A3 Polbarrow–The Balk

[SW 717 135]–[SW 715 128]

Highlights

This is the best locality for showing complex intrusive relationships between the mafic and felsic components of the Kennack Gneiss Group, and the thrust contact between the Lizard peridotite and the Landewednack Hornblende Schists.

Introduction

This is a beach and cliff section 500 m in length, much of it is accessible only for a short period of time around low tide (Figure 3.11). The site shows two of the important geological relationships of the Lizard Complex. First, that between the Landewednack Hornblende Schists and the overlying Lizard peridotite in the southern part of the Complex, and, secondly, between the gabbros and felsic and mafic components of the Kennack Gneiss. The relationships seen from Parn Voose along the coast, past Whale Rock to Polbarrow, show a deformed intrusive complex of gabbro and banded gneiss, and are most important in an assessment of the origin of the Kennack Gneiss Group. A detailed account of the background research on the Kennack Gneiss Group was given previously with the Kennack Sands site description.

Description

The contact between the Lizard peridotite and the Landewednack Hornblende Schist is seen at The Balk, along the road leading into the old quarry from Church Cove and around the lower part of the old quarry face. The Landewednack Hornblende Schist is a dark, slightly banded, schistose amphibolite with a flat-lying foliation. Close to the contact with the overlying peridotite, the amphibolites are noticeably more gneissose. Some of this is possibly the effect of metamorphism, locally induced by the overriding peridotite, similar to that described by Green (1964c) at a similar contact north of Cadgwith. There are also some deformed pods of gabbro at this horizon. The actual contact with the peridotite is highly sheared, with a fairly gentle dip to the north-west; locally there is calcite and altered sulphide mineralization along the thrust plane. The thrust is offset by small, late, upright faults in several places. The peridotite also shows the effects of intense shearing and, in the quarry and on the beach below, blocks can be found with augen of orthopyroxene in a highly sheared matrix of streaky serpentinite, a peridotite mylonite. This section clearly shows that the peridotite was thrust over the Landewednack Hornblende Schists at relatively high temperatures; it is not an intrusive contact.

There is little outcrop between the Balk Quarry and Parn Voose Cove where the rocks are very different. The south side of the cove appears to be along a fault as, along the south wall, the peridotite is at sea-level, but at the back of the cove it is at the top of the cliff, some 50 m higher. A few outcrops and most of the boulders in the cove are dominantly mafic gneiss with thin veins of felsic material such as that figured by Flett (1946, p. 104). The gneiss has been highly folded and bears a striking resemblance to migmatites from high-grade metamorphic terranes. Much of the rock around the back of the cove is a medium- to coarse-grained gabbro (Figure 3.12), locally sheared and cut by flaser zones. Along the western side of the cove, xenoliths of peridotite and gabbro are included in banded gneiss.

Further north, between Parn Voose and Polbarrow, along the rocky ledges (only accessible at low tide), the relationships with the banded gneisses are most clearly seen. The gabbro body at the back of Parn Voose is quite extensive and forms much of the rock for some 500 m, but in many places it is intruded by thick sheets of banded gneiss. The intrusive relations are very clear, and there are numerous xenoliths of peridotite and gabbro within the gneiss. The gabbro intrudes into the peridotite and these are then in turn intruded by the banded gneiss. Often at the margins of the felsic gneiss, there is a rock of intermediate composition which has lobate contacts with the mafic rock and appears to have reacted with it. In some places, offshoots of felsic gneiss finger out into the gabbro, and in others, lenses of gabbro are streaked out within the foliation of the gneiss. The two rock types have clearly been deformed together at high temperatures. Many of the features of the contacts between the felsic gneiss and the gabbro suggest that the gabbro was hot and relatively soft at the time of injection of the gneiss. This was pointed out by Flett and Hill (1912) and Kirby (1979b). The peridotite appears to have acted as rigid blocks during the plastic deformation of the other rocks showing that, at the time of deformation, it was crystalline peridotite not serpentinite which would have had much weaker mechanical properties.

