Clay Minerals (1981) **16**, 309–312.

NOTE

CLAY MINERALS IN THE VEINS OF THE NORTH PENNINE OREFIELD, UK

The clay mineralogy of wall-rock alteration adjacent to the fluorite–baryte–quartz–galena–sphalerite veins of the North Pennine Orefield, northern England, has been described by Dunham (1948). Some alteration products, particularly illite, have been used for K–Ar and ^{40}Ar–^{39}Ar dating of the mineralization and of later thermal events (e.g. Dunham *et al.*, 1968). Recent work has shown that clay minerals can also occur as discrete aggregates and veinlets within the mineralized zones. Typical occurrences are described below.

Muscovite

Muscovite occurs commonly as a breccia matrix and veinlet infilling in the 2–3 m wide hanging-wall breccia zone of Burtree Pasture Vein at the horizon of the Nattrass Gill Sandstone and Four Fathoms Limestone, Gargets' Level, Burtree Pasture Mine; as fracture infillings within 5 m of Red Vein at Redburn Mine, in the Nattrass Gill Sandstone; and in a drill-hole intersection of Greenclaugh Vein at Frazars Hush, in a brecciated siltstone of the Coal Sills Group. In each case the muscovite is compact, fine-grained and pale yellowy green. It was identified by X-ray diffraction of cavity mounted samples, using iron-filtered cobalt radiation. Comparison of the diffraction data with those of Yoder & Eugster (1955) and Bradley & Grim (1961) showed that all the samples are mixtures of the $1M$ and $3T$ polymorphs, always with a marked predominance of the $1M$ type.

At Burtree Pasture and Redburn, muscovite is associated with siderite and minor quartz mineralization adjacent to wide fluorite–galena veins. At Frazars Hush the muscovite occurs alone, but is also close to high-grade fluorite–galena mineralization. The occurrence of the mineral shows promise, therefore, of being a useful indicator of ore proximity during underground exploration.

*Cookeite/chlorite-I*a

Several siderite-lined pockets (1–2 cm) of cream-coloured clay, identified by X-ray diffraction as a chlorite-Ia of the cookeite type, were intersected by borehole 65 at Redburn Mine. Chemical analysis has confirmed a content of 0·82% Li in the mineral (cf. 1·13% Li in cookeite from the Ogofau gold mine, Wales (Brammall *et al.*, 1937)). The occurrence is in an area of minor fluorite–quartz–galena mineralization in the Nattrass Gill Sandstone, near a 1 m wide dolerite dyke. The latter marks the transgression of the Little Whin Sill from a horizon within the Three Yards Limestone (at Rookhope) to the base of the Four Fathoms Limestone, where it pinches and eventually terminates within Redburn mine workings. The siderite lining to the clay pockets seems, however, to

0009-8558/81/0900-0309$02.00

TABLE 1. X-ray patterns of clay minerals from North Pennine veins compared with published patterns from other localities

Cookeite Chlorite-I*a*				Berthierine–chamosite								Kaolinite				Dickite			
1		2		3		4		5		6		7		8		9		10	
d	*I*	*d*	*I*	*d*	*I*	*d*	*I*	*d*	*I*	*d*	*I*	*d*	*I*	*d*	*I*	*d*	*I*	*d*	*I*
14·2	70	14·1	80	7·19	100	7·18	100	7·17	90	7·1	100	7·22	100	7·18	100	7·16	100	7·15	100
7·07	60	7·05	70	4·64	30	4·65	20	4·65	20	4·63	50	4·48*	10	4·48*	80	4·44	30	4·44	30
4·74	100	4·70	90	3·56	100	3·56	90	3·55	90	3·53	90	3·57	100	3·58	100	4·37	30	4·36	30
4·45	20	4·47	40	2·681	30	2·69	50	2·681	40	2·69	70	2·55	40	2·57	80	4·27	20	4·26	20
3·54	70	3·52	90	2·516*	40	2·52*	50	2·516*	60	2·53	70	2·52	40	2·50	80	4·11	50	4·12	65
2·84	40	2·82	30	2·140	5	2·14	5	2·140	10	2·16	20	2·39	20	2·39	80	3·95	10	3·95	10
2·56	30	2·56	40	1·767	5	1·76	40	—	—	1·78	10	2·29	40	2·34	90	3·79	20	3·79	55
2·51	30	2·51	70	1·550	5	1·56	20	1·55	50	1·557	80					3·58	90	3·58	90
2·38	10	2·37	5	1·526	30	1·52	10	1·518	20	1·524	70					3·43	10	3·43	20
2·32	40	2·32	100	1·428	20	1·430	20	1·42	5	1·427	40					3·27	5	3·26	8
2·20	10	2·21	10	1·345	10	1·358	20	—	—	1·350	20					3·08	5	3·10	10
				1·328	5	1·330*	5	—	—	1·328	20					2·94	5	2·94	8
																2·79	10	2·79	10
																2·66	5	2·66	2
																2·55	20	2·56	35
																2·50	30	2·51	50
																2·39	20	2·39	15
																2·32	60	2·32	95
																2·21	10	2·21	15
																2·18	<5	2·18	2
																2·14	<5	2·13	2
																2·11	<5	2·10	5
																1·975	20	1·974	40
																1·895	5	1·896	10
																1·854	10	1·852	15
																1·789	10	1·790	10
																1·649	30	1·650	50

* Broad diffuse peaks.

