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Mineralization at Le Pulec, Jersey, Channel Islands; No. 1 Lode

THE No. 1 Lode is the westernmost and most extensive of three lead–zinc veins cutting Brioverian sediments at Le Pulec. It was described by Williams (1871) as being between 1.5 and 1.8 m in width and 183 m in length, with a trend of 340°, and the galena was reported to have a high silver content. Since the investigation of the No. 3 Lode (Ixer and Stanley, 1980) it has been possible to examine several specimens, collected from the recently rediscovered No. 1 Lode.

As with the No. 3 Lode, two main mineralization episodes can be distinguished. The earlier of these is a pyrite–marcasite–arsenopyrite episode associated with minor quantities of galena, sphalerite, and chalcopyrite, occurring in thin veins in the metasediments. Sphalerite, galena, tetrahedrite, pyrite, and bournonite occur in the later episode with minor chalcopyrite and native antimony associated with a quartz gangue. The primary opaque minerals have been extensively altered to secondary sulphides and carbonates.

The mineralogy of the No. 1 Lode is based on a study of hand specimens and polished sections, and is described in its suggested paragenetic sequence.

Detrital minerals within the metasediments

The Brioverian sediments contain 60–75 μm euhedral zoned zircons, some of which have small (< 1 μm chalcopyrite inclusions and relict skeletal laths of iron titanium oxide minerals.

Mineralization within the Brioverian sediments

Anatase is common within the sediments as 2–10 μm anhedral grains associated with silicates or as 10×2 μm laths, parallel to the basal cleavage of the altered phyllosilicates, particularly muscovite. Anatase is also found with hematite laths (20×2 μm) included in early pyrite grains. A coarse-grained (600×20 μm) generation of anatase or rutile is included in and replaced by a coarse-grained pyrite.

Minor quantities of *pyrite* are present along basal cleavages of the phyllosilicates or form small (20–70 μm) subhedral to euhedral grains in the thin quartz veins which cut the sediments. However, most of the pyrite occurs as large fractured grains, subsequently recemented by quartz, or by minor amounts of galena. This pyrite encloses hematite laths, anatase, rutile, minute inclusions (< 2 μm) of pyrrhotine and marcasite (2–5 μm), gàlena (< 5–30 μm), and sphalerite (< 10–20 μm). It is commonly surrounded by a spongy pyrite rim (< 60 μm) and by arsenopyrite. Pyrite also occurs intergrown with *marcasite*, forming shattered tabular aggregates that are cemented and replaced by galena. The marcasite displays twinning and anisotropy boundaries perpendicular to the length of the tabular aggregate.

Arsenopyrite is present mostly as rhombs (20–80 μm) or lath-shaped grains ($< 400 \times 20$ μm) that surround the coarse-grained pyrite. The rhombs are fractured and cemented by galena. Arseno-

pyrite is extensively oxidized to limonite and other secondary minerals. *Galena* in minor quantities cements anatase and rutile, and cements and replaces arsenopyrite, pyrite, and marcasite.

Main mineralization of Lode No. 1

Sphalerite is the major sulphide within the lode and also the earliest; it has a consistently low iron content, less than 4.2 mole % FeS (Table I). Inclusions of rod-shaped tetrahedrite, which show a crystallographic orientation with respect to the sphalerite, are common; however, inclusions of chalcopyrite are rarely found. Sphalerite is cut by very thin (< 1 μm) veinlets of chalcopyrite, galena, and tetrahedrite, and by discontinuous thin pyrite veins. It is also found as 20–120 μm rounded grains intergrown with galena, tetrahedrite, and bournonite. Inclusions of sphalerite in bournonite are surrounded by a 10–20 μm wide chalcopyrite rim. Sphalerite alters to covelline along its cleavages, but is more commonly replaced by tabular smithsonite enclosing relict sphalerite and covelline flecks.

Isolated euhedral crystals of *pyrite* (< 60 μm) occur within sphalerite, these are commonly zoned and this is exhibited by fine gangue inclusion trails. Pyrite is also seen as discontinuous veinlets 2–20 μm wide and up to 300 μm long that cut across sphalerite or are preferentially alligned along its cleavages. Pyrite is also found in galena, as subhedral grains or as framboids, particularly near to sphalerite grain boundaries. Galena, and to a lesser extent sphalerite and tetrahedrite, replace pyrite giving a sieve-like texture.

Tetrahedrite is common as oriented rods up to 20×2 μm within sphalerite, as thin veinlets along the cleavage and fractures of sphalerite, or as wider (< 20 μm) veins associated with galena and chalcopyrite. It occurs as large subhedral grains (< 500 μm) around the main sphalerite and may form complex intergrowths with chalcopyrite and bournonite (< 100 μm). It commonly has small (2–10 μm) chalcopyrite, sphalerite, galena, bournonite, and pyrite inclusions. In all these associations there is little difference in tetrahedrite's silver content, which shows a narrow range from 6.7–8.4 wt. % Ag. Tetrahedrite has been extensively replaced by galena, and is also found as 2–10 μm inclusions in chalcopyrite. It alters to bournonite and covelline.

Minor amounts of *native antimony* (confirmed by semi-quantitative electron probe microanalysis) occur as thin 1–2 μm veinlets in tetrahedrite and within chalcopyrite, galena, and bournonite. Isolated grains (< 5 μm) occur together with anhedral grains of sphalerite and tetrahedrite in quartz.

