

# Silver mineralization at Sark's Hope mine, Sark, Channel Islands

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**ABSTRACT.** Sark's Hope silver-lead lode, which was mined during the 1830s and 1840s cuts a Late Precambrian granite at the southernmost point of the island of Sark. The primary ore assemblage is pyrite, galena, chalcopyrite, tennantite, tetrahedrite, sphalerite, marcasite, arsenopyrite, pyrrhotine, bravoite, enargite, and the silver minerals pyrrargyrite, pearceite, polybasite, and acanthite. Gangue minerals are hematitic quartz, calcite, and illite. Alteration products include chalcosine, covellite, blaubleibender covellite, limonite, malachite, azurite, cerussite, and anglesite. The generalized paragenesis is of early Fe, Co, Ni, As, and S species and later minerals of Pb, Cu, Ag, Zn, Fe, As, Sb, and S. The earliest alteration products are copper sulphides; these are followed by lead and copper carbonates and sulphates, and hydrated iron and manganese oxides. Growth zoning is a common feature of many of the ore minerals, and electron microprobe analysis shows that this is sometimes related to compositional differences. Tetrahedrite and tennantite, particularly, exhibit a wide range of compositions.

THE small island of Sark, about 10 km east of Guernsey, was a site of active mining and exploration during the middle of the nineteenth century. Of all the mineral prospects on the island Sark's Hope mine on Little Sark was the most important and, indeed, was the only metalliferous mine in the Channel Islands to produce significant amounts of ore. The most comprehensive account of the mineralization and mining history is that of Mourant and Warren (1934), which includes sections and maps of Sark's Hope mine and an extensive list of mineral species. Their work is largely a review of early accounts by Prince (1846) and Henwood (1871a, b), supplemented by reports of the mining from the local press. A more recent systematic mineralogical and paragenetic study is that of Bishop *et al.* (1977) on one specimen, BM 1964R, 440 from the Russell Collection in the British Museum (Natural History).

The lead-silver-bearing vein, 'Sark's Hope Silver-Lead lode', cuts a foliated hornblende granite of Late Precambrian age (Sutton and Watson, 1957). Although there is little trace of the vein today, with the outcrop workings being mostly obscured by a thick cover of vegetation, the early accounts describe it as 0.4 to 2.5 m in width, more than 600 m in length, oriented 028-037° and dipping at 65-85° to the northwest.

Small amounts of *in situ* ore were obtained from the poorly exposed and weathered parts of the vein at the southwestern end, but most of our specimens were collected from the spoil tips, in particular from Le Pelley's shaft tip at the northeastern end of the lode. Additional material was obtained from the Guernsey Museum collection, and the specimen in the British Museum (Natural History) collection BM 1964R, 440 was re-examined. Forty-three polished sections and five polished thin sections were investigated by reflected and transmitted light microscope techniques. Selected sulphides and sulphosalts were analysed by electron microprobe, and some secondary minerals were identified by X-ray diffraction.

The present study forms part of a general investigation of the mineralization of the Channel Islands.

## Mineralogy

The host-rock is a coarse-grained granitic rock with major hornblende, plagioclase and orthoclase feldspars, and quartz, and it is cut by numerous quartz-epidote veinlets. Adjacent to the vein the rock is intensely altered to quartz, sericite, chlorite, and calcite. Brecciated fragments of this altered granite are contained within the ore, cemented by rhythmically banded pyrite, hematitic quartz, and

galena, or by mixed grains of galena, euhedral pyrite, and quartz.

The primary ore consists predominantly of pyrite and galena. In some specimens, chalcopyrite and members of the tennantite-tetrahedrite group are common, and there are subordinate quantities of sphalerite and marcasite. Minor amounts of

bravoite, enargite, pyrrargyrite, pearceite, polybasite, acanthite, pyrrhotine, and arsenopyrite occur. Gangue minerals are hematitic quartz, calcite, and illite. Chalcosine, covellite, blaubleibender covellite, limonite, malachite, azurite, cerussite, and anglesite have formed as alteration products of the primary ore minerals.

