SHORT COMMUNICATIONS

MINERALOGICAL MAGAZINE, MARCH 1978, VOL. 42, PP. 149–50

The distribution of bravoite and nickeliferous marcasite in central Britain

BRAVOITE and nickeliferous pyrite as primary phases have two major low-temperature associations. Firstly, they occur within the Pb-Zn-baryte-fluorite deposits of the Mississippi Valley type. The bravoite is paragenetically early, either being diagenetic as in the Cave-in-Rock district of Illinois (Park, 1967), or epigenetic as at Millclose mine (Bannister, 1940) and Masson Hill (Ixer, 1974) in south-east Derbyshire and Dirtlow Rake and Treak Cliff in northern Derbyshire (Lunn *et al.*, 1974).

Secondly, they occur within mineralized red-bed sandstone deposits of a more variable mineralogy. These include the highly zoned bravoites from the Pb-Zn deposits within the Bunter sandstones of Mechernich, Eifel, and of Maubach, Rhineland, Germany (Baumann, 1976), occurrences within the Zn-Cu-Pb-Co-Ni deposits of the Permo-Triassic sandstones of Beyrède quarry, southern France (Wahbi *et al.*, 1973) and the Cu-Ni deposits of the Devonian of the Voronezh region U.S.S.R. (Ageykin *et al.*, 1969). They also occur in an allied class of deposits, those formed from leached red-beds. Here bravoite can occur epigenetically as in the Magnet Cove Mine, Walton-Cheverie area, Nova Scotia (Boyle, 1971), or syngenetically as at Fredericktown, Missouri (El Baz *et al.*, 1963).

Townley (1976) has shown the first association to be common, and the second association to be present, in central Britain. Optically identifiable bravoite and nickeliferous pyrite have been found in fifty-six localities throughout the South Pennine Orefield including the outlying anticlines of Ashover and Crich and the anomalous copper area of Ecton. It is normally the earliest sulphide, occurring as lilac or brown subhedra associated with pyrite, marcasite, chalcopyrite, sphalerite, and galena and more rarely with millerite (Ashover), pyrrhotine and tetrahedrite (Millclose mine), and bornite (Odin mine). Bravoite also occurs as small (< 20 μm) inclusions of zoned euhedra surrounded by pyrite and marcasite rims and within fluorite, calcite, baryte, and quartz. This paragenesis appears to be remarkably uniform, a fact reflected in the chemical compositions of these sulphides. Comparison of the available analyses of nickel and cobalt contents of bravoites are given in Table I and show consistently low cobalt values of less than 1·5 wt% and a range of nickel values mainly within 10–20 wt% nickel.

At eleven localities, notably at Winster, Oxclose mine, Dirtlow Rake, and Odin mine, marcasite enclosing bravoite displays faint anomalous lilac and brown colours associated with grain boundaries, or coloured bands and zones, often as continuations of zoning within the enclosed bravoite. These bands cross-cut twin and grain boundaries. Electron microprobe analyses (Table II) show these coloured marcasites to be nickeliferous. The nickel and cobalt values are similar to those

TABLE I. *Ranges of nickel and cobalt content for Derbyshire bravoites*

	Millclose Mine	Oxclose Mine	Winster	Shuttle Rake	Dirtlow Rake
Ni wt%	16·20–16·69	12·13–18·92	7·6–24·83	5·99–13·01	10·07–14·59
Co wt%	tr.–1·40	0·83–1·22	tr.–0·29	tr.	tr.–0·91
No. of anal.	2	4	4	3	6
Analyst	Hey in Bannister (1940) Vaughan (1969)	Ixer (1974)	Townley (1976)		

TABLE II. *Microprobe analyses of nickeliferous marcasites*

	Dirtlow Rake	Winster		
Ni wt%	1·57	6·39	5·98	0·13
Co wt%	n.d.	n.d.	n.d.	n.d.
Fe wt%	43·01	40·16	38·78	47·07
S wt%	53·29	53·68	53·37	51·67
Total	97·87	100·23	98·13	98·87
	Faint zoning	Deep violet	Lilac band	Uncoloured

obtained by Desborough *et al.* (1970) for hydrothermal nickeliferous marcasites from the Sudbury Basin.

Essentially similar bravoite associations have been identified elsewhere, such as at eight new localities in the Askrigg Block (including the Swaledale, Arkengarthdale, and Greenhow areas), one in the Alston Block (at Nenthead) and two in the Mendip Hills (at Haydon Grange and Green Ore). These localities augment those at Clitheroe and Rimington, Lancashire, and in Wensleydale and Wharfedale described by Rogers and Ixer in Lunn *et al.* (1974).

Only one example of the red-bed association has been investigated, the copper mineralization at Alderley Edge, Cheshire. Nickeliferous and cobaltian wad has been described from this locality (Warrington, 1965). Material from the undoubtedly epigenetic lead-zinc mineralization from Engine Vein and the stratiform copper mineralization both contain early zoned bravoites. They occur as small (< 10 μm) euhedra (without pyrite and marcasite rims) apparently as inclusions in detrital quartz grains, or more commonly as larger 20–30 μm zoned subhedra associated with the galena, chalcopyrite, chalcosine, or carbonate cements, in a similar manner to the Voronezh mineralization.

It has now been established, therefore, that bravoite is a widespread accessory mineral in the low-temperature mineralization of central Britain. Its distribution outside this area is as yet unknown, although the occurrence of other nickel minerals, notably ullmannite and nickeline in the North Pennine Orefield of Co. Durham (Dunham, 1948) suggests a wider distribution.

Acknowledgement. Thanks are due to Dr. D. J. Vaughan for critically reading the manuscript.

REFERENCES

Ageykin (A. S.), Chernyshov (N. M.), Molotkov (S. P.), and Bukovshin (V. V.), 1969. *Intern. Geol. Rev.* **11**, 132–4.
Bannister (F. A.), 1940. *Mineral. Mag.* **25**, 609–14.
Baumann (L.), 1976. *Introduction to Ore Deposits.* Scot. Academic Press.
Boyle (R. W.), 1971. *Geol. Surv. Can. Bull.* **166**, 82–4.
Desborough (G. A.) and Larson (R. A.), 1970. *Econ. Geol.* **65**, 728–30.
Dunham (K. C.), 1948. *Geology of the Northern Pennine Orefield*, **1**, H.M.S.O.
El Baz (F.) and Amstutz (G. C.), 1963. *Mineral. Soc. Am. Spec. Paper*, **1**, 190–7.
Ixer (R. A.), 1974. *Mineral. Mag.* **39**, 811–15.
Lunn (P. E.), Rogers (P. J.), and Ixer (R. A.), 1974. *Bull. Peak Dist. Mines Hist. Soc.* **5**, 332–4.
Park (W. C.), 1967. *Miner. Deposita*, **2**, 372–6.
Townley (R.), Unpublished M.Phil. thesis, University of Aston in Birmingham.
Wahbi (Y.), Picot (P.), and Tallon (F.), 1973. *Bull. Soc. fr. Minéral. Crystallogr.* **96**, 231–2.
Warrington (G.), 1965. *Mercian Geol.* **1**, 111–29.
Vaughan (D. J.), 1969. *Am. Mineral.* **54**, 1075–83.

[*Manuscript received 16 March 1977; revised 8 July 1977*]

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