Chalcopyrite occurs as rounded inclusions (1–2 μm) in sphalerite or as veinlets, sometimes associated with galena and tetrahedrite, which cut the main sphalerite. Chalcopyrite (< 200 μm) is also found around the main sphalerite where it encloses galena (< 10 μm), tetrahedrite (< 40 μm), and sphalerite (< 10 μm), and minor amounts of pyrite, marcasite, bournonite, and native antimony. It is commonly altered at grain boundaries to bornite and covelline.

Bournonite is closely associated with galena. Commonly, it occurs as rounded inclusions (20–75

TABLE I. *Electron microprobe data—Le Pulec No. 1 Lode*

Mineral species	Cu	Ag	Fe	Zn	As	Sb	S	Total	
Tetrahedrite	32.0	7.4	4.1	3.2	0.3	29.3	23.3	99.6	along fracture in sphalerite
	31.9	6.7	3.8	4.2	0.1	29.0	23.6	99.3	adjacent to bournonite
	32.3	8.4	4.1	3.4	—	29.2	23.8	101.2	oriented rods in sphalerite
	31.6	7.7	3.6	3.1	0.5	28.8	23.2	98.5	rounded grains in galena
			Pb	Cu	As	Sb	S		
Bournonite			44.8	12.8	—	25.0	18.1	100.7	large bournonite
			45.3	12.4	—	24.9	18.1	100.7	inclusion in galena
			Zn	Fe	Cd	Cu	Mn	S	
Sphalerite			64.8	2.4	0.5	0.2	—	32.2	100.1	main sphalerite adjacent to tetrahedrite
			64.2	2.2	0.4	0.2	—	32.6	99.6	sphalerite inclusion in bournonite

Instrument: Cambridge Instruments Microscan Mk. 9.   Accelerating voltage: 20 kV
Radiations: Cu-$K\alpha$, Ag-$L\alpha$, Fe-$K\alpha$, Zn-$K\alpha$, As-$K\alpha$, Sb-$L\alpha$, S-$K\alpha$, Pb-$L\alpha$ Analyses in wt. %
Standards: Pure elements and PbS, FeS.

μm) and displays its characteristic parquet twinning. Bournonite encloses pyrite, sphalerite, native antimony, tetrahedrite, chalcopyrite, and galena. Small amounts are intergrown with sphalerite, chalcopyrite, and galena around the main sphalerite, or form thin rims around tetrahedrite in galena, or occur together with chalcopyrite as rims surrounding tetrahedrite in sphalerite. It alters to covelline, blaubleibender covelline, bornite, and limonite. Analyses are given in Table I.

Galena is the second most abundant sulphide after sphalerite, which it cements. Thin veinlets (1–2 μm) cut sphalerite, and it also occurs in veins with tetrahedrite and chalcopyrite which cut the main sphalerite. Galena encloses and replaces fractured pyrite, tetrahedrite, marcasite, arsenopyrite, and bournonite. It is altered to bournonite (2–5 μm rims), covelline ($< 50 \times 10$ μm aggregates), cerussite, and anglesite. A later generation of galena appears to be associated with the alteration of the primary sulphides. It occurs as 1–5 μm grains, botryoidal in texture, associated with colloform pyrite and enclosed within cerussite and anglesite.

Colloform pyrite occurs as thin veinlets (100 × 4 μm) consisting of 2–4 μm grains associated with alteration minerals around the main sphalerite, and along its cleavage. Isolated grains occur up to 5–20 μm, or it occurs as framboids (< 20 μm).

Bornite occurs as rims (< 30 μm) around altered bournonite, sphalerite, and tetrahedrite, and is itself altered to *covelline*. The latter occurs as patches of bladed crystals (< 50–60 μm) or forms fine-grained aggregates replacing galena and sphalerite at grain boundaries and along cleavages. Covelline pseudomorphs small (5–10 μm) grains of chalcopyrite, sphalerite, and tetrahedrite, or forms alteration rims 10–20 μm in width at their margins.

Smithsonite, *cerussite*, and *anglesite* replace galena and sphalerite and form crystals up to several millimetres across, where developed in cavities. Relict galena and sphalerite occur within these grains in addition to flecks of covelline.

It might be expected that closely related veins, such as the No. 1 and No. 3 Lodes at Le Pulec, would show broad chemical and mineralogical similarities. For the most part this is true, but there are also significant differences between the lodes which can be summarized as follows: (i) there is no dolomite or calcite gangue in the No. 1 Lode; (ii) grains of tetrahedrite and bournonite in the No. 1 Lode are considerably larger than those seen in the No. 3 Lode; (iii) no plagionite or stibnite has been detected in specimens from the No. 1 Lode, and native antimony is much less common than in the No. 3 Lode; (iv) no cubanite has been observed in the No. 1 Lode and there is less chalcopyrite than in the No. 3 Lode; (v) tetrahedrite from the No. 1 Lode has a lower silver content (6–8 wt. % Ag) than that from the No. 3 Lode (9–20 wt. % Ag), and a correspondingly higher copper content.

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Lattice parameters and composition limits of mixed Mg–Al hydroxy structures—a discussion

WE wish to thank Professor Brindley (pers. comm.) for drawing our attention to the differences in lattice parameters and the limiting values of composition between synthetic hydroxy carbonates of Mg, Al (Brindley and Kikkawa, 1979), and synthetic hydroxide structures of Mg, Al (Mascolo and Marino, 1980). The lattice parameter values for different Mg, Al ratios in the two studies are different, and in particular $\Delta a/\Delta x$ with $x = \text{Al}/(\text{Al} + \text{Mg})$ is noticeably lower for plain hydroxides (fig. 1, Brindley, 1980).

Comparing the syntheses in the two studies, no