B6 Botallack Head–Porth Ledden

[SW 362 339]–[SW 355 322]

Highlights

Within the Land's End aureole, this classic site provides the best section of basic hornfels formed by the metamorphism and metasomatism of massive dolerite sills and basaltic pillow lavas. Uniquely, these pre-Variscan basalts contain grani-toid xenoliths, possibly indicating an underlying continental crust at the time of their extrusion. This site also contains industrial relicts of some of the most famous and productive tin and copper mines in the mining history of South-west England.

Introduction

Scenically and geologically, this site is one of the best coastal sections within the aureole of the Land's End Granite. Steep cliffs and deep, inset, narrow gullies (locally called 'zawns'), together with a few exposures on the grassy cliff-top platform, provide excellent examples of both metamorphic and metasomatic hornfelses derived from basaltic pillow lavas and massive greenstones.

This area represents a classic example of contact metamorphism of basic volcanic rocks by the Land's End Granite, although gross morphology, relict textures and mineralogy often enable their original composition to be deduced. In general, contact metamorphism produced both typical hornblende-bearing hornfelses, as well as more unusual hornfelsic assemblages whose origin has been often debated and for which this area is famous.

The 'normal' basic hornfelses mainly display ilmenite–plagioclase–hornblende ± biotite assemblages and have often been intensively sheared into bands and lenses. It is not always possible to determine whether they were originally extrusive or intrusive, although the degree of heterogeneity within the sequences and the sheared outline of pillow lavas indicates that the majority of the normal, as well as the exotic, hornfelses were probably extrusive. A petrographic relict of the intensive deformation prior to contact metamorphism, is seen in the granulation of primary ilmenite into parallel trains across which new contact minerals have grown. All aureole hornfelses (including the metasediments) have been metasomatized by the granite and exhibit enhanced contents of Sn, Zn, Be, B, F, Cl, U and the light-REE (Floyd, 1966b, 1967; Wilson and Floyd, 1974; Alderton and Jackson, 1978; Mitropoulos, 1982, 1984; van Marcke de Lumnien, 1985).

This part of the aureole initially became known for the presence of two groups of hornfelses with unusual mineral associations:

1. Mg-rich assemblages with anthophyllite–cordierite and cummingtonite–plagioclase, and
2. Ca-rich assemblages with sphene–diopside–hornblende, diopside–garnet and garnet–epidote–calcite.

Early work suggested that the two unusual hornfelsic groups represented the metasomatically derived end products of the normal hornblende-bearing hornfelses, under the influence of hydrothermal solutions emanating from the granite (Tilley and Flett, 1930; Tilley, 1935). However, rather than an origin invoking purely Mg and Ca metasomatism, it is now considered that they were developed by the isochemical contact metamorphism of previously altered basaltic volcanics (Vallance, 1967; Chinner and Fox, 1974). Alteration would have taken place during earlier, low-grade regional metamorphism (late Devonian), with the patchy development of variably degraded assemblages ranging from chlorite-rich (isochemically producing the Mg-rich assemblages) to epidote–carbonate-rich (eventually producing the Ca-rich assemblages). During contact metamorphism, Ca-rich solutions, however, were mobilized from Ca-bearing degraded areas and together with granite-derived mineralizing fluids (containing Sn, B, etc.) also locally metasomatized the adjacent normal hornfelses (Floyd, 1965; Jackson and Alderton, 1974; Floyd, 1975; Alderton and Jackson, 1978; van Marcke de Lummen, 1985). During the redistribution of elements within the aureole volcanics on contact metamorphism, it is clear that Sn-rich fluids were also circulating so that ore deposition within the aureole is often marked by Ca-rich skarn-type alteration (Jackson, 1974). However, oxygen and hydrogen isotope studies indicate that fluids in equilibrium with the skarn minerals were not purely magmatic, but, as temperatures fell, were mixed with an increasing meteoric component (van Marcke de Lummen, 1985).

