Botallack Mine and Wheal Owles, Cornwall

[SW 358 328]–[SW 363 342]

Introduction

The remarkable stretch of coastline from Cape Cornwall to Pendeen Watch is an area of outstanding importance in relation to the history of Cornish metalliferous mining (see (Figure 7.17)). Here, in cliff section and at cliff top are exposed the geological features of this area (see (Figure 7.18)), and the multiple dumps still provide opportunities for study of the mineral assemblages of numerous lodes of the area. The lodes were rich in both copper and tin, and exploited by a series of mines such as Wheal Edward, Wheal Owles, Botallack, Levant, and in more-recent times Geevor (see (Figure 7.17)). All activity has now ceased. The GCR site constitutes the coastal strip which runs from Wheal Edward Zawn northwards to Carn Vellan. An excellent interpretation centre and museum has recently opened at the Geevor Mine site.

The Land's End Granite was emplaced into middle- to late-Devonian-age country rock ('killas) consisting of argillaceous rocks containing altered basic intrusions ('greenstones'). Metamorphism and metasomatism of this sequence has caused the formation of a variety of hornfelses and skarns (e.g. below the Botallack engine-houses). The hornfelses can best be studied in a series of minor folds in the cliff section. South of Botallack, the cliff-top exposures are formed of several types of basic hornfelses, some with large cordierite crystals. A series of fine-grained granite intrusions and leucogranite-aplite-pegmatite veins and sheets are common at the contact zone, and are reported as running through the various levels of the mines. The emplacement and consolidation of the granite (in late Carboniferous to Permian times) led to fracturing of the rocks of the metamorphic aureole and the already consolidated granite, so that hydrothermal mineralizing fluids were driven through the rock pile and led to mineralized infill to the available fractures. A great range of mineralized structures were therefore formed rich in a variety of metals. That several phases of mineralizing fluids or fluid movement were involved can be seen by the generally intense sequence of alteration associated with the fissure veins so that both hangingwall and footwall may be feldspathized, hematized or chloritized. Extensive tourmalinization also occurred directly consequential upon the infill.

Full listings of the minerals present for the Wheal Edward–Wheal Cock–Wheal Owles area can be found in the Field Notes, Russell Society AGM Meeting, Cornwall 1998, and are given in (Table 7.1)

The minerals and mineralization are described in Embrey and Symes (1987), while Dines (1956) gave full details of the mines with recorded outputs. In addition, there is a very extensive literature on the history of mining and industrial archaeology of the area (see Noall, 1973).

(Table 7.1) List of minerals recorded in the Wheal Edward–Wheal Cock–Wheal Owles area. From Elton and Hooper (1998).

Actinolite	Chalcopyrite	Kaolinite	Sphalerite
Agardite-(Ce)	Chrysocolla	Kasolite	Torbernite
Amorphous copper sillicate	Clinoclase	Langite	Tourmaline
	Connellite	Lavendulan	Triploidite
Anthophyllite	Copper	Limonite	Trogerite
Aragonite	Cordierite	Malachite	Tyuyamunite
Arsenopyrite	Compreignacite	Metanovacekite	Unidentified rare-earth calcium uranyl carbonate hydrate
Atacamite	Cumengeite	Metavoltine	
Autunite	Cummingtonite	Metazeunerite	
Barite	Cuprite	Mixite	Unknown basic lead uranyl carbonate

Biotite	Cuprosklodowskite	Neotocite	
Bismuthinite	Dewindtite	Novacekite	Uraninite
Boltwoodite	Djurleite	Orthoclase	Uranophane
Bornite	Erythrite	Pharmocosiderite	Uranopilite
Botallackite	Fluorapatite	Phenakite	Vandendriesscheite
Brochantite	Fluorite	Phosphuranylite	Vivianite
Calcite	Galena	Pyrite	Widenmannite
Cassiterite	Goethite	Rutherfordine	Wolsendorfite
Cerrusite	Hematite	Saleeite	Zeunerite
Chalcedony	Ilmenite	Schoepite	Zippeite
Chalcocite	Johannite	Siderite	

Description

Wheal Owles [SW 366 325] was situated 1.2 km NNW of St Just, and as such it falls outside the boundary of this GCR site. However, it is mentioned here, as the lodes pass through the defined area. As Dines (1956) stated, a group of lodes with a general north-west–south-east trend extends from the Nancherrow valley, north of St Just, passes beneath Kenidjack village and crosses the coast between Wheal Edward Zawn and the Warren. The Wheal Edward and West Wheal Owles sections are near the coast, along with those of Lower Boscean Mine about 180 m west of Kenidjack. To the north are two adjacent lodes; the Wheal Owles Lode, coursing southeast and underlying steeply south-west; and the Hangar Lode, coursing a few degrees more to the east and underlying 20° south-west. The latter crosses the coast just east of the Warren headland. These are old mines and records are never complete, but Wheal Owles is known to have restarted in 1810. In 1863 Wheal Edward was re-opened (although first returns show a date of 1821). In 1880 all of the development faces in Wheal Owles were declared unproductive, although some production continued in the Cargodna section. The mine closed in 1893, due to flooding. In 1978, when the Botallack Mine was reconstructed, the whole of the Wheal Owles group was included. However, no further exploration was undertaken beyond some limited prospecting for uranium (pitchblende) in the Wheal Edward section. Between 1957 and 1959, 19 tons of uraniferous ore were extracted from the Wheal Edward cliff lode by the Atomic Energy Authority (C. Sparrow, pers. comm.).

