A7 Porthallow Cove–Porthkerris Cove

[SW 798 232]–(SW806 226)

Highlights

The boundary fault of the Lizard Complex is uniquely exposed here; within an imbricate zone, the highly deformed mafic and ultramafic rocks of the Traboe Cumulate Complex are best exposed at this locality.

Introduction

The boundary between the igneous rocks of the Lizard Complex and Devonian sediments to the north is of major geological importance. It has been a point of controversy since the earliest research, and the first Lizard Memoir (Flett and Hill, 1912) left it as an open question, due to disagreement between the two authors. The position of the boundary can easily be located within a few tens of metres, but whether it is a major thrust separating Archaean rocks from Ordovician slates, or a faulted contact bringing together rocks of a similar age (Ordovician?) with different metamorphic grade, was disputed at an early stage. The second version of the Lizard Memoir (Flett, 1946) considered new evidence and favoured a major thrust contact. Controversy broadly along these lines has continued for many years between those who considered the Lizard Complex a thrust mass, possibly part of a much larger Lizard–Start thrust sheet (Hendricks, 1939; Styles and Kirby, 1980), and those who thought it an upfaulted block of basement (Bromley, 1979; Matthews, 1981). Barnes and Andrews (1984) showed that there was no noticeable increase in metamorphic grade in the Devonian Meneage Formation immediately beneath the Lizard Complex. During the final emplacement of the ophiolite it was no longer above the ambient regional temperature of around 250–350°C.

Description

There are no exposures of the Lizard Complex–Devonian sediment boundary inland, and it can only be seen on the west coast at Pollurian and to the east at Porthallow. The contact at Pollurian is a very distinct, late, steep fault with fault breccia, gouge and slickensides. It separates amphibolites from the Devonian mudstones of the Meneage Formation. The boundary at Porthallow is much less clear, and it seems that the controversy cannot be resolved solely on the basis of the field relations at these localities.

To the south of the Lizard boundary at Porthallow, is a thin zone of Old Lizard Head metasediments and then, south of this for some two kilometres, a spectacular section of the Traboe-type hornblende schists. At Porthkerris Cove there is Traboe-type hornblende schist to the north and Landewednack-type to the south. The main differences between the two are that the Landewednack type has been supposed to be derived from basaltic lavas and tuffs and the Traboe type from either contact metamorphism of the Landewednack type (Green, 1964b), or from metagabbros (Flett and Hill, 1912; Bromley, 1979; Styles and Kirby, 1980). Leake and Styles (1984) proposed that the Traboe type, as seen at Porthkerris, was part of a Traboe cumulate complex which also included dunites, pyroxenites and anorthosites (Figure 3.17). This occurred extensively inland, but the only good surface outcrop of the cumulate complex was at Porthkerris. This site is an excellent one at which to see the relationships between the different types of hornblende schists.

This section will be described starting at Porthallow and proceeding southwards to Porthkerris Cove, a continuous section of nearly 2 km where a tremendous variety of rocks is encountered (Figure 3.18). On the north side of the cove at Porthallow, are greenstones with pillow-like structures and altered rhyolites within the turbidite mudstones of the Roseland Breccia Formation (Holder and Leveridge, 1986). On the south side of the cove the first rocks encountered are fine-grained, cleaved mudrocks with a gentle southerly dip. They do not contain visible mica. The first few inlets along the cliff are along deeply eroded, steep faults dipping to the south, and the second one brings together the previously mentioned mudrocks with the fine-grained mica schists of the Old Lizard Head 'Series'. Thin-section studies show that these rocks have recrystallized mica and small garnets and thus are quite distinct from the adjacent sediments. This is indeed the contact between the Lizard Complex and the Devonian sediments, a late fault. The outcrops are very weathered, but the schists have a strong, flat-lying, schistosity and abundant evidence of intense shearing, including mylonitic fabrics seen in thin section. On the beach are large boulders of a pink quartzofeldspathic rock that have fallen from the quarry, the Porthallow Granite Gneiss of Flett and Hill (1912). This rock contains garnets in addition to the quartz, feldspar and mica and in the author's opinion are more likely to be metamorphosed quartzofeldspathic sediments than granite. There are also hornblendic schists within the sequence, although these are now extensively altered to chlorite. Overall, the rocks along this section bear a strong resemblance to those seen around Lizard Point, although here they are much more sheared and retrogressed.