Interpretation (Kennack Sands and Polbarrow–The Balk)

The introduction to both Kennack Sands and Polbarrow showed that there has been a long-running controversy over the origins of the Kennack Gneiss Group. Proposals fall into two main groups:

1. migmatization of various mixtures of pelitic metasediments and hornblende schists, and
2. late composite intrusions of felsic and mafic magmas.

The outcrops within these sites are the most important for assessment of the origin of the rocks as they encompass the widest range of lithologies of this diverse group.

The finely banded, highly deformed rocks seen at Kennack and Parn Voose bear a striking resemblance to migmatitic rocks from high-grade terranes. At localities such as Polpeor local 'sweat outs' of granitic material suggest that local melting might have occurred in places where the temperature was a little higher. Similarly, at Porthkerris, local melting of the amphibolite seems to have taken place, so the circumstantial evidence for anatexis is present. However, even at Kennack the evidence (Sandeman, 1988) shows that the very banded rocks are restricted to the cliffs and innermost foreshore rocks and that overall there is a zonal arrangement. This zonal pattern was most clearly seen in some of the smaller outcrops, to the east of Kennack and at Little Cove Poltesco, but can also be demonstrated at Kennack. On the outer rocks is a granitic core, with few mafic rocks, followed farther inshore by a mixed, interbanded zone and finally a dominantly mafic zone with little granitic rock, close to the cliff. Such a regular pattern found at several localities is difficult to explain by a migmatitic origin, although some original inter-layering of sediment and amphibolite as proposed by Styles and Kirby (1980) might be plausible.

The field evidence from Kennack and Parn Voose is somewhat equivocal, but could be used to support a migmatitic origin. The proportions of felsic and mafic rocks are roughly correct, but the rocks have been so extensively deformed that any original contact effects or cross-cutting intrusive relations have been smeared out. The field relations around Whale Rock leave much less doubt as to the origin. It is the opinion of Flett and Hill (1912), Green (1964c), Sandeman (1988) and the author that the relationships seen here where the rocks are least deformed, are the key to the whole group. Here there are clear composite intrusions, with mafic magmas closely followed by felsic magmas and abundant evidence of hybridization processes. The location of the intrusions seems to be controlled by structural features, particularly flat-lying thrusts and, to a lesser extent, minor offshoots along steep faults. At Polbarrow and Parn Voose it may be the 'basal' thrust of the peridotite, but at Kennack a thrust within the lower part of the peridotite is also possible.

A borehole was drilled in 1980 by the Institute of Geological Sciences (now British Geological Survey) in the car park at Kennack (Figure 3.9), about 100 m north-west of the site described here (Institute of Geological Sciences, 1982). This penetrated some 150 m of Kennack Gneiss with interlayers of peridotite (Styles and Kirby, 1980). Such a thickness was much greater than expected, as most previous models had suggested that the gneiss was essentially a thin development at the base of the peridotite sheet. It would be difficult to generate such a thickness of gneiss by melting, as there would be a problem in achieving sufficient heat; sandwiching the protolith material between slabs of peridotite is one of the few possibilities. There is no real problem about the thickness if the origin was intrusive.

Kirby (1979b) and Malpas and Langdon (1987) put forward chemical data which they interpreted as supporting a migmatitic origin. The chemical compositions of parent rocks, felsic anatectites and mafic restites seemed to fall on linear trends, as would be expected if they were related by partial melting. The composition of granitic fractions was also similar to minimum melt compositions. The chemical data of Sandeman (1988), with a much larger number of samples, do not clearly show these important linear trends. He has suggested that only the felsic fractions show linear trends, and that the mafic rocks show either scattered or possibly curved distribution. The trends suggested by Malpas and Langdon (1987) may be a fortuitous accident of their small, and hence unreliable, data set. A summary of this new data (Sandeman *et al.,* in prep) is given below.