(1) Borehole 65, Redburn Mine, Rookhope, Durham. (2) Londonderry, Western Australia; Cookeite in pegmatite (J.C.P.D.S., 1974, pp. 16–363); see Brown & Bailey (1962). (3) Redburn Mine, Rookhope, Durham. (4) North Wear Tunnel, Frosterley, Durham. (5) Thingdon Mine, Finedon, Northamptonshire, see Brindley (1951). (6) Ironstone beds, Frodingham, Lincolnshire; see Brindley (1951). (7) Groverake Mine, Rookhope, Durham. (8) Kaolin-sandstone deposits, Pugu Hills, Tanganyika; see Robertson *et al.* (1954). (9) Stonecroft Mine, Newbrough, Northumberland. (10) Geneva Mine, Michigan; see Bailey (1963).

preclude an association with the dyke, since siderite is a characteristic member of the hydrothermal mineral suite that post-dates this intrusion. No other lithium minerals are known from the orefield.

Berthierine

Berthierine-chamosite has been found in vein workings of all the operating Weardale fluorspar mines. It was identified from X-ray diffraction patterns obtained using iron-filtered, cobalt radiation and a Debye-Scherrer camera (see Table 1). It usually occurs as dark, olive green coatings on vugh and vein minerals, and vein breccias, throughout the stratigraphical ranges of the mines. Very rare pockets of up to 3 g of berthierine have been found inside blocks of intergrown iron, lead and zinc sulphide minerals in the veins. At Redburn the mineral commonly coats breccias produced by post-mineralization faulting and at the North Wear Aqueduct Tunnel it commonly coats late 'nail head' calcite in vughy ground, as well as coating earlier quartz and siderite in veins. Open, water-bearing fissures alongside fluorite–quartz–pyrrhotite–pyrite veins at Cambokeels Mine are also lined with berthierine. These particular occurrences suggest that berthierine might be unrelated to the primary mineralization, but has been deposited from groundwaters percolating through the veins and remobilizing iron and silica from the vein minerals.

Kaolinite

A well-defined veinlet containing 4 cm of pure, white kaolinite branches from the wall of the Middle Groverake Vein in the Firestone Sublevel, Groverake Mine. The occurrence is near the top of the thick, quartzose Firestone Sandstone, about 65 m below surface. Other occurrences in the same area had been seen by miners, but not collected. Euhedral fluorite (with a fluid inclusion formation temperature of 165°C), coated with spherules of marcasite, lines the veinlet walls. X-ray diffraction data (Table 1) from cavity mounted samples, showed that the kaolinite is a poorly crystalline variety and the pattern produced was very similar to a *b*-axis disordered kaolinite described by Robertson *et al.* (1954). The only impurities detected were fluorite and marcasite.

Normal vein- and fault-gouges in the Firestone Sandstone contain abundant illite, some muscovite and minor smectite, with no kaolinite. This is, therefore, an unusual occurrence.

Dickite

Tough, turquoise dickite fills cavities up to 1 cm across in some specimens of calcite–galena—sphalerite veinstuff from the old Stonecroft Mine dump. Identification was by X-ray diffraction, using nickel-filtered copper radiation (Table 1). The mineral has a radiating habit and is clearly seen to be the final phase to have been deposited. There is no indication as to its source, but it is interesting that dickite associated with lead–zinc–fluorite–barite mineralization also occurs in the Magnesian Limestone of eastern Durham (Fowler, 1957).

ACKNOWLEDGMENTS

We thank the Department of Geological Sciences, University of Durham, for identification facilities and Mrs C. L. Mines for typing the manuscript.

17 Lambton Crescent,
Sedgefield,
Stockton on Tees,
Cleveland

F. W. SMITH

Department of Geological Sciences,
University of Durham,
South Road,
Durham,
UK

R. G. HARDY

23 April 1980; revised 25 November 1980

REFERENCES

BAILEY S.W. (1963) Polymorphism of the kaolin minerals. *Am. Miner.* **48,** 1196–1209.

BRADLEY W.F. & GRIM R.E. (1961) Mica clay minerals. Pp. 208–241 in: *The X-ray Identification and Crystal Structures of Clay Minerals* (G. Brown, editor). Mineralogical Society, London.

BRAMMAL A., LEECH J.G.C. & BANNISTER F.A. (1937) The paragenesis of cookeite and hydromuscovite associated with gold at Ogofau, Carmarthenshire. *Miner. Mag.* **24,** 507–520.

BRINDLEY G.W. (1951) The crystal structure of some chamosite minerals. *Miner. Mag.* **29,** 502–525.

BROWN B.E. & BAILEY S.W. (1962) Chlorite polytypism: I. Regular and semi-random one layer structures. *Am Miner.* **47,** 819–850.

DUNHAM K.C. (1948) *Geology of the Northern Pennine Orefield,* **1,** HMSO, London.

DUNHAM K.C., FITCH F.J., INESON P.R., MILLER J.A. & MITCHELL J.G. (1968) The geochronological significance of argon-40/argon-39 age determinations of white whin from the northern Pennine orefield. *Proc. R. Soc. A.* **307,** 251–266.

FOWLER A. (1957) Minerals in the Permian and Trias of north-east England. *Proc. geol. Assoc.* **67,** 251–265.

J.C.P.D.S. (1974) *Selected Powder Diffraction Data for Minerals* (L. G. Berry, editor). Joint Committee on Powder Diffraction Standards. 1601 Park Lane, Swarthmore, Pennsylvania 19081, U.S.A.

ROBERTSON R.H.S., BRINDLEY, G.W. & MACKENZIE R.C. (1954) Mineralogy of kaolin clays from Pugu, Tanganyika. *Am. Miner.* **39,** 118–138.

YODER H.S. & EUGSTER H.P. (1955) Synthetic and natural muscovites. *Geochim. Cosmochim. Acta,* **8,** 225–280.