Economic mineralization within the Owles sett occurs within fissure veins, generally trending north-west–south-east, which inland were locally rich in tin (cassiterite), while coastal sections were enriched in copper (chalcopyrite-chalcocite). Also important in the Wheal Owles sett was the formation of late N–S-trending cross-course veins (Pearce, 1878). These carried argentiferous galena, bismuth and uranium ores. In Wheal Edward pitchblende is said to have occurred on the 40-fathom level, and uraninites (Dines, 1956) on the 20-fathom level. Interestingly a specimen of uraninite from the Wheal Edward cliff lode has been dated at 58 ± 3 Ma (Pockley, 1964). The main-stage mineralization took place considerably earlier, around 270 Ma consequent upon the emplacement of the granite (Jackson *et al.,* 1982). The Tertiary date of the Wheal Edward specimen may be due to remobilization of uranium by later mineralogical processes.

For the period 1821 to 1856 Wheal Edward output is recorded as 2 tons of 'black tin' and 955 tons 9% copper ore. The tips around the Wheal Edward Incline and elsewhere have recently yielded specimens of cassiterite, chalcocite and copper secondaries and the rare mineral compreignacite (Elton *et al.,* 1994).

The West Wheal Owles site includes the exposures in Loe Warren Zawn (Elton and Hooper, 1995) and some mine tips. It is possible to study underground exposures on the Cargodna vein section, and recently a variety of rare supergene minerals have been recorded.

A group of important tin-copper lodes trending north-west–south-east cross the granite–killas contact and the coast at Botallack. Here the coastal strip of metamorphosed killas is underlain by granite at relatively shallow depth. The Botallack Mine, north of St Just, is probably the best known of all Cornish mines. The images of the Crowns section (see (Figure 7.19)) of the famous Botallack Mine are known worldwide, and the area has World Heritage status for the former mining history landscape heritage. Both the winding and pumping engine-houses are now mostly restored and preserved. The mine is justly renowned for the richness and variety of its mineral deposits. The section of the workings on the Crowns Lode of Botallack Mine (Figure 7.20) shows the relationship of the orebodies to the Land's End Granite.

The mine is noted for the variety of minerals that have been recorded, these being chiefly secondary copper minerals but also include minerals containing cobalt, bismuth, lead, zinc, arsenic, uranium and silver.

The lodes worked together under the name Botallack have been described by many authors, for example Borlase (1758), Pryce (1778), Hawkins (1818), and Dines (1956). The lodes fall into two groups, namely those with a more-or-less north–south trend, and those with an east–west trend. Of the former, perhaps the best known was the Wheal Cock Lode, and of the latter Bunny Lode. The Wheal Cock and North lodes were opened up from Crowns Engine Shaft on the cliffs just south of Wheal Cock Zawn. The famous Crowns Lode (see (Figure 7.21)) courses S30°E and underlies about 12°E and was worked from the Boscawen Diagonal Shaft. The cavernous stope on the Hazard Lode contains atacamite, rare aurichalcite, botallackite, connellite and native copper. Heulandite has been reported from the adit portal. Skarns are seen in two localities within the Botallack sett. At Crowns Rock (and at depth in the mine) mineralogical zoning in the skarn can be studied, with garnet-magnetite and some axinite being found. At Grylls Bunny the exposures have been formed by mining near-horizontal tin-bearing skarns. In both cases the host rocks are metabasalts and metapelites belonging to the Middle Devonian Mylor Slate Formation.

The occurrence of 'tin floors' has attracted much attention. These occur throughout the St Just area, but are best seen at Grylls Bunny (Came, 1822) within the Botallack sett. They consist of nearly horizontal orebodies 1–4 m thick, irregular in outline and 3–12 m across. They occur in killas, greenstone, or granite rocks. At Grylls Bunny, several 'floors', separated by a few metres of country rock, occur one above another. The cassiterite in the 'floors' is associated with tourmaline, the latter often occurring as layers with high tin values (Jackson, 1974).

In the Botallack lodes copper was obtained principally from the coastal area in metamorphic rocks, while tin was obtained principally from the inland sections in granite.

The early history of the Botallack mines is not known, although some of the mines were active in the early part of the 18th century. Wheal Cock was re-opened in 1778, and was united with Botallack after 1841. In 1906 all became part of Botallack Mines Ltd. Operations ceased at the end of 1914. Various workings extended 760 m beyond the cliffs; indeed Pryce (1778) quoted that 'The mine of Wheal Cock in the parish of St Just is wrought eighty fathoms in length under the sea'. Collins (1912) quoted a prospectus stating the value of ores between 1836 and 1895 was in excess of million.

Botallackite (a copper chloride) is named for the locality, from where it was found by Tailing in 1865, almost certainly from the upper levels of Wheal Cock (see Embrey and Symes, 1987).