Description

The site comprises the coastal strip between Botallack Head in the north to Porth Ledden, near Cape Cornwall, in the south. An outline geological map of the area is shown in (Figure 4.17). It contains a prehistoric cliff castle at the Kenidjack Castle headland and is particularly famous for its mining history that covered an active period of nearly 200 years. Botallack Mine, probably one of the oldest in the St Just mining area, commenced mining in 1721 and became one of the richest tin mines by the early nineteenth century. Between 1815 and 1905, about 20 000 tons of copper ore and 14 000 tons of tin ore were won, with workings extending 800 m beyond the cliffs under the sea at a maximum depth of about 500 m (240 fathom level, (Figure 4.18)) (Barton, 1965; Embrey and Symes, 1987). Two derelict engine-houses still stand perched on the cliff edge at The Crowns, just south of Botallack Head (Figure 4.19), from which the famous, diagonal Boscawen shaft descended into the mine. Inland from Kenidjack Cliff was the extensive Wheal Owles Mine that, apart from tin, was one of the few mines to produce uranium (pitchblende, zeunerite and various secondary uranium minerals) on the Penwith Peninsula. Nearby, to the north of Botallack Head, is the Wheal Cock Mine, where a number of rare beryllium minerals within a hydrothermal sulphide-bearing skarn have been recorded, as well as botallackite (a Cu chloride) that derives its name from the local area (Kingsbury, 1961, 1964).

The intimate association of both sediments and volcanics, as well as normal and unusual basic hornfelses, are well displayed in the cliffs adjacent to Botallack Head and The Crowns ([SW 362 336], (Figure 4.17)). The sedimentary wedge (mainly a retrogressed chlorite-bearing biotite–cordierite pelitic hornfels) has been locally metasomatized to a pale-grey adinole at the junction with the metavolcanics. In the vicinity of The Crowns the basic metavolcanics are variably biotitized plagioclase–hornblende hornfelses, although below the upper engine-house, they are replaced by hard, dark cordierite–anthophyllite hornfelses with cordierite porphyroblasts aligned along the major foliation. Thin-section examination shows stellate groups of anthophyllite needles, developed parallel to the ilmenite granule foliation, traversing large cordierite porphyroblasts which often enclose relicts of replaced plagioclase. (Figure 4.20) is a composite drawing of the mineralogical relationships often seen in cor-dierite–anthophyllite assemblages: it illustrates two growth periods for both anthophyllite (stellate and prismatic) and biotite. Cummingtonite-bearing Mg-rich hornfelses are intimately associated with biotite–cordierite–anthophyllite-bearing bands on the promontory [SW 362 333] between De Narrow Zawn and Zawn a Bal. Grey cordierite–anthophyllite hornfelses, with some bands of brown biotite-bearing variants, are well exposed at Kenidjack Cliff headland [SW 355 326], and, in the adjacent quarries, grade into normal hornblende-bearing hornfelses. Both anthophyllite-and cummingtonite-bearing hornfelses may sometimes exhibit silica-deficient assemblages containing green spinel (pleonaste) and diaspore (Figure 4.20).

Various skarn-type Ca-rich hornfels are well exposed below and around the lower engine-house at The Crowns; they form pale-coloured grey, pink and green masses. The banded foliation of the adjacent hornblende hornfelses may be lost where the skarn replaces it, although the latter often develops almost monomineralic horizons subparallel to the main hornfels banding. The main calc-silicate minerals are green diopside, red grossularite garnet (anisotropic and zoned) and amphibole, with minor idocrase, epidote, axinite, tourmaline, calcite, chlorite, spinel, sphene and sulphides (largely chalcopyrite). A number of stages for the migration of Ca-rich fluids are indicated by the cross-cutting of the skarn masses by a 0.3–0.35 m thick tourmaline–diopside-bearing garnet vein.

Massive volcanics and pillow lavas composed of the more normal hornfelsic assemblages are present on the rocky platforms of Kenidjack Castle. The pillow lavas are generally thin (<1 m) with interpillow spaces filled with silica. Secondary amphibole veinlets are common throughout the volcanics. Chemical data for the pillow lavas indicate that they are tholeiitic and form part of the same group as the other lavas within the south Cornish magmatic province of the Penwith–Camborne area (Floyd, 1982a, 1984). Although chemically similar to the coeval Clodgy Point and Gurnard's Head basalts, differences in their Zr/Y ratios and degree of light-REE-enrichment implies that the lava occurrences are not comagmatic, but represent three separate volcanic centres generated by variable partial melting of a common mantle source.

Within the basic hornfelses near Zawn a Bal are rare, small (0.1–0.4 m diameter), pink, weathered, feldspar-rich crystalline xenoliths (Goode and Merriman, 1987). These unusual xenoliths, some of which exhibit a pre-Hercynian tectonic fabric, range from intermediate to acid in composition and were derived from granitic precursors. The significance of these granitic xenoliths, carried upwards by late Devonian basic magmas, lies in the possibility that they represent remnants of continental crust lying below the Penwith Peninsula, and as such might have provided a source for the Cornubian granites (Goode and Merriman, 1987).