The mafic magmas that formed the mafic portion of the gneiss are quite distinct from the Landewdnack Hornblende Schists and most of the ophiolite dykes that have oceanic affinities. They are light-REE-enriched and have affinities with volcanic arcs and show evidence of crystal fractionation. The mafic magma chambers were intruded by felsic magmas, leading to the magma mingling which, on intrusion into the peridotite, etc., gave the very banded gneisses and some mixing and hybridization to produce intermediate magma types. In most cases, these phenomena can only be assumed from the chemical characteristics, and only at localities such as Whale Rock can they actually be seen. The subsequent intense deformation of possibly hot, incompetent rocks accentuated the degree of banding and gneissic appearance of these mixed rocks.

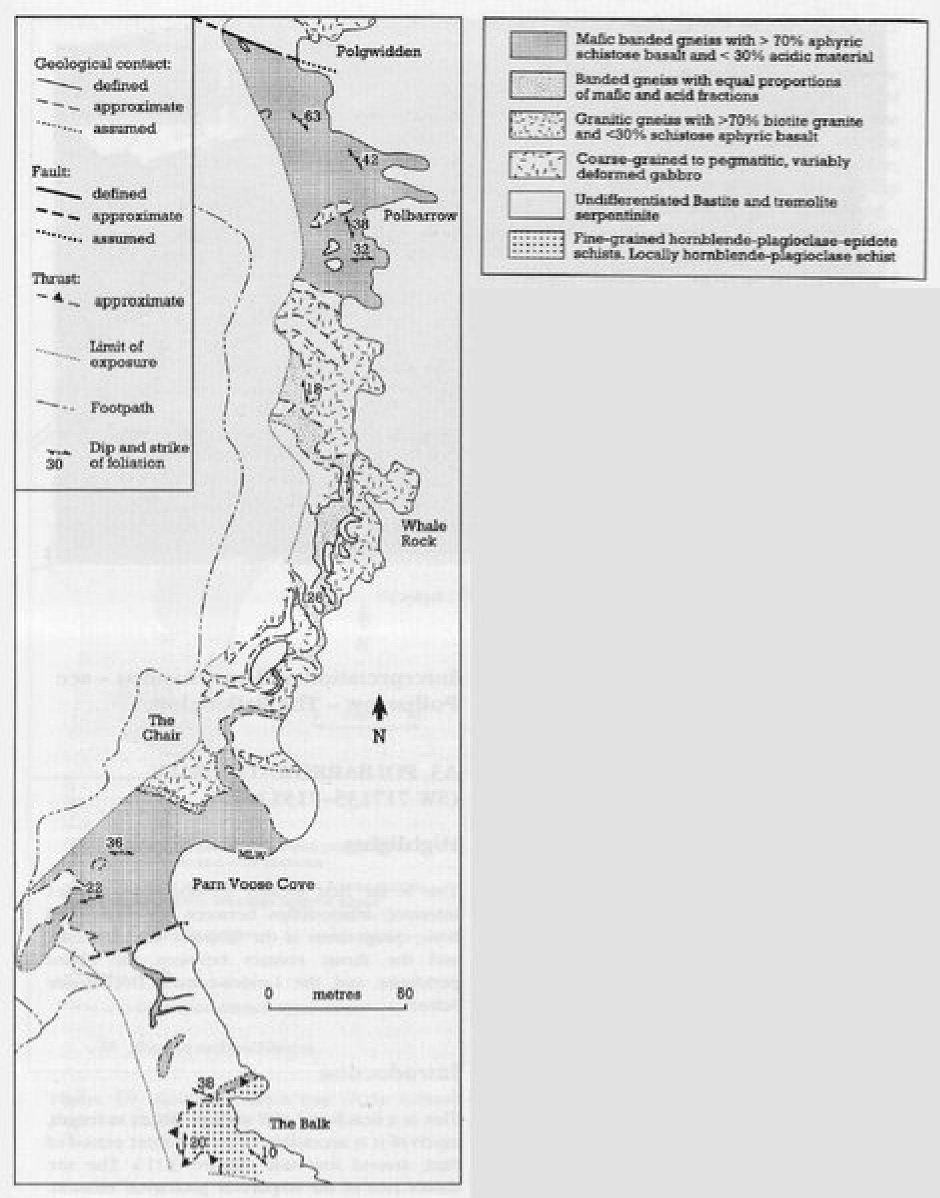
It is interesting to note that the two most detailed studies by Flett some 80 years ago, based entirely on field relations, and by Sandeman with the aid of modern geochemistry, have come to essentially the same conclusion. The Kennack Gneisses are a series of composite mafic and felsic intrusions that subsequently have been extensively deformed.