On the Wheal Cock section the tips of greatest interest are those around Wheal lien and around Skip and Crowns Engine Shaft. Specimens of chalcomenite, a rare copper selenide, have recently been recorded. The cliff exposures of Roscommon, 'Wheal Cock Zawn and Stamps an Jowl Zawn [SW 362 340] are of considerable mineralogical interest. The rare Sn silicate mineral stokesite has been described from the cliffs on the south side of Wheal Cock Zawn, which is the type locality (Couper and Barstow, 1977).

The Levant Mine sett [SW 368 345] and the Geevor Mine sett [SW 372 349], just to the north of this GCR site area, are not discussed here, although they constitute an essential part of the Aire Point to Carrick Du SSSI.

Spectacular developments of cordierite-anthophyllite and cordierite-cummingtonite hornfels in greenstones are best seen at Kenidjack Cliff Zawn. Massive cordierite-rich hornfels, with large cordierite porphyroblasts (1 cm in size) form the rocks on which the Crowns winding engine is built. Below this exposure, the rocks upon which the Crowns pumping engine is built contain a massive, zoned skarn in which an outer amphibole-rich zone and an inner garnet-rich zone can be recognized (Figure 7.22).

Some of the metabasic rocks below the lower engine-house contain deformed vesicles, showing that they were originally lavas. In Dc Narrow lawn, the inlet which forms the south side of Crowns Rock, a belt of iron staining marks the trend of a barren fault, the structure being filled only with quartz and hematite.

There appear to be two mineral assemblages in this area, namely a low SnO_2 vesuvianite magnetite assemblage with accessory axinite, chlorite, biotite, tourmaline and amphibole, and a Sn-bearing skarn consisting of chlorite, amphibole,

cassiterite and titanite, with silicates containing high SnO_2 values.

Tourmaline is invariably present, being late stage and almost certainly associated with mineralization.

Interpretation

This is an internationally important mineralogical locality demonstrating varying stages of mineralization in the tin zone and lower part of the copper zone. This main-stage mineralization clearly post-dates the granite and the metamorphism of the killas rocks. The development of primary skarn assemblages in greenstones and metasedimentary rocks, and later tin mineralization has superimposed a secondary assemblage on the primary skarns. This area also provides a study area for petrology, petrogenesis and geochemistry of granite, contact and aureole rocks.

Records from the mines show a story of complex lode mineralization, wall-rock alteration and skarn formation, with many stages of differing metamorphic–metasomatic action and alteration of previously formed assemblages. The fact that underground access is now so limited, means that three-dimensional interpretation has to be based mostly on former mine records and scientific papers. Important papers are those by Jackson (1974), Alderton and Jackson (1978), and Van Marke de Lummen and Verkaeren (1985).

The Geevor Mine lies slightly to the north of the designated GCR site. However, as it only closed in the 1990s a modern interpretation has been possible. The geological and mineralogical features are relatively similar to all mines of the area (see (Figure 7.18)), and perhaps the most important evidence for interpretation comes from the studies of the mine geologists at Geevor Mine during the last development period at Geevor Mine. This episode involved dewatering of the Boscaswell Downs Mine, which gave access to the north-east, allowing working on the Simms Lode, and also involved the sealing of a breach between the seabed and submarine workings of Levant Mine, followed by progressive dewatering of lower levels. This provided access to the vein swarm converging on the Levant workings offshore. It was there. fore possible to make a three-dimensional interpretation of the underground workings and mineralization of the lodes, for reference (see Mount, 1985).

Skarn rocks are an important part of the rock sequence in this GCR site area, forming ore-bearing horizons at Grylls Bunny and on the coast below the Crowns. At Grylls Bunny the ore-body consists of a series of sub-horizontal sheet-like horizons. These have been described as 'floors', and plunge in a northerly direction at between 20° and 30°. The zone is some 30 m thick and is localized within a sequence of metasomatized iron- and calcium-rich hornfelses in rocks of predominantly basaltic parentage. The re-distribution and fixation of calcium within a metabasite sequence has produced a rock type with a skarn mineral assemblage. Contact metasomatism has locally (and at depth in Geevor Mine) formed rock rich in garnet and magnetite, while the following K-metasomatism caused the development of biotite-rich horizons. The whole is encompassed in relatively undeformed banded hornblendic hornfels.

Mineralization occurred soon after granite emplacement, with some selective boron metasomatism of Al-rich horizons, followed by precipitation of cassiterite and quartz. Mineralizing fluids were controlled by the structure, lithology and chemistry of the zonal rocks. The mineralization associated with the skarn formation appears to be a separate event to the main-stage lode mineralization, and to precede the main tin-copper lodes.

The north-west flank of the' Land's End Granite, at Geevor, consists mainly of medium-to coarse-grained megacrystic granite with minor exposures of fine-grained granites at deeper levels, evidence for which is found at various sites at Geevor. Mount (1985) considered that the fine-grained granite is one of the subsequent but important controls of mineralization. The fine-grained granite intrudes the coarse-grained granite as a late differentiate. Where these granite types have penetrated the hornfelses important replacement mineralization has taken place. Several dykes can be traced towards the fine-grained granite masses. The hornfels roof is penetrated by numerous granite dykes of variable dip and strike. Acting as local structural controls some dykes have provided sites for ore deposition. The 'carbona' of Levant Mine is considered to have been formed in this way.