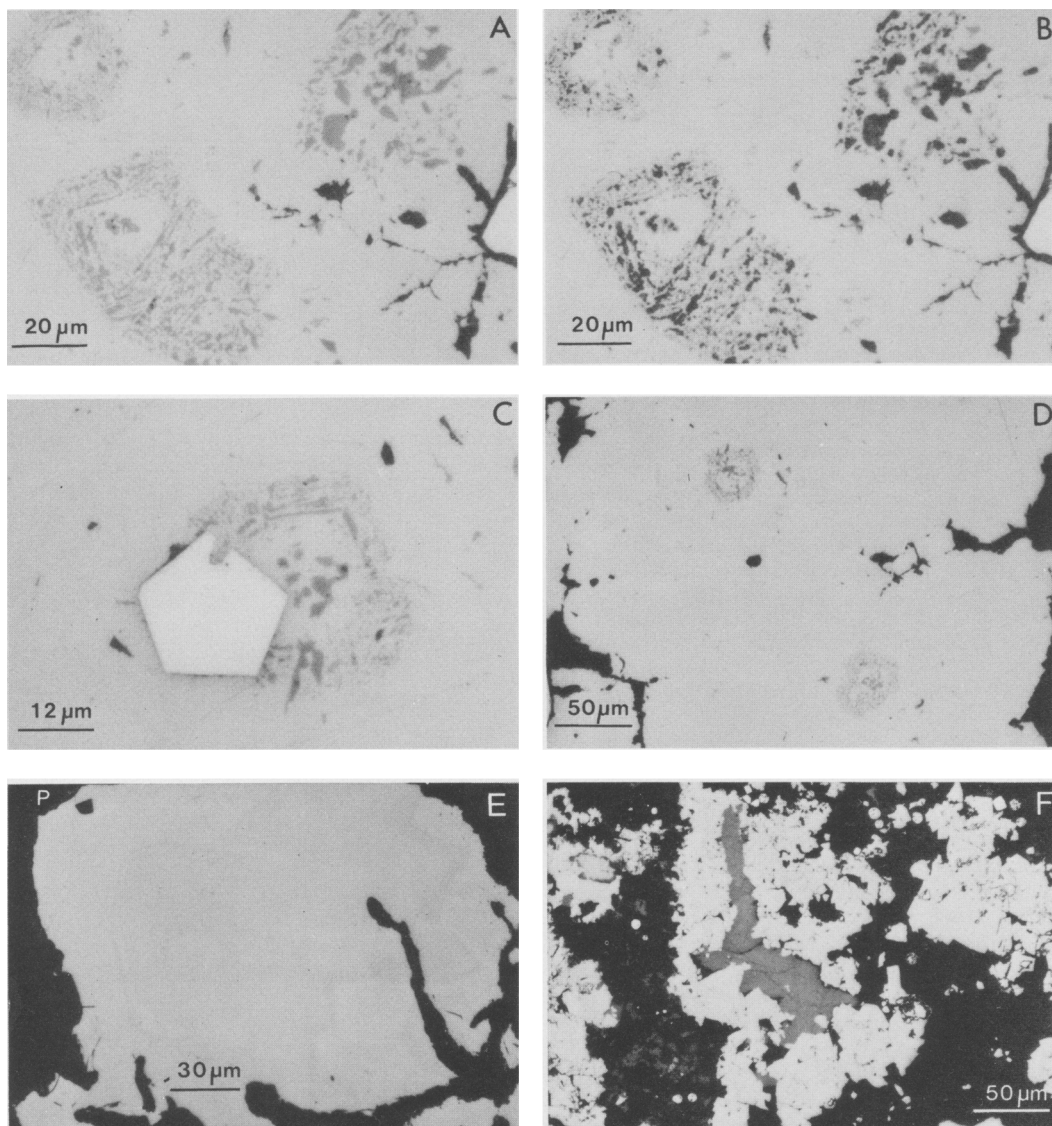


FIG. 1. Reflected light photomicrographs; plane polarized light with oil immersion. A. Intergrowths of polybasite (grey) in galena (light grey). E. 598. B. As for A but polybasite shows light-etching (after 10 minutes exposure to the quartz-iodide microscope lamp). C. Skeletal polybasite intergrowth in galena. Polybasite may have nucleated on euhedral pyrite (white). E. 598. D. Oriented aggregates of polybasite grains form the cores of galena grains. E. 598. E. Zoning, demonstrated by reflectance differences, in 'plumbian tennantite'. BM 1964R, 440. F. Pyrrargyrite (grey) with minor tetrahedrite (dark grey inclusions in black gangue) and chalcopyrite (white). SH.1.

