SKEO TAING TO CLUGAN

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Introduction

The site lies on the east side of Unst within the Lower Nappe of the Shetland Ophiolite. It is bound to the east by a nearly continuously exposed low-lying cliff section which is of great importance in that it illustrates the uppermost kilometre of the metadunite layer, the geophysical Moho (not exposed), and a kilometre of the overlying lower metagabbro layer. Inland the site is not well exposed but presents evidence complementary to that in the cliffs. The metadunite layer has been interpreted conventionally as an ultramafic layer which, like overlying basic layers, accumulated in a magma chamber resting on the mantle below a constructive plate margin (Gass *et al*., 1982; Prichard, 1985). However, much field evidence supports an alternative origin wherein the metadunite layer and the basic layers are separate intrusive bodies and not cumulate layers. Xenoliths of interbanded clinopyroxenite and wehrlite are prominent (Flinn, 1996). The site offers an easily accessible view of the passage from ultramafic to mafic rocks in the ophiolite succession and the very different form that this takes from the conventional ophiolite model.

Description

The geology of the Skeo Taing to Clugan site is summarized in Figure2.8; note that the metadunite outcrop shown is a continuation (across strike) of that part of the same layer shown in Figure 2.6 and previously described at Wick of Hagdale (seeThe Punds to Wick of Hagdale GCR site). At Skeo Taing the top of the metadunite layer is exposed and typically is rich in wehrlite–clinopyroxenite xenoliths and screens, much more so than in the equivalent layer at Wick of Hagdale. Clinopyroxenite xenoliths too small to show on the map also occur in the Skeo Taing area; all are closely associated with interstitial clinopyroxene in the host metadunite.