From Geevor and also from records of the lodes within the GCR site, it can be seen that in this area all of the various types of Cornubian Batholith lodes have been fully exploited, which are:

1. mineralized faults ('normal lodes'), which are repeatedly opened mineralized fault structures, the mineralizing fluids here of Sn-Cu hypothermal origin;
2. replacement veins of adjacent wall-rocks, or veins remote from fissures usually due to lithological control;
3. carbonas — rich local replacement of wall-rock by migrating solutions along small fractures, which are most commonly found in the granite assemblages; and
4. stockworks — vein swarms usually associated with granitic cusps.

The hypothermal Sn-Cu lodes were extensively mined from the area. These lodes exhibit a classical zoning, with tin occurring close to the granite contact and copper farther away (Dines, 1956). Crowns Lode is in the copper zone at surface but passes into tin at depth. In Crowns Engine Shaft the granite contact is located at 220 m and slopes at 40° NNW.

Production from the mine also included replacement mineralization in wall-rocks adjacent to the fissure veins, mainly in the metabasites and calc-silicates. Again this development depends both on structural and lithological controls. In places elongate or podiform stockwork systems have formed where sub-horizontal lithological variation in the hornfelses are cut by sub-vertical fractures in the roof zone of the fissure-vein system.

Conclusions

This composite and complex site is of great importance to the understanding of the geological and mineralogical processes in this coastal area of the Land's End Granite contact. Some underground access is still possible in places from the side of the zawns; however dump material still provides the best evidence of the nature and formation of the mineralogical assemblages.

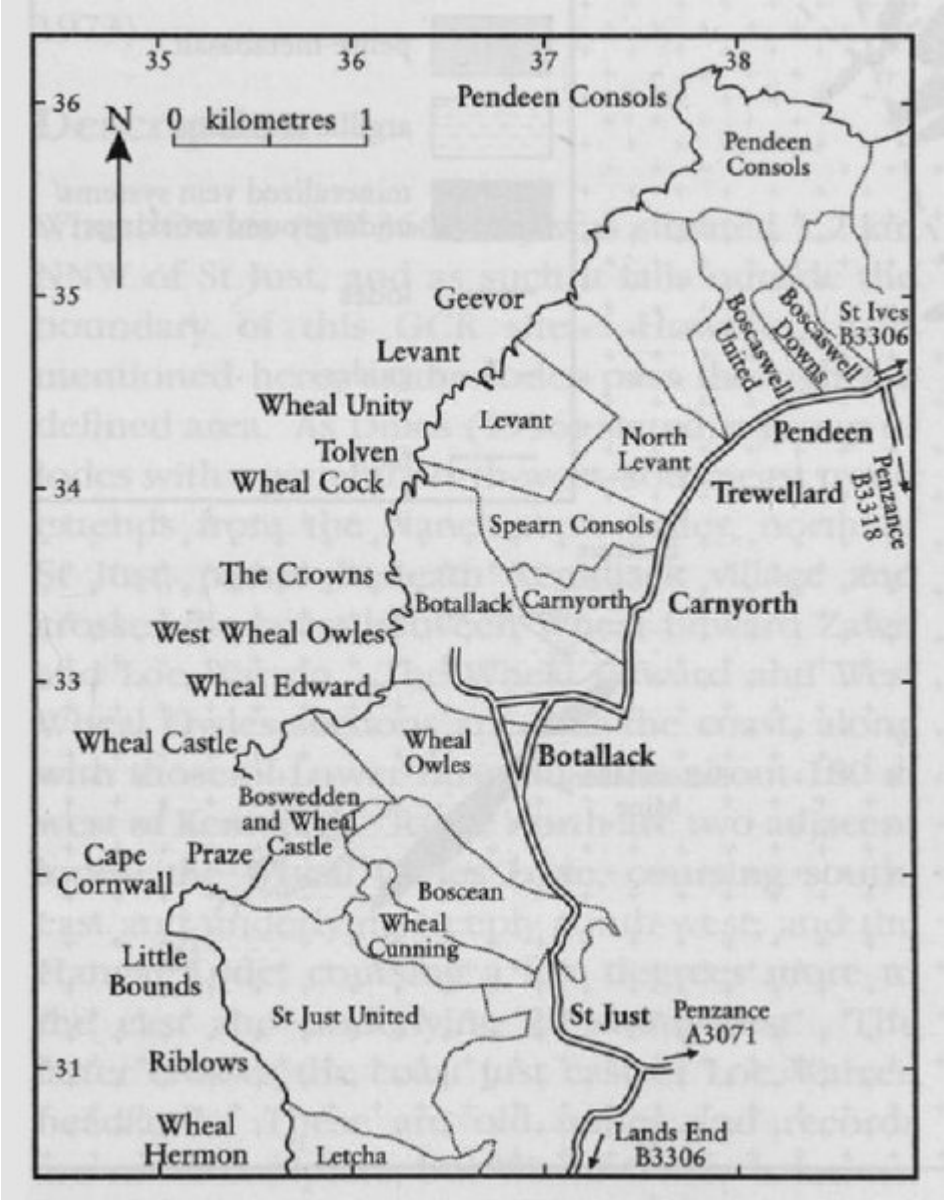
Several stages of mineralization and their effects on host rocks of varying composition can be studied in natural cliff sections.

