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KEYWORDS: fractional crystallization, partial melting.

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Hetaerolite from Eastern Cliff, Kennack Sands, Cornwall: the first British occurrence

HETAEROLITE ($ZnMn_2O_4$) is a relatively rare mineral, having been reported from only a few localities world-wide. It was first described from Sterling Hill, New Jersey, associated with chalcophanite by Moore (1877), who considered it to be the zinc analogue of hausmannite. In a subsequent examination of the Sterling Hill material, Palache (1910) identified a hydrous phase, hydrohetaerolite. Other reports of hetaerolite from North America include those from the Lucky Cuss Mine, Tombstone, Cochise County, Arizona (Butler *et al.*, 1938; Rasor, 1939; Hewett and Fleischer, 1960), Franklin Mine, New Jersey and Leadville, Colorado (Frondel and Heinrich, 1942), the Domeroy Property, Pioneer District, Pinal County, Arizona (Dean *et al.*, 1952), Contact Mine, Grant County, New Mexico (Hewett and Fleischer, 1960), 79 Mine, Banner District, Gila County, Arizona (Keith, 1972), Bisbee, Arizona (Graeme, 1981) and Mohawk Mine, San Bernardino, California (Pemberton, 1983). The first description of a European occurrence of hetaerolite was probably that by Udubasa *et al.* (1973) for material from the Pb-Zn deposit at Rodna, Romania. More recently, hetaerolite, associated with smithsonite, has been reported from Moesnet, Belgium (Fransolet and Mélon, 1975). A brief review of hetaerolite occurrences is presented by Frenzel (1980). The present paper reports the first British occurrence of the mineral.

Occurrence. During the course of a systematic study by one of us (VH) of the extensive secondary mineral veins which cut serpentinized peridotites of the Lizard Complex, small, black crystals of hetaerolite were collected from an area of Eastern Cliffs (at National Grid Reference SW 74251665), in the neighbourhood of Kennack Sands. The hetaerolite-bearing veins are thin, usually no wider than 4 cm, typically planar, and are generally of NE-SW orientation, although this is quite variable. They extend laterally for a maximum distance of about 30 m before thinning and terminating. The veins occur in different forms. Some are composite in that they are made up of a series of parallel-sided discrete veins, others are anastomosing, and several bifurcate. They are composed mostly of a soft, white, fine-grained to massive mineral shown by X-ray diffraction to be lizardite. Calcite predominates in some of the veins. Other veins which also cut the serpentinized peridotite contain hematite.

Description. During the course of this work hetaerolite was initially identified in a lizardite vein, up to 2 mm thick which cuts serpentinized peridotite. Individual hetaerolite crystals within this vein are small, generally less than 0.75 mm across. Subsequently, however, other veins from the same locality were shown to contain crystal aggregates up to 4 mm across which, in places, have coalesced to form irregular lenses of hetaerolite parallel to the length of the vein and up to 9 mm long. Because hetaerolite is more resistant to weathering than lizardite, hetaerolite crystals stand out on exposed surfaces. The crystals are black, opaque and have a sub-metallic lustre. Individual crystals are octahedral, and show well-developed faces, whilst crystals within aggregates commonly show twinning.

Results. Hetaerolite crystals from Kennack Sands were initially examined using a JEOL 35 CF scanning electron microscope equipped with an energy-dispersive analyser, and operated at 21 kV, in the Department of Metallurgy and Materials Science, University College, Cardiff. The ED X-ray spectrum of the mineral showed peaks due to Zn and Mn. The crystals were also analysed at the British Museum (Natural History) using X-ray and electron-microprobe techniques. The X-ray powder

TABLE 1. Electron-microprobe analyses of hetaerolite from Kennack Sands

	wt%*	range+	Number of ions on the basis of 4 oxygens
Mn_2O_3 [a]	67.2	66.3 - 68.1	Mn 2.0260
ZnO	32.6	31.7 - 33.0	Fe 0.0048
Fe_2O_3 [b]	0.17	0.09 - 0.21	Zn 0.9537
Total	99.97		

Analyst F. Wall

* Average of 9 analyses from NMW 85.71G.M1a.

\+ Range of 9 analyses from NMW 85.71G.M1a.

[a] Total Mn as Mn_2O_3

[b] Total Fe as Fe_2O_3

diffraction pattern matches the PDF data for hetaerolite. A polished grain mount was analysed using a Cambridge Instruments Microscan MK9, operated at 20 kV and 2.5×10^{-8} A, and using pure iron, zinc and manganese as standards. Results are shown in Table 1. As well as the major elements Zn and Mn, Fe was detected in all analyses of the Kennack Sands hetaerolite; no other elements were detected. The average of nine analyses is in close agreement with the analysis of material from Sterling Hill presented by Palache *et al.* (1944). Material from both localities contains less zinc than that from Rodna (Udubasa *et al.*, 1973). Hetaerolite from Kennack Sands, like that from Sterling Hill, is slightly deficient in zinc relative to the composition expected from the idealized formula, and total Mn increases to cover this deficiency in Zn (Table 1).

Association. So far as we are aware, the association of hetaerolite with lizardite ± calcite in serpentinized peridotite at Kennack Sands is unique. In other reported occurrences hetaerolite is a secondary mineral in the weathered zone of primary Zn-bearing sulphide deposits, as at Sterling Hill, New Jersey (Moore, 1877), Franklin, New Jersey and Leadville, Colorado (Frondel and Heinrich, 1942) and Rodna, Romania (Udubasa *et al.*, 1973). In the present case the source of the Zn and Mn is not known. There are no Zn-bearing ore bodies recorded in the Lizard area, and no other Zn-bearing mineral species have been identified in the veins of the Kennack Sands area. Nevertheless, the occurrence described here shows that hetaerolite is not restricted to areas of primary zinc ore bodies, and that its distribution might be more widespread than previously considered.

The original specimen of lizardite with hetaerolite in serpentinized peridotite, 8 × 7 × 1·5 cm, was broken into four pieces. Three pieces are registered in the mineral collection of the National Museum of Wales as NMW 85.71G.M1a-c and one in the mineral collection of the British Museum (Natural History) as BM 1985, 355.

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