To the east the Old Lizard Head metasediments are overlain by a very altered, carbonated, amphibole-bearing peridotite. The contact between the two is a thrust. The schists are epidotized and chloritized, and near the contact are mylonitized but there is no evidence of high-temperature alteration and it is assumed that the peridotites were 'cold' at the time of thrusting.

From here southwards, for about 150 m, are seen interlayered dunite serpentinite and gabbroic granulites, the contacts probably being tectonic rather than intrusive. The dunite serpentinite is a fine-grained, green-black rock, with small chlorite pseudomorphs after spinel. It is traversed by a network of joints that are the site of later chrysotile formation. The orthopyroxene-bearing, 'bastite serpentine', so familiar elsewhere in the Lizard peridotite, is absent. The amphibolites are fine grained and have a banded appear. ance but a granular texture, and in thin section contain small clinopyroxenes. These are Traboe-type amphibolites and it appears they have formed from 'layered' gabbroic rocks. On the beach are numerous boulders which have fallen from the quarry, which are superb examples of the highly deformed gabbroic granulite. They show very clearly the effects of high-temperature plastic deformation and shearing (Figure 3.19). Several phases of folding can be seen in the 'layered' gabbros, and classic fold interference patterns are developed.

For about 150 m to the east of another fault, the sequence is largely dunite serpentinite with several interlayers of a pale-grey rock. The observable field relations suggest that this is an early, possibly primary interlayering, but that some of the repetition is due to folding. Thin sections show that these are not basic rocks as might be expected, but are composed of Mg hornblende and chlorite, and probably derived from some kind of aluminous ultrabasic rock, possibly a spinel pyroxenite. This part of the section ends at another thrust, and the remainder of the section can be seen in the quarry at Porthkerris.

At the western end of the quarry are fine-banded amphibolites, and on the seaward slabs at Pol Gwarra are several metre-thick layers of amphibole peridotite. On the small promontory between Pol Gwarra and Pedn Tierre, is a body of leucogabbro, which appears to retain a layering-like feature, even though it is highly deformed. In this area, shear zones abound: many have gabbro pegmatites associated with them and it is possible that the shearing may have induced partial melting in the very hot, basic rocks. To the east around Pedn Tierre, is an area of very dark amphibolites and amphibolitized pyroxenites. To the east of a fault in an inlet there is a fine, granular amphibolite with *schlieren* of pale-green amphibole that contain relicts of rare clino-pyroxene. These 'pyroxenite' *schlieren* are usually lensoid and highly deformed but whether they originally formed layers cannot now be established. Very good examples of shear zones that have subsequently been folded can be seen immediately north of the Ministry of Defence buildings (Figure 3.18). The rocks to the south and east of the buildings are largely leucogabbroic amphibolites. There are scattered pyroxenite lenses and many superb examples of high-temperature deformation phenomena.

There are no exposures across Porthkerris Cove and on the south side, the lithology of the rocks is very different. Here are massive Landewednack-type amphibolites with a flat-lying foliation, and in a few places isoclinal folds can be seen. The very regular nature of the folds and foliation, contrasts strongly with the almost chaotic relations in the Traboe-type amphibolites to the north. The contact between the two types cannot be seen, but in the overgrown roadway at the back of the cove there are mylonitized amphibolites, of rather indeterminate nature, which suggest that the contact is possibly a thrust fault.

Most of the rocks along this section have a northerly dip to the foliation, but the 'stratigraphy' in the Traboe rocks youngs to the south. Allowing for some minor movements with later faulting, the sequence from north to south is dunite, pyroxenite, gabbro with pyroxenite, leucogabbro. This implies that the sequence is overturned relative to normal ophiolite 'stratigraphy'. The structures seen in the quarry at Porthkerris suggest a large fold plunging north, that the steep foliations in the wall of the quarry are the steep limb and the floor of the quarry is on a short flatter limb. This folding gives rise to the apparent diapiric shape referred to by Green (1964c) and Flett and Hill (1912).