The metamorphism of sedimentary rocks containing some volcanic horizons of Devonian age by intrusion of the Variscan Land's End Granite has also been accompanied by metasomatism and formation of iron-rich and calcium-rich skarns. In the excellent exposures at Grylls Bunny and Crowns Rock the nature of this alteration is seen to be a function of the original chemistry and lithology. Again, fine exposures in coastal sections provide important information on the mineral parageneses, showing the complex sequence of mineralizing and alteration events.

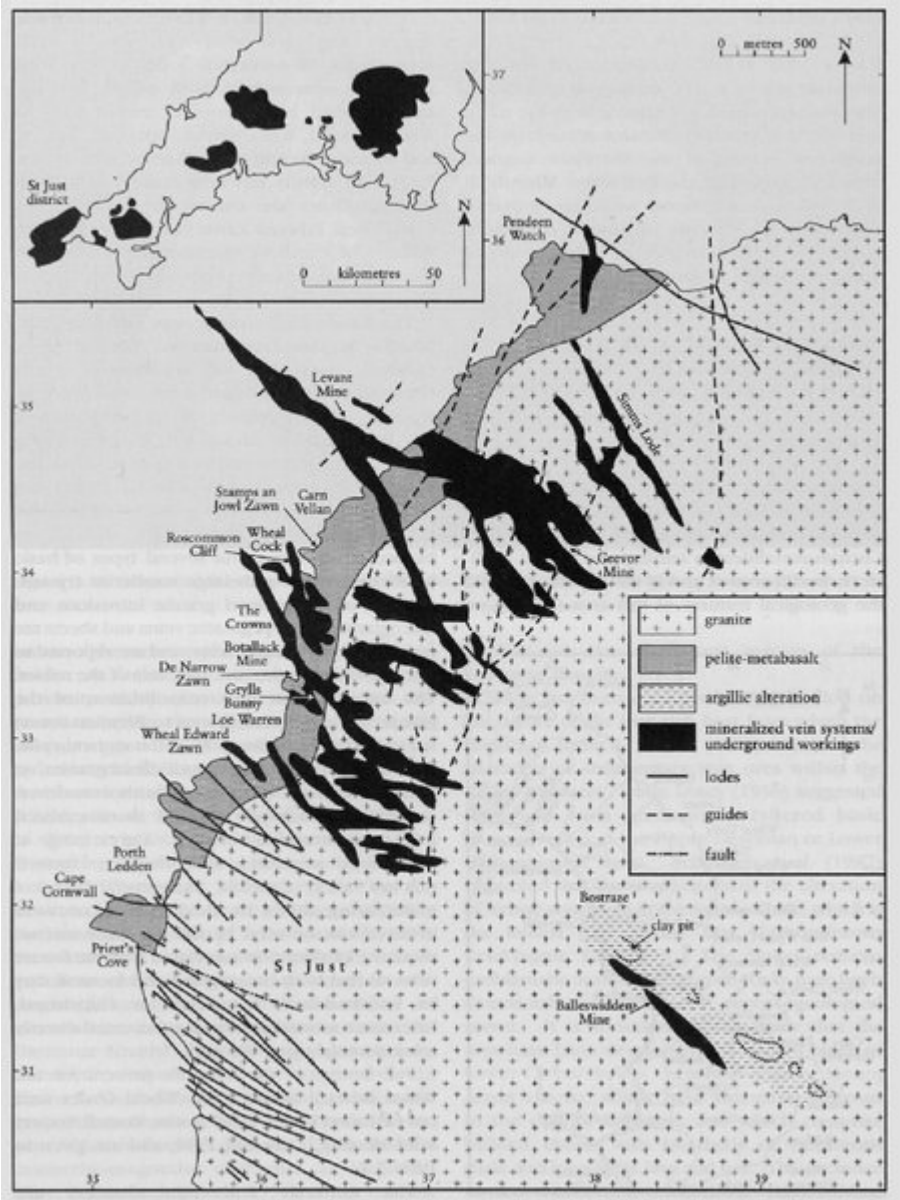
The dumps associated with each of the mining setts are of considerable importance to studies of the differing mineral assemblages. A number of type minerals, first finds and rare species adds even greater emphasis to this internationally recognized site. Several tin lodes are exposed in cliff sections around Crowns and surrounding zawns. Excellent specimens of the primary tin assemblage are found on the Wheal Cock dumps. This area is the type locality for botallackite and paratacamite, while Roscommon Cliff is the type locality for stokesite. The Wheal Owles dumps have yielded many interesting minerals, particularly around the western section of the mine at Wheal Edward where a range of uranium minerals are recorded. The opencast tin workings at Grylls Bunny and the adjacent area expose the only example of a tin 'floor' deposit on view in South-west England. Here mineralization has selectively migrated along suitable (horizontal) lithologies and structures.

The site constitutes an internationally important locality of the study of mineralogical and mineralization processes.

References



(Figure 7.17) Mines of the St Just district. After St Just Mines Research Group (2000).



(Figure 7.18) Geology and mineralization of the St Just mining district, between Cape Cornwall and Pendeen Watch. After Jackson et al. (1982).