Interpretation

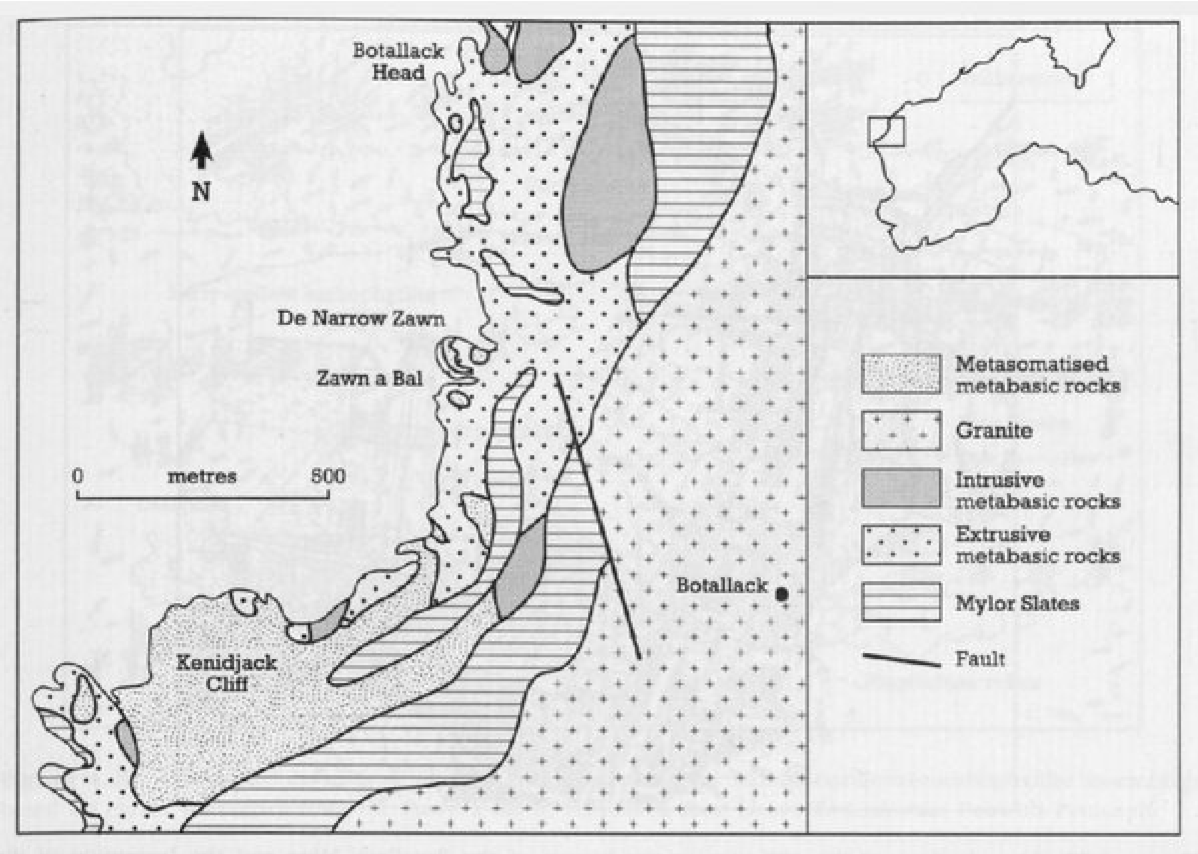
The Botallack area has long been famous for its history of tin and copper mining, with the engine-houses and dumps along this coastal strip now providing silent testimony to past endeavours. Apart from its past economic significance, the site provides excellent examples of the different hornfelsic types produced during the contact metamorphism of variably degraded basaltic volcanics. Initially, studies by Tilley (1935) identified the possible derivation of exotic anthophyllite–cordierite- and cummingtonite-bearing assemblages by variable Fe + Mg metasomatism of the adjacent normal hornblende hornfelses. This was one of the first detailed petrographic descriptions of these rocks within a granite aureole in Britain, and Tilley (1935) compared them with occurrences within the Precambrian crystalline terranes of Scandinavia. For example, early studies by Eskola (1914) indicated that the anthophyllite–cordierite rocks of the Orijarvi region had been derived by the wholesale Mg metasomatism of siliceous leptites' (acidic lavas and tuffs). Tilley (1935) considered the Botallack exotic hornfelses to have been formed by the same metasomatic process, but with the important difference that the former rocks were derived from basic parents via the internal redistribution of Mg (together with the loss of Ca, etc.), and not by the addition of Mg from an external granitic source as at Orijarvi. The origin of these unusual rocks is important, not only in terms of metamorphic paragenesis and parental composition, but as economic guides because they are often associated with massive sulphide deposits in many parts of the world. Although the theory of a metaso-matic origin held sway for some time, work on the regional degradation of basaltic volcanics has indicated that they could also be generated by the isochemical metamorphism of the low-grade secondary products of such rocks (Valiance, 1967; Chinner and Fox, 1974). However, as indicated by Floyd (1975), removal of Ca, etc. from the degraded assemblages is still required to produce a suitably Mg-rich precursor. In this context, Floyd (1975) linked the derivation of the skarn hornfelses to the Mg + Fe-rich hornfelses, with the former representing the repository of the released Ca. Thus, both groups of exotic hornfelses can be related to the variable degradation of basaltic volcanics and the differential migration of Ca-rich fluids. The normal hornblende hornfelses were developed isochemi-cally from metabasalts containing relatively small proportions of secondary Ca-bearing phases. It is interesting to record, however, that Reynolds (1947), noting the intimate association of the exotic hornfelses, suggested that the Mg + Fe-rich group were derived from calcareous sediments (remnants becoming the Ca-rich group) which suffered Mg metasomatism from an advancing basic front produced by local granitization.