Interpretation

The section between Porthallow and Porthkerris is well exposed and has received much attention from geologists, as outlined in the introduction. It is an excellent location to study two of the main controversies of the Lizard Complex, the nature of the Lizard boundary and the relations between the Traboe and Landewednack Hornblende Schists.

The contact between the Old Lizard Head schists and the Roseland Formation mudstones is a late, steep fault; as it is on the west coast at Pollurian. However, the schists immediately south of the fault have a gently dipping mylonitic fabric that is truncated by the fault, which suggests that thrusting was important at an earlier stage. The observable field relations show that the actual contact is a steep fault, but can this necessarily be extrapolated to signify the nature of the Lizard boundary in a wider context? Flett (1946) pointed out that the boundary has a sinuous trace across the north of the peninsula, which would be more compatible with a gently dipping structure rather than a simple steep fault. Recent geophysical evidence shows that the Lizard Complex is less than a kilometre in thickness and that it is underlain by Devonian sedimentary rocks (Brooks *et al.,* 1984; Rollin, 1986) as previously suggested by Styles and Kirby (1980). This tends to favour a thrust sheet, and, allied with dating of Lizard rocks showing Devonian ages, (Davies, 1984; Styles and Rundle, 1984) makes models involving upfaulted basement blocks untenable.

The question of the two types of amphibolites may now be examined here. Green (1964c) maintained that the effects seen at Porthkerris were due to the metamorphism of essentially homogeneous Landewednack-type amphibolites by the intrusion of peridotite: seen at the top of the quarry, and in a fault block on the beach at Porthallow. The aureole where these effects occurred was some 350 m wide, with an outer limit through the bay at Porthkerris and unaffected amphibolites at the south side of the bay. The metamorphic assemblages developed in the 'aureole' were clinopyroxene, and, in some places, two-pyroxene granulites. These can be found at Porthkerris, even though most of the rocks are extensively retrogressed.