Actinolite	Chalcopyrite	Kaolinite	Sphalerite
Agardite-(Ce)	Chrysocolla	Kasolite	Torbernite
Amorphous copper silicate	Clinoclase	Langite	Tourmaline
Anthophyllite	Connellite	Lavendulan	Triploidite
Aragonite	Copper	Limonite	Trogerite
Arsenopyrite	Cordierite	Malachite	Tyuyamunite
Atacamite	Compreignacite	Metanovacekite	Unidentified rare-earth calcium uranyl carbonate hydrate
Autunite	Cumengeite	Metavoltine	Unknown basic lead uranyl carbonate
Barite	Cummingtonite	Metazeunerite	Uraninite
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Bismuthinite	Cuprosklodowskite	Neotocite	Uranopilite
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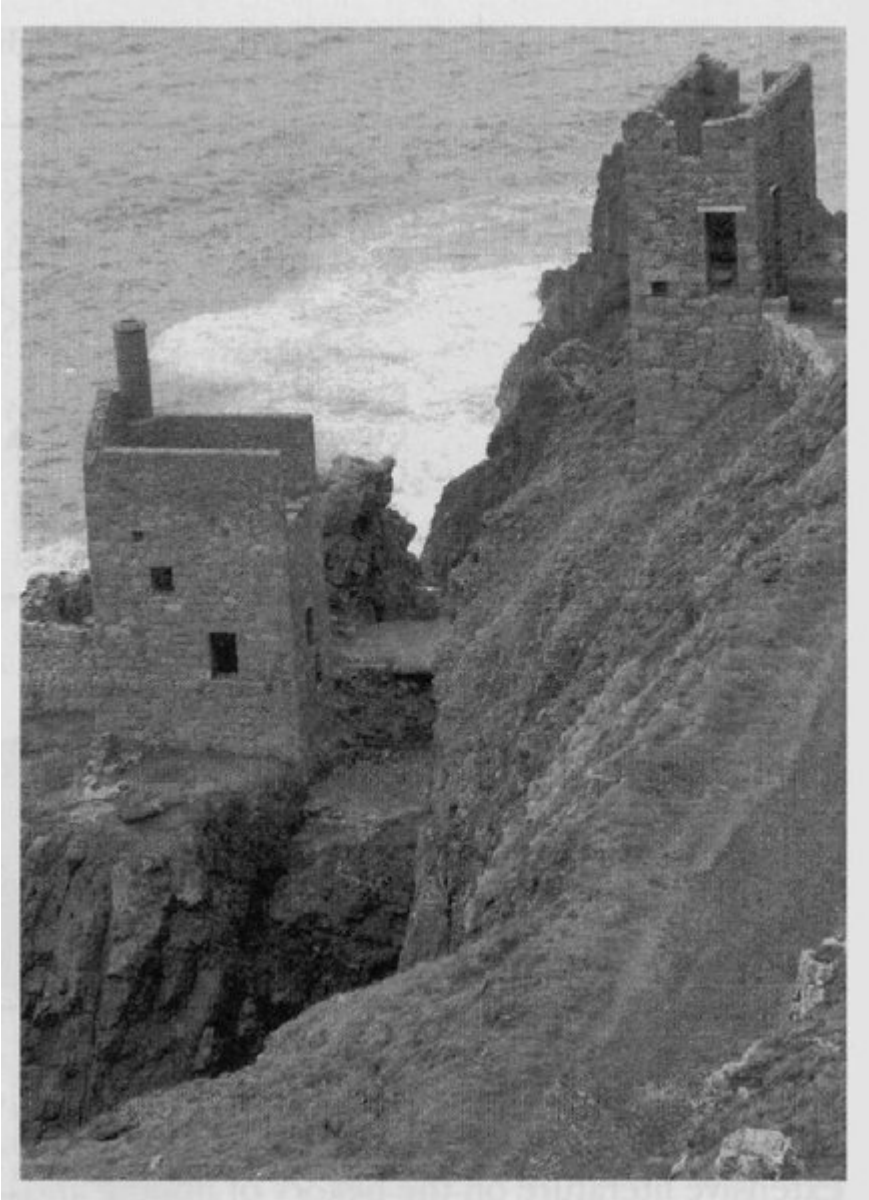
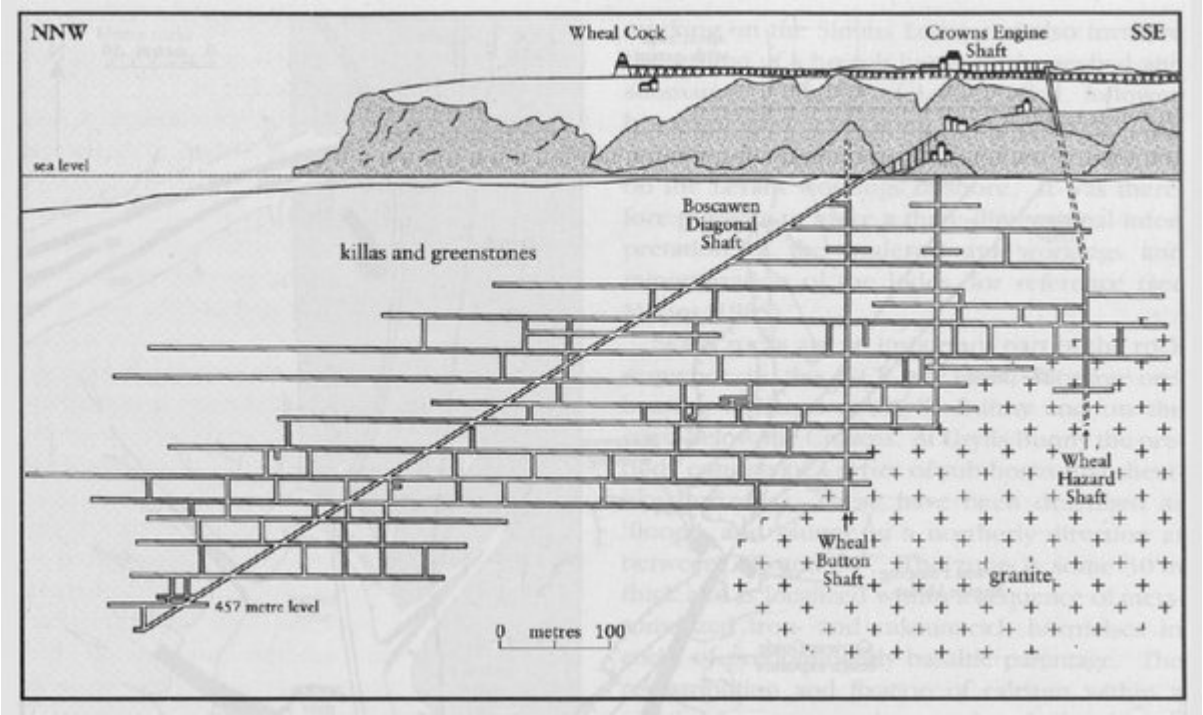
Botallackite	Erythrite	Pharmocosiderite	Widenmannite
Brochantite	Fluorapatite	Phenakite	Wolsendorfite
Calcite	Fluorite	Phosphuranylite	Zeunerite
Cassiterite	Galena	Pyrite	Zippeite
Cerrusite	Goethite	Rutherfordine	
Chalcedony	Hematite	Saleeite	
Chalcocite	Ilmenite	Schoepite	
	Johannite	Siderite	