The other major significant feature of this site is the discovery of possible continental basement as xenoliths within the basaltic lavas. Apart from some crustal fragments within Permian lavas, no deep-seated xenoliths, either crustal or mantle, have been found in the Variscan basaltic lavas of south-west England. The granitic xenoliths at Botallack may represent the only example we have of continental crust underlying this area, although Goode and Merriman (1987) speculate that some of the foliated granites of Haig Fras might be comparable with and not related to the Cornubian batholith as previously thought.

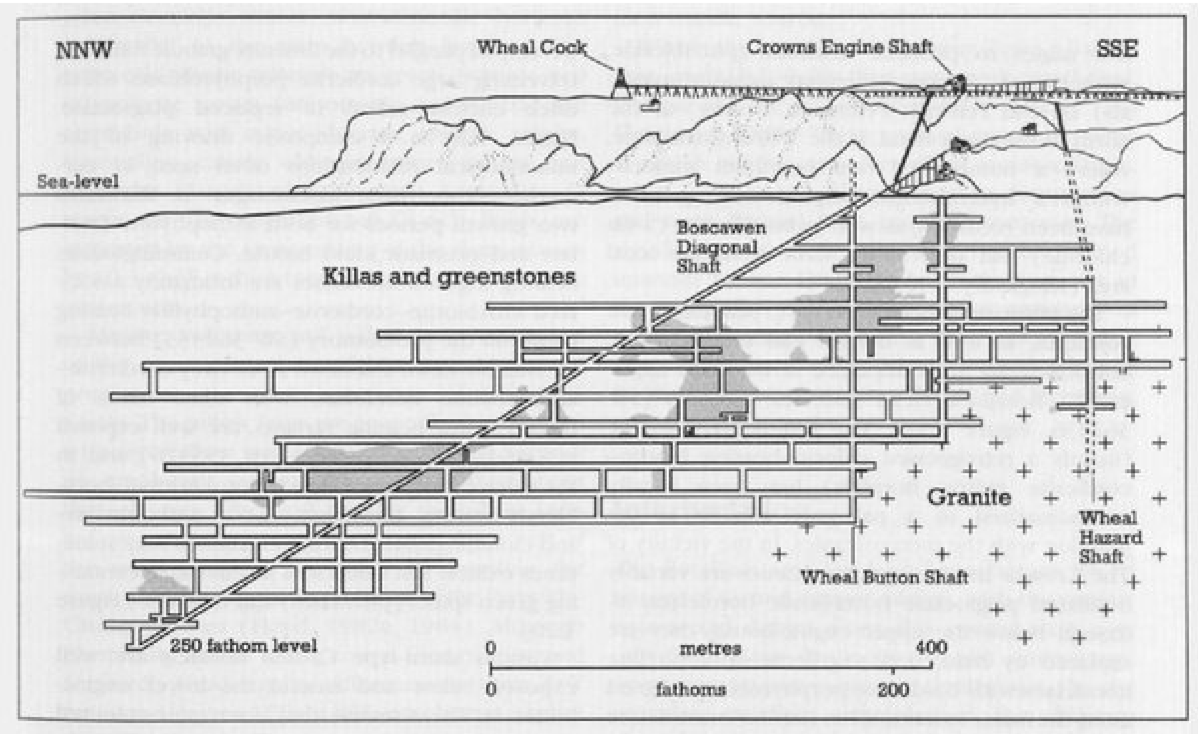
Conclusions

This site is world famous for its copper and uranium minerals and the mining activity which they attracted in the last century. These minerals occur within rocks, which were originally marine sediments and lavas formed in late Devonian