TABLE I Electron microprobe analyses - Sark's Hope Lode.

		wt %														
Mineral species		Cu	Ag	Fe	Zn	Hg	As	Sb	S	Total	Spec. No.					
1	Polybasite	3.0	73.2	0.1	0.3	-	-	10.3	12.8	99.7	E.598					
2	Pearceite	1.9	76.2	0.2	0.1	-	5.7	-	14.1	98.2	S6 5/80					
3	Pyrargyrite	1.6	61.3	-	-	-	-	22.0	15.6	100.5	SH 1					
4		1.4	60.0	-	-	-	-	22.6	15.7	99.7						
5		0.6	58.7	-	-	-	-	24.2	16.1	99.6						
6	Acanthite	1.5	85.3	-	-	-	3.0	0.2	10.1	100.1	S6 5/80					
7	Enargite	44.5	3.9	-	-	-	18.3	1.3	31.4	99.4	S6 5/80					
8		44.4	1.5	-	-	2.6	18.7	1.4	30.6	99.2						
		Cu	Ag	Fe	Zn	Cd	Hg	Pb	Bi	As	Sb	S	Total	Spec. No.		
9	Tennantite/ tetrahedrite	42.7	0.4	2.2	4.6	0.3	-	0.1	-	10.9	12.6	26.6	100.4	E.600	BM 1964, B440	margin
10		43.2	0.6	1.5	4.2	-	-	1.8	0.9	15.1	7.2	26.9	101.4			
11		43.2	1.8	1.2	2.0	-	-	4.4	-	11.5	9.7	25.7	99.5			
12		40.0	6.5	1.3	1.9	-	-	5.5	-	11.7	9.2	25.4	101.5		core	
13		42.4	1.5	2.4	3.1	-	-	0.7	-	11.7	10.6	26.2	98.6			
14		41.8	1.4	2.0	3.7	0.4	-	2.0	-	14.2	6.8	26.6	98.9		incl. in gn	
15		35.7	6.4	1.9	4.9	-	-	2.9	-	16.0	6.1	26.4	100.3		incl. in gn	
16		35.7	7.9	2.6	3.9	0.2	-	1.3	-	17.5	3.3	26.8	99.2			
17		38.7	1.4	0.9	7.1	-	-	-	-	3.7	23.7	25.2	100.7			
18		38.4	0.9	1.2	6.5	-	-	-	-	2.7	25.0	25.3	100.0		incl. in cpy	
19		38.4	3.5	2.3	4.2	0.1	2.0	-	-	9.6	14.1	25.6	99.8	S6 5/80		incl. in cpy
20		38.6	1.4	2.4	4.4	-	-	-	-	4.5	23.3	25.4	100.0			
21		41.1	1.1	2.0	5.0	-	-	-	-	8.9	15.3	26.2	99.6			incl. in cpy
22		40.9	0.7	1.7	5.5	-	-	-	-	9.0	16.3	26.5	100.6			incl. in cpy
23		40.1	1.3	2.3	2.7	2.9	1.1	0.7	-	9.3	12.4	26.0	98.8			
24		34.4	9.5	1.9	3.7	0.6	2.3	-	-	6.8	17.3	24.2	100.7			
25		34.0	10.0	2.0	3.1	3.0	1.3	0.2	-	9.2	12.8	24.4	100.0			incl. in cpy
26		30.8	13.1	2.7	4.1	1.2	3.0	1.4	-	7.5	15.2	22.6	101.6			
27		27.2	17.9	2.2	4.3	1.2	0.3	-	0.4	7.1	14.6	24.1	99.3			incl. in cpy
28		24.9	20.2	1.4	4.5	0.5	1.1	0.1	-	10.0	12.5	24.1	99.3			
29		22.9	21.5	0.8	6.2	-	-	-	-	4.5	20.5	23.2	99.6	E.598		incl. in cpy
30		21.9	23.2	1.0	5.0	-	-	-	-	0.5	25.8	21.9	99.3			
31	Galena	38.4	0.9	0.7	6.8	-	-	-	-	3.0	24.3	25.4	99.5	E.598		incl. in cpy
32		38.3	1.0	1.7	6.2	-	-	-	-	2.4	25.6	25.1	100.3			
33		6.2	45.1	1.4	4.8	0.9	-	1.8	-	8.5	12.0	20.5	101.2	SH1 17/80		incl. in gn
34		6.5	44.9	1.4	3.6	1.6	1.9	2.5	-	11.1	6.5	20.4	100.4			
35		16.0	30.7	5.1	1.0	-	-	-	-	-	27.6	19.9	100.3			
36	Galena	-	0.2	-	-	-	-	86.1	-	-	0.2	12.7	99.2	E.598		'normal' lower reflectance
37		-	0.5	-	-	-	-	86.8	-	-	0.4	12.6	100.3			
38	Sphalerite	-	-	4.0	62.8	-	-	-	-	-	33.1	99.9	S6 5/80	E.600		
39		0.4	0.3	0.9	66.3	-	-	-	-	-	0.5	32.5	100.9			
40	Chalcopyrite	33.6	-	30.5	-	-	-	-	-	0.4	0.3	34.7	99.5	E.600		
		Cu	Fe	Ni	Co	As	S	Total	Spec. No.							
41	Pyrite	0.1	45.1	-	0.1	4.5	49.9	99.7	E.598	margin						
42		0.1	44.9	0.1	0.1	5.5	49.2	99.9								
43	Bravoite	2.2	13.9	10.7	20.4	1.3	50.9	99.4	SH 1	core						
44		3.4	14.2	10.2	16.4	2.6	51.2	98.0								