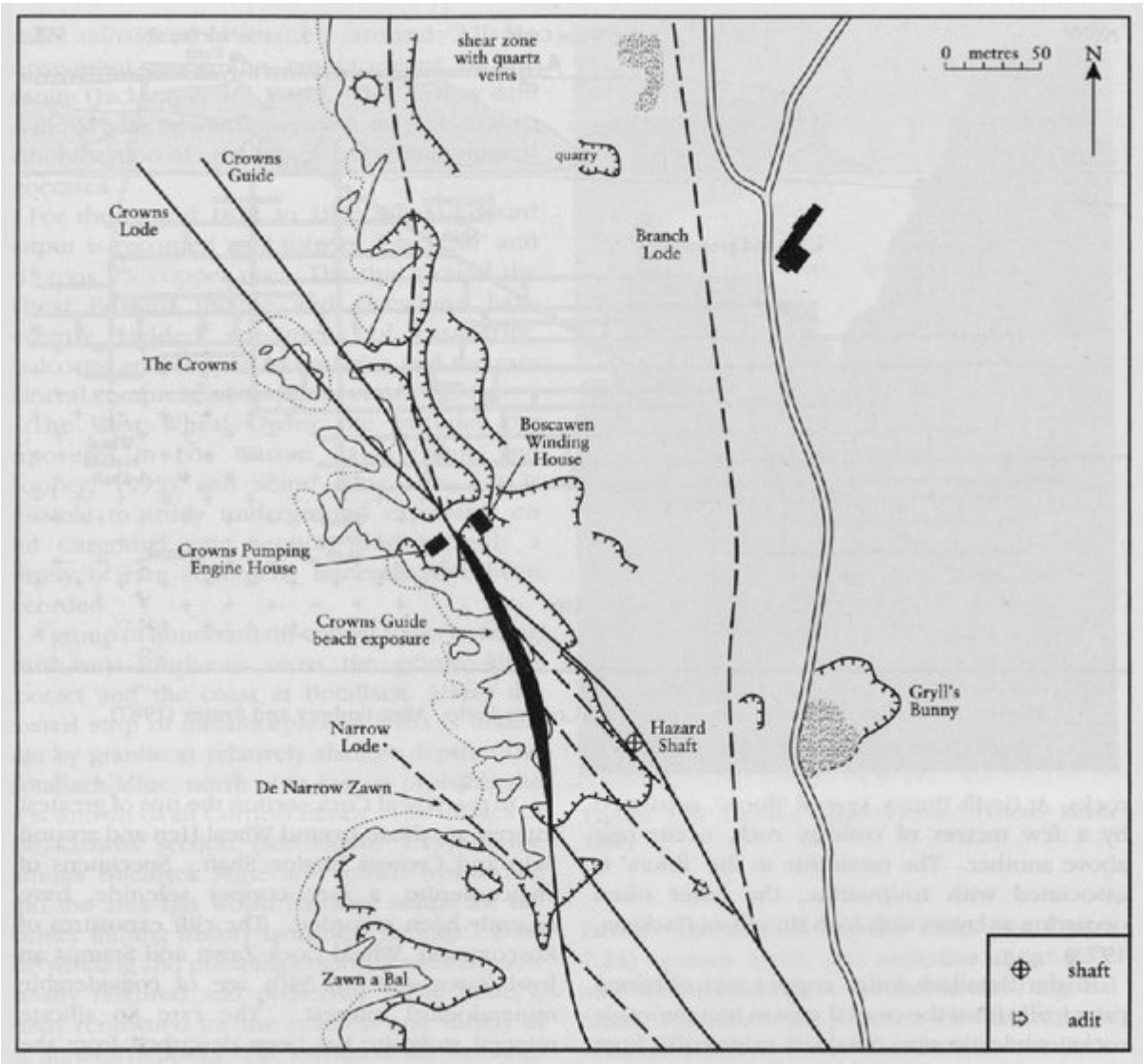
(Table 7.1) List of minerals recorded in the Wheal Edward&ndashWheal Cock–Wheal Owles area. From Elton and Hooper (1998).