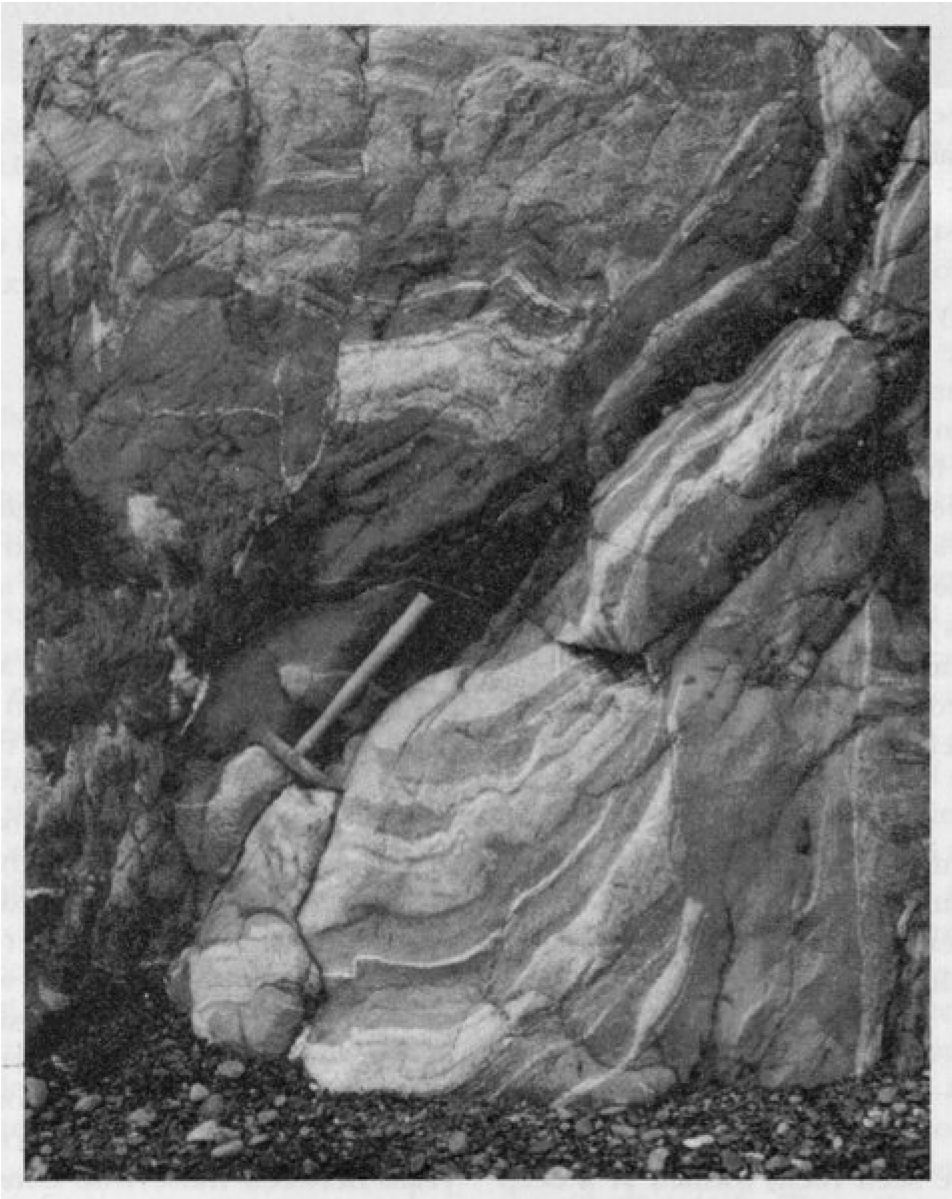
The most recent authors have questioned this interpretation, and have pointed out the wide range of rock types from dunite to anorthosite (Bromley, 1979; Styles and Kirby, 1980) and also the wide range of chemical compositions of the Traboe-type (Kirby, 1979b; Leake and Styles, 1984), which are markedly different from the Landewednack-type amphibolite. For this huge variety of bulk compositions to be produced from a homogeneous parent, would require chemical mobility of large amounts of material on a scale of tens of metres, and require a very fortuitous final distribution. In the light of the observed chemical inhomogeneities on a millimetric scale preserved in many rocks, this is extremely unlikely. It is much more likely that the variation in bulk compositions is essentially primary and that this is a fragment of a cumulate complex very similar to that in the Traboe area described by Leake and Styles (1984). It is important to note that none of the peridotites in this area are the 'typical' lherzolite or harzburgite mantle peridotites seen in most of the Lizard: they are mostly dunites and minor amphibole peridotites which are typical of the Traboe cumulate complex. The features seen here therefore cannot be taken as showing the relations between mantle and crustal rocks and extrapolated to the rest of the ophiolite.

The rocks in this site are in a series of thin thrust slices that form an imbricate zone at the base of the ophiolite nappe close to the Lizard boundary. Within these thrust slices are the only good exposures of the Traboe Cumulate Complex – a series of rocks formed by the high-temperature deformation of cumulates from magma chambers in the lower oceanic crust. The composition of coexisting ortho- and clinopyroxenes is controlled by the temperature at which they formed. Hence analysis of coexisting pyroxenes can be used to calculate their temperature of formation by geothermometry. Pyroxene geothermometry using the method of Wells (1977), gives temperatures in the range 900–1050°C, for granulites from the Traboe cumulate complex in the Traboe area (Styles, unpublished data). This is much hotter than normal regional metamorphism, and probably indicates the breakup of hot, newly formed crust, rather than prograde metamorphism of colder rocks.