Instrument: Cambridge Instruments Microscan IX. Accelerating voltage: 20kV

Radiations measured: Cu-K $\alpha$ , Ag-L $\alpha$ , Fe-K $\alpha$ , Zn-K $\alpha$ , Cd-L $\alpha$ , Hg-L $\alpha$ , Pb-M $\alpha$ , Bi-M $\alpha$ , As-L $\alpha$ , Sb-L $\alpha$ , S-K $\alpha$ , Ni-K $\alpha$ , Co-K $\alpha$ 

Standards: Pure elements and FeS, HgS, PbS.

Analyses are for different grains except where bracketed.

Table I summarizes the electron microprobe data obtained from some of the Sark's Hope lode minerals. In the specimens studied, Ag is present as an essential constituent of the minerals acanthite, pearceite, polybasite, and pyrargyrite. It substitutes for Cu and other elements in the minerals enargite, tennantite-tetrahedrite, sphalerite, and galena. *Polybasite* occurs as fine-grained blebs and elongate grains (1–10  $\mu$ m) which commonly form oriented aggregates (40–50  $\mu$ m across) in galena (fig. 1A–D). It was identified by its optical properties and chemistry, as the grains were too small for X-ray identification. In association with galena it appears

pale greenish grey with no observable birefractance, but a distinct anisotropy, the rotation tints being slate-grey to brown. It is strongly susceptible to etching by light from the quartz-iodide microscope lamp. At normal illumination, etching begins within a few seconds at grain boundaries with galena, and along fractures, and proceeds rapidly until, after a period of several minutes, alteration is almost complete and only holes are left (fig. 1B). Polybasite, along with a number of other minerals with a high Ag content, has a tendency to disintegrate in the electron beam (owing to phase changes induced by heat) and, therefore, short counting times were

employed, as the beam could not be defocused on account of the small grain size of the mineral. The analysis shows a minor Cu content (Table I, 1), but no As substituting for Sb. *Pearceite*, the arsenic member of the pearceite-polybasite solid-solution series, was identified in some sections, where it is associated with enargite as anhedral inclusions in galena. However, unlike polybasite, it does not form regular intergrowths with galena. Although pearceite has similar optical properties to polybasite, it is less susceptible to light etching and generally forms larger grains ( $< 50 \mu\text{m}$ ).

*Pyrargyrite*, more commonly found in the association chalcopyrite and tennantite-tetrahedrite (fig. 1F) than with galena, is distinguished from pearceite and polybasite by its strongly blue hue against the coexisting minerals and the presence of deep red internal reflections. It shows no light-etching properties over a period of several minutes. Some analyses indicate a minor copper content (Table I, 3–5). *Acanthite* (Table I, 6) is present in small grains ( $5\text{--}20 \mu\text{m}$ ), usually included in galena. It takes a poor polish and is also distinguished from pearceite and polybasite by its extreme sensitivity to light-etching.

*Enargite* commonly occurs as irregular grains in pearceite. It is strongly bireflecting in shades of grey and has a strong anisotropy, the rotation tints varying from blue to orange-red. Analyses (Table I, 7–8) show the presence of a small amount of Ag and Hg, apparently substituting for Cu, and a minor Sb content.