times, around 370 million years ago. These rocks were subsequently mineralized by the action of hydrothermal solutions emanating from the Land's End Granite that caused the mobilization and redistribution of economically important elements. Prior to granite emplacement, the basaltic lavas had undergone low-grade alteration with the development of two different chemical groups – one Fe + Mg-rich, the other Ca-rich. On contact metamorphism by the granite, these two groups developed a unique set of exotic mineral assemblages for which the area is famous. Within the Devonian lavas are found inclusions of granitic rocks that are considered to represent fragments of continental crust through which the basalt magmas passed. Their presence is the only direct evidence for the existence of continental crust below the submarine basins of south-west England.

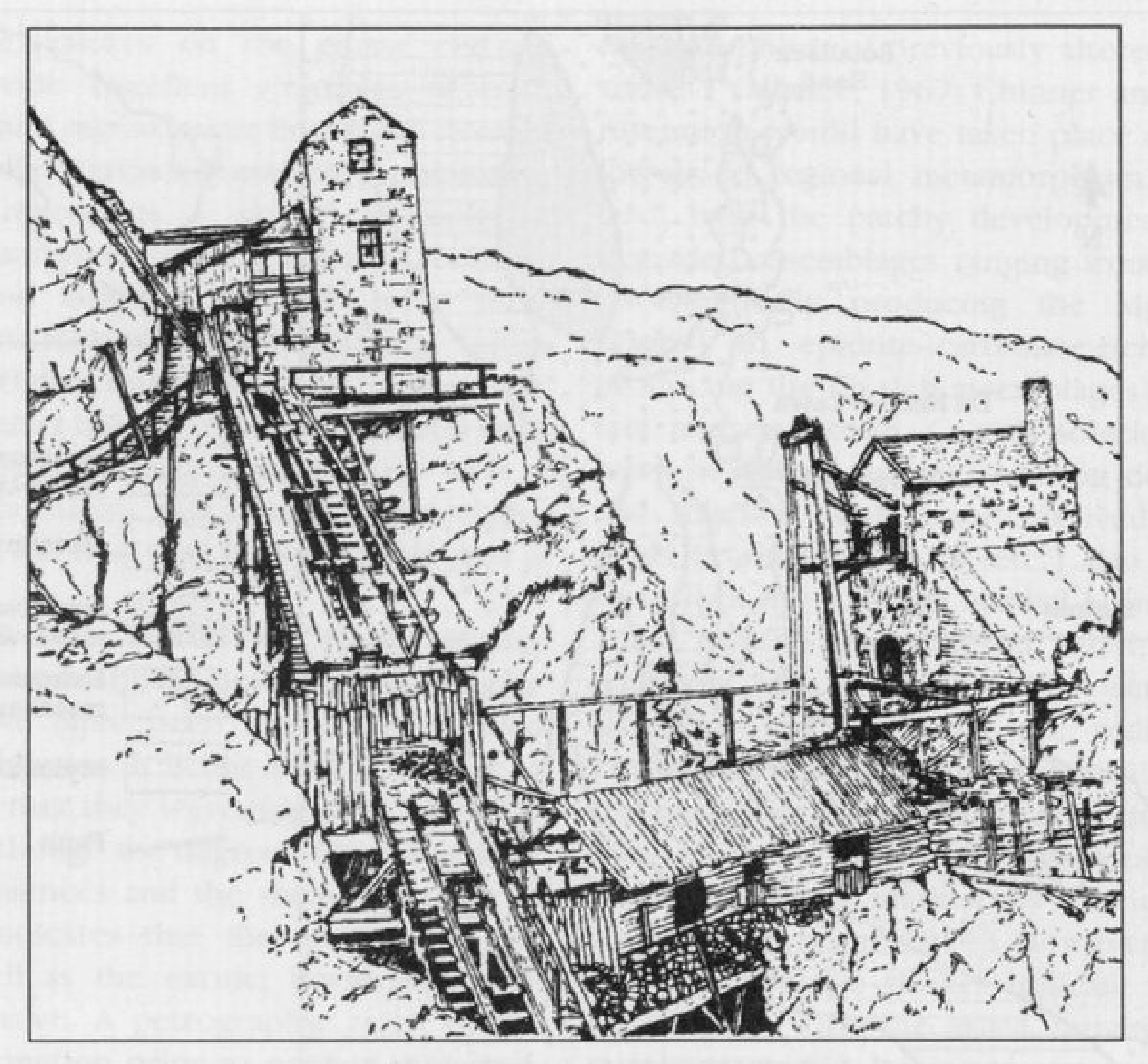
[**References**]



