and aurichalcite. The latter two minerals are known from elsewhere in the flat (Braithwaite and Ryback, 1963).

Conclusions

The mode of occurrence and the mineralogy throughout the flat is consistent with a low-temperature hydrothermal origin. The textural evidence is more consistent with a single long-term primary mineralization event followed by extensive oxidation by meteoric waters. The occurrence of bravoite within the flat and elsewhere suggest it may be a characteristic accessory sulphide of this type of mineralization.

Acknowledgements. This paper forms part of a Ph.D. thesis submitted to the University of Manchester. Thanks are due to Dr. A. C. Dunham who suggested the research topic and supervised the work. Financial support from Laporte Chemicals Limited is gratefully acknowledged, as is help from their Divisional Geologist, Dr. J. E. Mason.

REFERENCES

BANNISTER (F. A.), 1940. *Min. Mag.* **25,** 609–14.
BRAITHWAITE (R. S. W.) and RYBACK (G.), 1963. Ibid. **33,** 441–9.
DUNHAM (K. C.), 1952. *Geological Survey on the Mineral Resources of Great Britain,* **4**. *Fluorspar,* 97–101. London (H.M.S.O.).
FORD (R. D.), 1967. *Some Mineral Deposits in the Carboniferous Limestone of Derbyshire,* 53–75, in *Geological excursions in the Sheffield Region.* University of Sheffield.
—— 1969. *The Stratiform Ore Deposits of Derbyshire,* 73–96, in *Sedimentary Ores Ancient and Modern.* University of Leicester.
—— and INESON (P. R.), 1971. *Trans. Inst. Min. Met.* **80,** B186–210.
—— and SARJEANT (W. A. S.), 1964. *Proc. York. Geol. Soc.* **34,** 371–86.
INESON (P. R.) and AL-KUFAISHI (F. A. M.), 1970. *Mercian Geol.* **3,** 337–51.
IXER (R. A.), 1972. Unpublished Ph.D. Thesis, University of Manchester.
MUELLER (G.), 1954*a*. *Mining Mag.* **90,** 148–54 and 208–17.
—— 1954*b*. *XIX Int. Geol. Congr. Alger. Fasc.* **15,** 532–9.
SMITH (E. G.), RHYS (G. H.), and EDEN (R. A.), 1967. *Geology of the Country around Chesterfield, Matlock and Mansfield. Mem. Geol. Surv. Gt. Britain.*
VAUGHAN (D. J.), 1969. *Amer. Min.* **54,** 1075–83.

[*Manuscript received 3 July 1973; revised 14 January 1974.*]