Electron microprobe analysis showed members of the *tennantite-tetrahedrite* series to have an extremely variable chemistry (Table I, 9–35) both within individual grains and between different sections. Some of the grains analysed could more properly be termed *freibergite*, although X-ray confirmation of this variety could not be made owing to the small grain size. In addition to Pb, which shows a tendency to substitute in the tennantite members of the series, minor amounts of Bi, Cd, and Hg were detected, mostly in tetrahedrite. Ag was found in all the analyses, with an apparent preference for tetrahedrite. The amounts of Bi, Cd, and Hg fall within the range of published analyses (Yushkin, 1978; Patrick, 1978; Boldyreva and Borodayev, 1973; Vasil'yev and Lavrent'yev, 1974). One of the analyses of plumbian tennantite has a higher Pb content (5.5 wt. % Pb) than that determined by Bishop *et al.* (1977)—4.64 % Pb. The two grains with very high Ag contents are comparable to the *freibergites* of Riley (1974), but ours have a high arsenic content. Few of the tennantite-tetrahedrite grains exhibited any qualitative variation in optical properties, although the plumbian tennantite in BM 1964R, 440 was

subtly colour-zoned in shades of bluish grey (fig. 1E). This colour zoning is reflected in the chemistry (Table I, 9–12); zones of higher reflectance tending to have higher silver and lead contents than lower reflecting zones.

*Galena* commonly contains zones of lower than normal reflectance ( $10\text{--}20 \mu\text{m}$  across) which follow the outlines of the skeletal intergrowths of polybasite. Electron microprobe analysis (Table I, 36–77) indicates that there is a detectable difference in the Ag and Sb contents of 'normal' galena and the lower reflecting zones. However, it is uncertain whether the zones are the result of sub-microscopic intergrowths of sulphosalts or whether they represent the lowering of the reflectance of galena by Ag and Sb in solid solution.

*Sphalerite* is generally iron-poor and exhibits yellow to brown colour variations. Darker sphalerite contains up to 7 mole % FeS, while lighter coloured sphalerite contains about 1.6 mole % FeS (Table I, 38–9). The minor Cu, Ag, and Sb in one of the analyses may possibly be due to sub-microscopic inclusions, or a sulphosalt inclusion immediately below the surface of the analysed area, rather than in solid solution. *Chalcopyrite* has a minor As and Sb content (Table I, 40) but Ag was not detected.

Some of the *pyrite* contains a significant amount of As. Where this type of pyrite is in the form of pentagonal dodecahedra, the core areas contain slightly more (5.5 wt. %) As than marginal areas (4.5 wt. %, Table I, 41–2). These As contents are close to that reported for collomorphic pyrite from Sark by Bishop *et al.* (1977). Variations in the As content are probably responsible for the observed slight colour differences between and within pyrite grains. Semi-quantitative analysis of late euhedral and framboidal pyrite gave an As content of about 0.5 wt. %.

*Bravoite* is strongly colour-zoned, but owing to its generally small grain size, and the narrow width of some of these zones ( $< 1\text{--}5 \mu\text{m}$ ), this could not be investigated in detail. Core zones of two bravoites (Table I, 43–4) show variations in the Cu, Co, and As contents.

#### Paragenetic interpretation

The paragenetic sequence is summarized in fig. 2. The host rock granite shows extreme alteration, with many of the original iron-titanium oxides altered to patches of fine-grained rutile and hematite intergrowths ( $50\text{--}100 \mu\text{m}$ ) some of which contain relict ilmenite cores. Recrystallized anatase is common, as small  $2\text{--}5 \mu\text{m}$  grains that lie along the cleavages of phyllosilicates; as aggregates ( $5\text{--}40 \mu\text{m}$  in diameter); or as euhedral grains ( $40\text{--}120 \mu\text{m}$ ) that