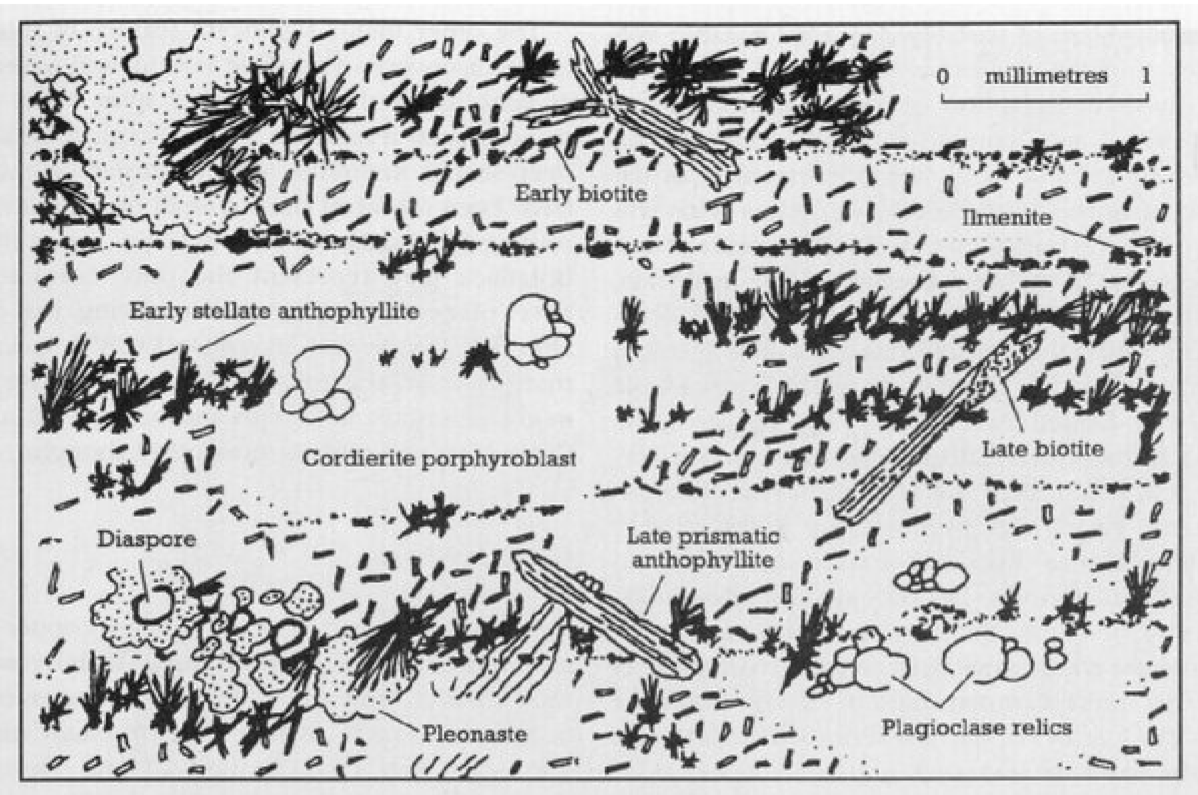
(Figure 4.17) Geological map of the Botallack—Cape Cornwall section of the Land's End aureole, Penwith Peninsula (after Goode and Merriman, 1987).



(Figure 4.18) Section through the Botallack Mine, showing the sub-sea-floor workings and famous diagonal shaft, near St Just, Penwith Peninsula (after Embrey and Symes, 1987).



(Figure 4.19) Line drawing of the cliff-edge engine-houses of the Botallack Mine and the beginning of the diagonal shaft at The Crowns, near St Just, Penwith Peninsula (reproduced from Barton, 1965).



(Figure 4.20) Composite drawing of mineral relationships in the biotite—cordierite—anthophyllite assemblage, based on exotic hornfelses from the Zawn a Bal to Kenidjack area, Land's End aureole, Penwith Peninsula.