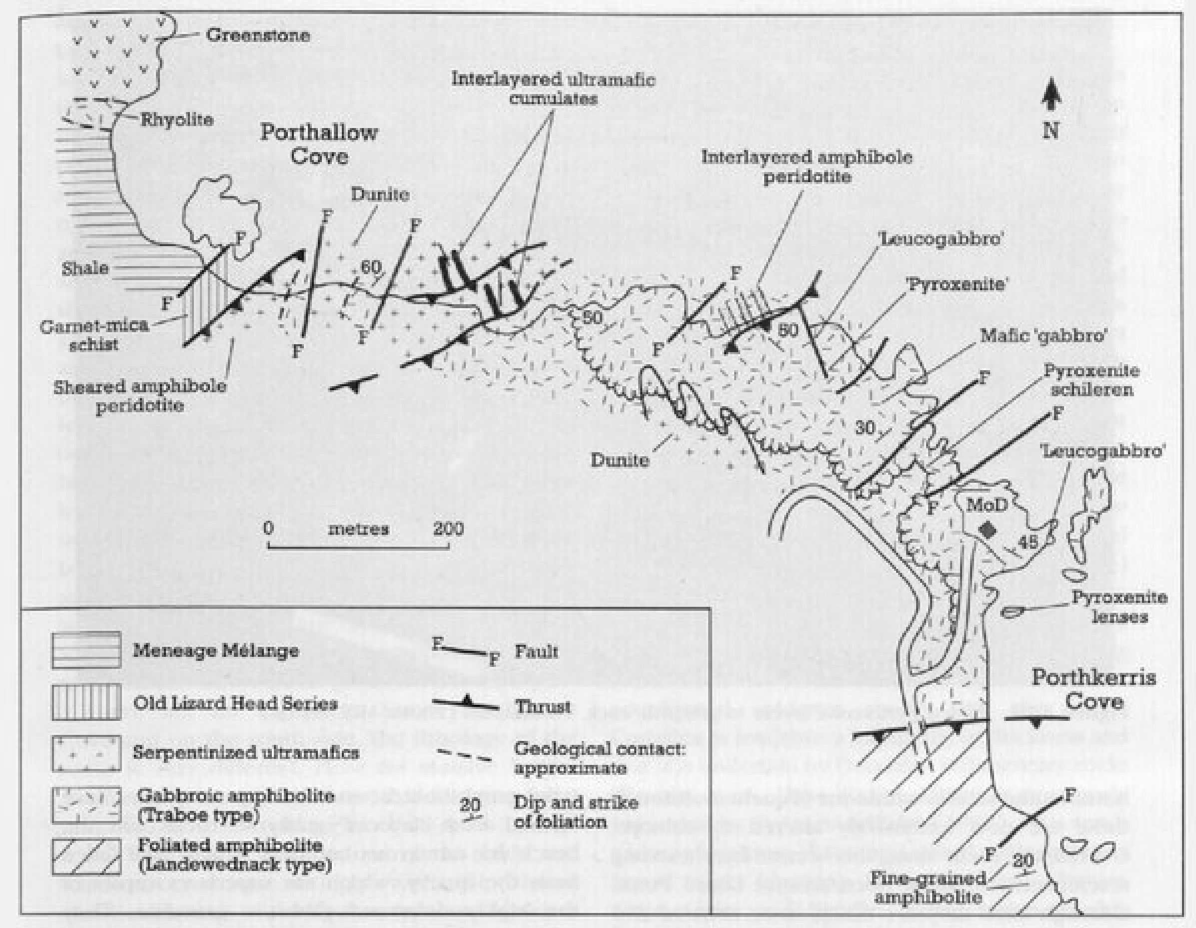
Conclusions

This locality is situated at the faulted boundary between hornblende schists of the Lizard Complex which are juxtaposed with low-grade 'normal' Devonian sedimentary rocks typical of most of south-west England. The Hornblende Schists here are part of the metamorphosed mafic–ultramafic unit within the Lizard Complex and representative of a segment of ancient ocean floor thrust subsequently into the adjacent continental margin. The thrust slice is now terminated by a high-angle steep fault that separates it from the continental sediments of the rest of Cornwall. The site provides evidence for major Earth movements that brought together rocks formed in very different environmental situations.

References



(Figure 3.17) Interlayered basic and ultrabasic cumulate rocks, Traboe-type schists, Porthkerris. (Photo: M.T. Styles.)



(Figure 3.18) Geological sketch map of the Porthallow Cove—Porthkerris Cove site ( )

(Figure 3.19) Folded pyroxenite layers in gabbroic rock, Porthkerris. (Photo: M.T. Styles.)