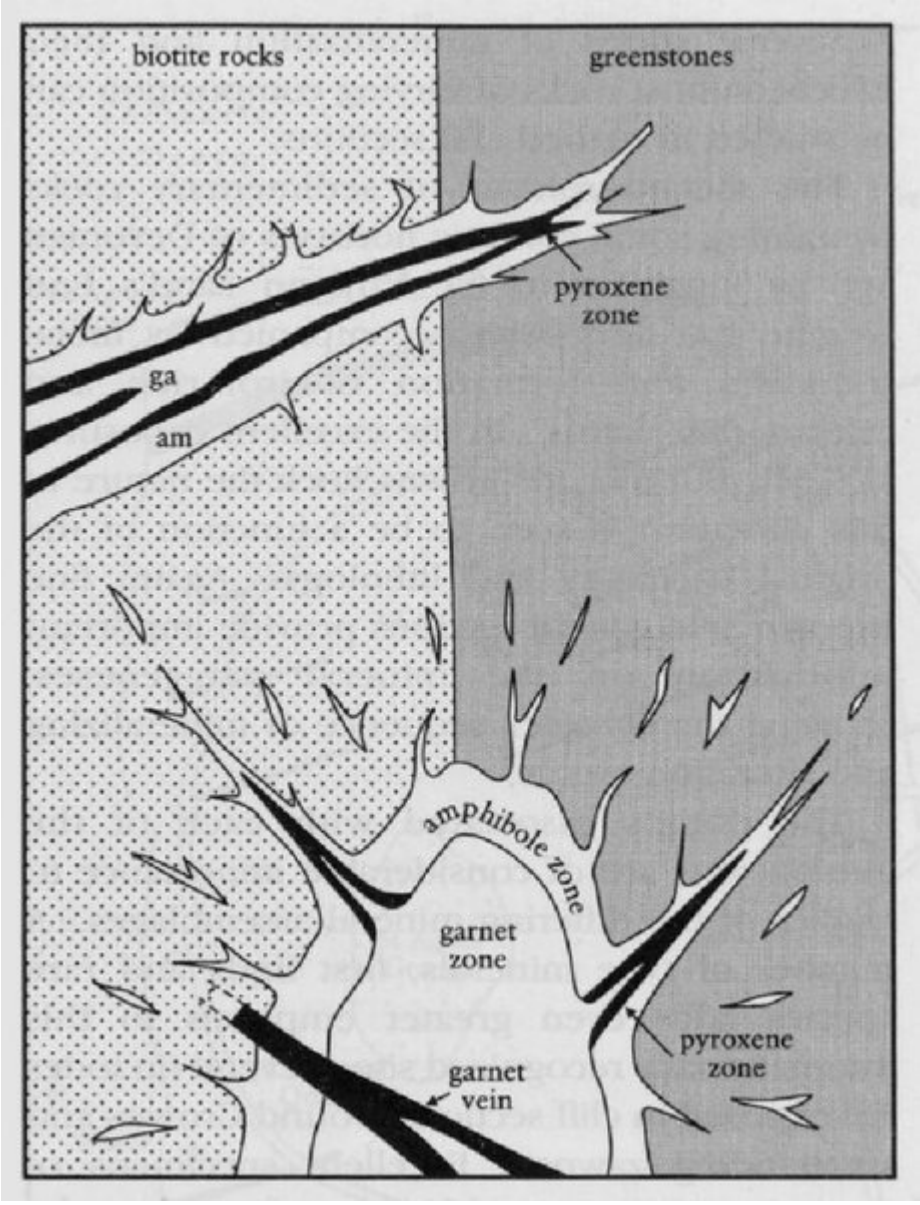
(Figure 7.19) Crowns Engine House. (Photo: Kevin Zim.)



(Figure 7.20) Section through the working on Crowns Lode. After Embrey and Symes (1987).



(Figure 7.21) Crowns Lode and Grylls Bunny. From unpublished field notes.



(Figure 7.22) Schematic structure of skarn zoning showing the relation between vein and massive skarns ('am' denotes the amphibole zone, the pyroxene zone is shown in black, and 'ga' denotes the garnet zone). After van Marke de Lummen and Verkaeren (1985).