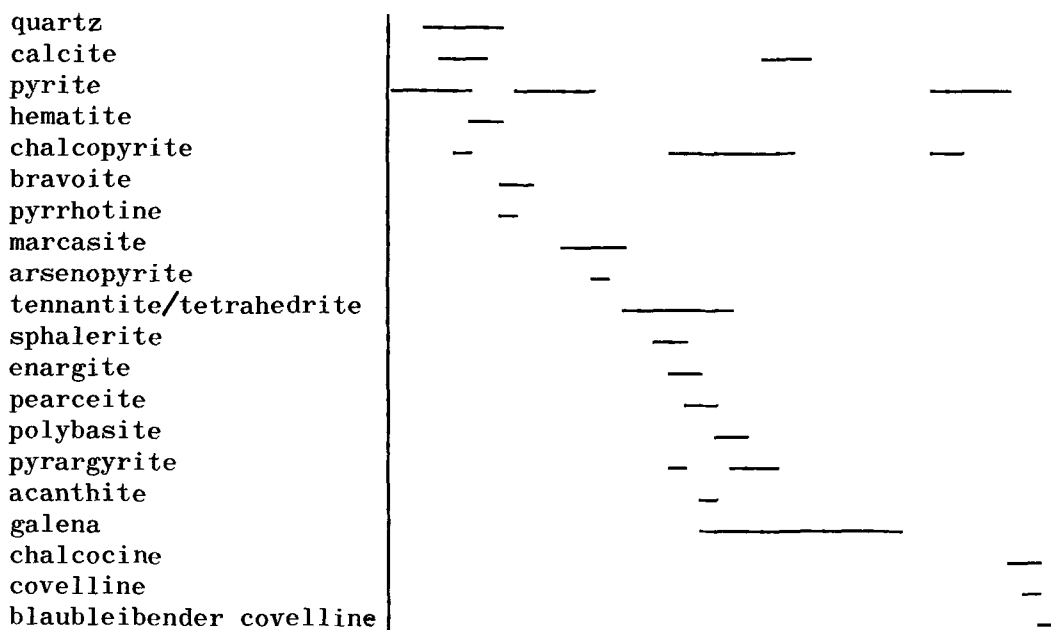


FIG. 2. Paragenetic sequence for Sark's Hope lode.

have infilled small voids. Anatase is found as inclusions in early pyrite and chalcopryite.

Early pyrite forms anhedral aggregates ( $< 1\text{--}2$  cm) and was the first sulphide deposited. This pyrite is intimately interbanded with hematitic quartz and both replaces and is replaced by quartz. Hematite inclusions in the quartz define growth zones and the fine acicular crystals ( $< 2 \times 10 \mu\text{m}$ ) often form radiating spheres ( $< 10\text{--}100 \mu\text{m}$  in diameter). Minor amounts of anatase, pyrite ( $10\text{--}30 \mu\text{m}$ ), and chalcopryite ( $10\text{--}20 \mu\text{m}$ ) are intergrown with this hematite. Pyrite and hematitic quartz fragments are cemented by later sulphides and sulphosalts.

Bravoite occurs either as inclusions in a second generation of pyrite which is associated with marcasite, or as inclusions in tetrahedrite-tennantite, chalcopryite, galena, and sphalerite. Pyrite of this generation is generally pentagonal dodecahedral in habit with pentagonal and hexagonal outlines in polished section. It has a variable As content resulting in hardness and colour variations. Growth zonation in the pyrite is marked by small inclusions of gangue minerals. In some of the larger pyrite crystals a change in habit from pentagonal dodecahedral to cubic is observed; in others, collomorphic pyrite forms overgrowths ( $10\text{--}100 \mu\text{m}$  in width). Pyrite is closely associated with marcasite, and contains inclusions of pyrrhotine, chalcopryite, and tennantite-tetrahedrite ( $2\text{--}10 \mu\text{m}$ ). Marcasite is less common than pyrite and

forms subhedral to euhedral bladed or rhombic grains ( $20\text{--}250 \mu\text{m}$ ) either enclosed in pyrite, or enclosing it. Colour zoning again probably reflects a variable arsenic content.

As a general observation (Table I), tetrahedrite members of the tennantite-tetrahedrite series are most closely associated with chalcopryite and sphalerite; the tennantite members of the series occur chiefly as inclusions in galena. Chalcopryite forms anhedral grains, or aggregates ( $40\text{--}350 \mu\text{m}$  in diameter) that cement and replace pyrite, bravoite, and marcasite. It also encloses and replaces tetrahedrite, sphalerite, and galena. Sphalerite forms irregular grains ( $40\text{--}200 \mu\text{m}$ ) intergrown with chalcopryite and tetrahedrite; it is not widespread as an inclusion in galena. Isolated sphalerite grains have narrow ( $< 20 \mu\text{m}$ ) tetrahedrite or chalcopryite rims. In some specimens tetrahedrite is found as inclusions in chalcopryite ( $< 250 \mu\text{m}$ ) or as rims ( $10\text{--}20 \mu\text{m}$ ) around chalcopryite or sphalerite. It is commonly associated with pyrargyrite which is later and replaces it. The boundary between pyrargyrite and tetrahedrite may be marked by numerous inclusions of acanthite ( $< 1 \mu\text{m}$ ). Pyrargyrite occurs as subhedral to euhedral grains ( $20\text{--}60 \mu\text{m}$ ) surrounding chalcopryite and tetrahedrite. An apparently later generation forms small inclusions ( $5\text{--}40 \mu\text{m}$ ) in galena, either along growth zones or irregularly distributed with enargite and pearceite. Tennantite is found as irregular inclusions