Conclusions (Kennack Sands and Polbarrow–The Balk)

These are important sites showing the juxtaposition by a major thrust plane of the Lizard peridotite and the Landewednack Schist, two constituent major parts of the Lizard Complex. A wide range of igneous rocks including gabbros, and acidic and basic gneisses, are also exhibited. Although the association of metamorphic and igneous rocks is complex, a sequence of events may be determined that helps to interpret the magmatic structure of the oceanic crust and upper mantle.

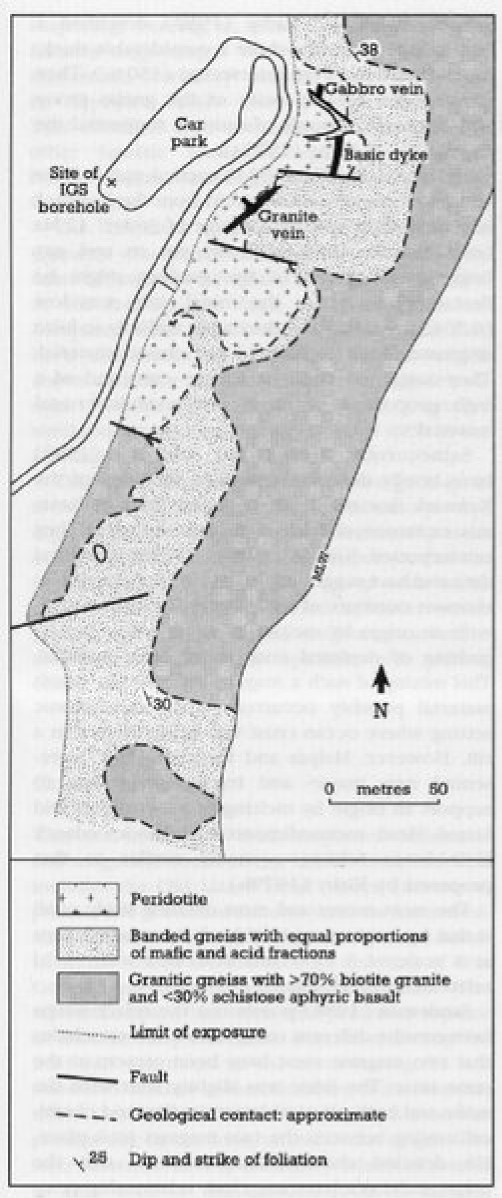
Peridotite occurs as blocks in the gneisses. Gabbro intrudes the peridotite and is in turn intruded by gneiss, the last dated to around 370 million years before the present (early to mid-Devonian). The intimate mixing (and, in places, hybridization) between basic and acid gneisses has been the subject of much debate. It is now thought to have been the product of the mixing of two very different but contemporaneous magmas. These sites tell us much about the development of the Lizard Complex as a slice of ancient ocean floor that was finally thrust over continental crust during late Devonian times.

References



(Figure 3.11) Geological sketch map of the Polbarrow—The Balk site (A3) (after Sandeman, 1988).

(Figure 3.12) Acid-veined gabbro at Parn Voose. (Photo: M.T. Styles.)



(Figure 3.9) Geological sketch map of the Kennack Sands site (A2).