in galena, or forms a rim around pyrite. In the latter association (the plumbian tennantite of Bishop *et al.*, 1977) it may contain minute irregularly distributed inclusions of galena ( $< 1\text{--}2\text{ }\mu\text{m}$ ), which may possibly be the result of exsolution.

In addition to the anhedral inclusions of tennantite, galena has inclusions of many of the early minerals and enargite, pearceite, polybasite, acanthite, and pyrargyrite. Enargite is replaced by pearceite and in this association the two form tabular inclusions ( $< 150 \times 20\text{ }\mu\text{m}$ ) which have then been replaced by galena; enargite also occurs as smaller but more numerous lath-shaped inclusions ( $10\text{--}20\text{ }\mu\text{m}$ ) along galena growth zones. Pearceite either replaces enargite, or forms isolated anhedral inclusions randomly distributed in galena. Polybasite forms skeletal intergrowths with regular, commonly hexagonal, outlines which appear to be cores on which galena has subsequently been deposited, and which appear to have been replaced by galena to some extent. In some instances polybasite seems to have nucleated on euhedral pyrite (fig. 1C). Acanthite occurs as small irregular inclusions in galena, pyrargyrite, and pearceite.

Galena occurs as small grains ( $10\text{--}40\text{ }\mu\text{m}$ ) to large aggregates ( $< 2\text{--}3\text{ mm}$ ). The large grains of galena show growth zoning which is defined by differences in the reflectance, and by regularly oriented inclusions. The colour zoning is observed in generally thin ( $10\text{--}20\text{ }\mu\text{m}$  in width) bands of lower reflectance which occur in the galena surrounding skeletal polybasite and they mimic the euhedral outlines of the polybasite cores. These zones, which may be due to very fine-grained intergrowths of another mineral, are replaced by later secondary minerals preferentially to 'normal' galena.

Framboidal pyrite ( $10\text{--}30\text{ }\mu\text{m}$  in diameter) with euhedral ( $5\text{--}20\text{ }\mu\text{m}$ ) pyrite, and minor amounts of chalcopyrite form aggregates in secondary carbonates and sulphates at the margins and along fractures of chalcopyrite and galena.

Alteration of the primary sulphides and sulphosalts is extensive; galena and chalcopyrite are replaced

by thin rims of chalcosine. More commonly, chalcopyrite, sphalerite, and galena are replaced and pseudomorphed by covellite and blaubleibender covellite; subsequently there has been further alteration to cerussite, anglesite, smithsonite, azurite, and malachite. Both limonite and manganese oxides form veins cross-cutting earlier secondary minerals.

Briefly, although there is some evidence of alternating deposition of sulphides, the general sequence seems to be one of early Fe, Co, Ni, As, S minerals; later Pb, Cu, Zn, Ag, Sb, S minerals (with minor Hg, Cd, As, and Fe); finally, alteration and remobilization to form secondary oxidation products.

### Discussion

This study shows close agreement with that of Bishop *et al.* (1977) in the identity of some of the mineral species, their textural relationships, and the overall paragenesis. However, because it was possible to examine more ore specimens and collect in the field, a significant number of minerals, mainly Ag-bearing, can be added to their assemblage, and a greater variation in the composition of members of the tennantite-tetrahedrite group can be demonstrated. Our assemblage remains simpler in many respects to that given by Mournant and Warren (1934), but their list of minerals was taken from the early literature when material was more readily available and the differences may be explained by the limitations of our sampling, and by the lateral and vertical variations in the vein described by Henwood (1871a). This zoning is summarized in Table II. An oxidized gossan with carbonate, sulphate, and chloride derivatives lay above the primary Pb-Ag minerals in the southwestern part of the vein, and a similar gossan, although richer in Ag, lay above Pb-Ag-Cu ores in northeastern section. The reported Ag values suggest an increase in the Ag content of the ores both in depth and towards the northeast (Prince, 1846; Henwood,

TABLE II. Zoning of the ore from Sark's Hope Lode, based on the descriptions of Henwood (1871a) and Prince (1846)

	SW part of lode	NE part of lode
Surface	Ag $< 1\%$ . Cerussite, limonite, pyrite, minor galena, anglesite, cerargyrite	Ag 10%. Cerargyrite, quartz, minor 'black Ag ore', azurite, malachite
50 metres	Galena, minor pyrargyrite, acanthite, cerussite, anglesite, leadhillite, azurite, malachite	'Earthy black Ag ore', quartz, minor acanthite, chalcopyrite, tetrahedrite, pyrite, pyrargyrite.
120 metres		

1871a). These variations in the silver content of the ore throughout the vein probably explain in part the variable quantity of silver sulphosalt and sulphide inclusions in different specimens of galena. However, they do not explain the extremely variable chemical composition, often within the same grain, of tennantite-tetrahedrite; this, and the chemical variations noted in other minerals, must reflect more local fluctuations in the composition of the mineralizing fluids.

Examination of some mineral concentrates (1–2 mm grains), labelled 'Sark's Hope mine, 1840' in the Guernsey Museum collection showed the presence of boulangerite, bournonite, and cinnabar, with galena and sphalerite. It is not known if the specimen has been mislabelled, or if cinnabar was actually present in some parts of the mine. Mourant and Warren (1934) include bournonite and boulangerite in their list of minerals, and further support for the possible presence of cinnabar is that traces of Hg were detected in some of our analyses, particularly in tennantite-tetrahedrite. Cinnabar has not previously been reported from the Channel Islands, and it is uncommon in deposits on the mainland in Brittany. Here, the association Sb–Hg has not been observed (Chauris, 1979), but cinnabar-pyrite veins cut Brioverian metamorphic rocks at Menildot, near Saint-Lô, and cinnabar occurs in Devonian shales at Bourgneuf-la-Forêt.

Silver mineralization was reported elsewhere on Sark (Mourant and Warren, 1934), as 'argentine pyrite' at Port ès Sées (on the southwest coast of Great Sark), and as pyrargyrite at Le Pot silver lode (approximately 400 m northeast of Sark's Hope mine). In this study, no specimens from Port ès Sées were examined, but specimens of galena from La Coupée, mid-way between Sark's Hope lode and Port ès Sées, have inclusions of tetrahedrite. Cu-rich ore from Le Pot was investigated, but no Ag-bearing minerals were found. On Guernsey Pb–Ag mineralization was reported (Mourant and Warren, 1934) from two veins on the south coast at Petit Bôt Bay and Moulin Huet Bay, but no specimens were available to allow a study of the mineralogy. On Jersey, vein-style Ag–Pb mineralization has recently been investigated (Ixer and Stanley, 1980; Stanley and Ixer, 1982) at Le Pulec. There are similarities between the Sark and Le Pulec occurrences in that tetrahedrite is a major Ag carrier in both deposits; indeed at Le Pulec it is the only Ag-bearing mineral found. However, the Sark deposit has As-bearing minerals associated with the Ag–Pb–Cu mineralization; at Le Pulec, only minor quantities of arsenopyrite occur and this is the only As-bearing mineral in the assemblage.

The ages of the Ag-bearing lead deposits of the

Channel Islands remain in doubt. The spatial relationship between the veins at Le Pulec and the nearby North-West granite indicates only that the mineralization is younger than the granite ( $490 \pm 15$  Ma: Adams, 1976). Sark's Hope lode is known to postdate the Late Precambrian granite (Chauris, 1979). Neither of the deposits shows evidence of major metamorphism resulting in re-equilibration of the sulphide assemblages and they appear not to have undergone significant deformation.

The Sark and Le Pulec occurrences have been classified as belonging to the same class of deposit, the 'sphalerite–galena–pyrite–chalcopyrite vein deposits' by Chauris (1977, 1979); this type is common in the Armorican peninsula of which the Normano-Breton (Chauris, 1977) or Cotentin province, which includes the Channel Islands, is a part. The ages and suggested origins of this type of deposit are diverse but Chauris (1977) proposed a relationship between the deposits, the regional tectonics, and granite emplacement.

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