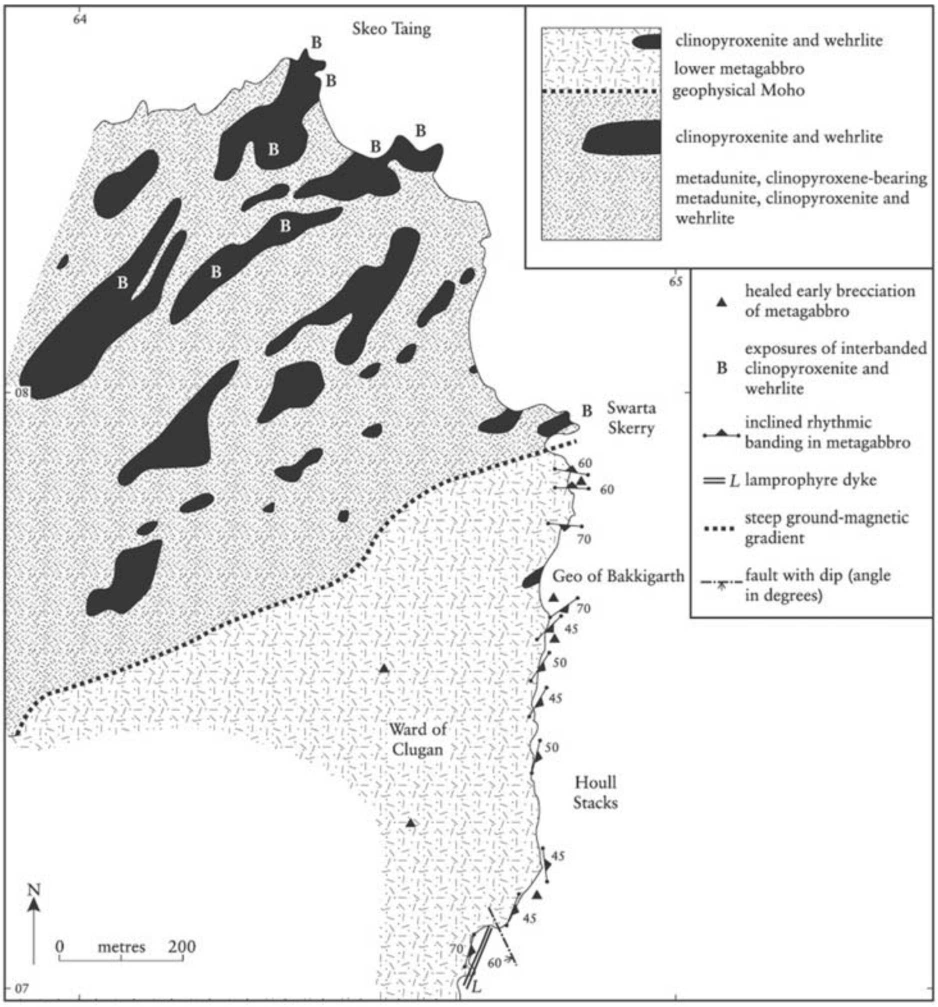

Figure 2.8: Map of the Skeo Taing area, Unst.

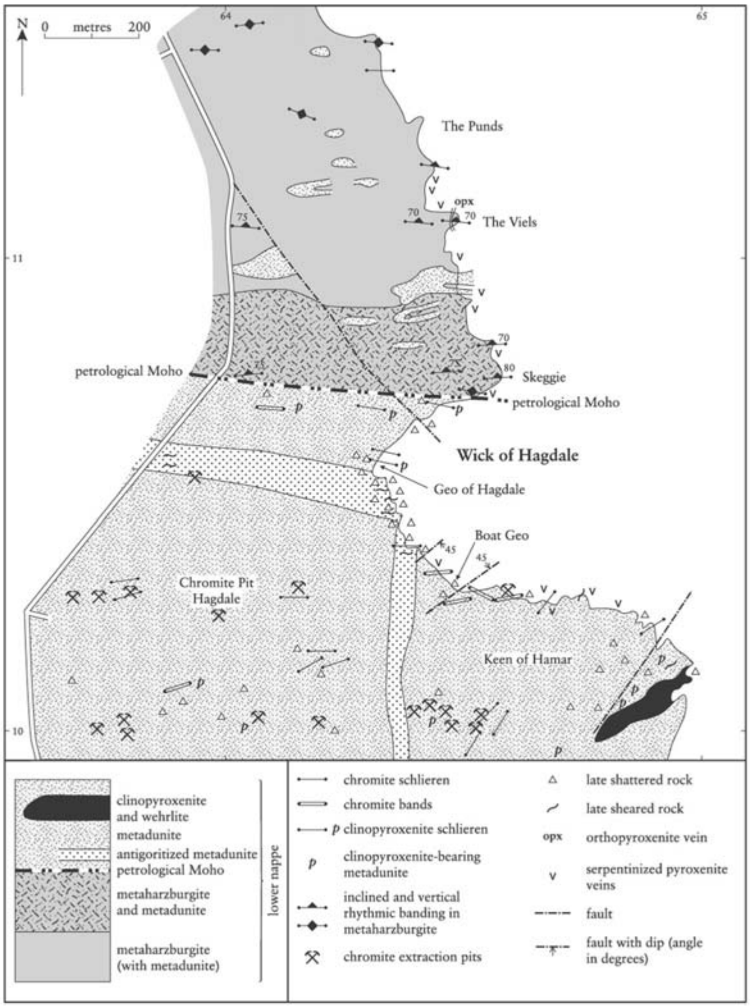

Figure 2.6: Map of the Wick of Hagdale area, Unst.

In this account, metadunite containing interstitial clinopyroxene will be called clinopyroxene-bearing metadunite even where it contains sufficient clinopyroxene to be petrographically classed as wehrlite (Figure 2.3). This is done in order to distinguish it from the wehrlite associated with clinopyroxenite from which it is texturally distinct. In the metadunite small, fresh clinopyroxene grains occur interstitially to the larger, several-millimetre-sized serpentinized olivine grains whereas, in the wehrlite, the serpentinized small olivine grains are interstitial to the much larger, fresh clinopyroxene grains which in some samples are as much as a centimetre across.

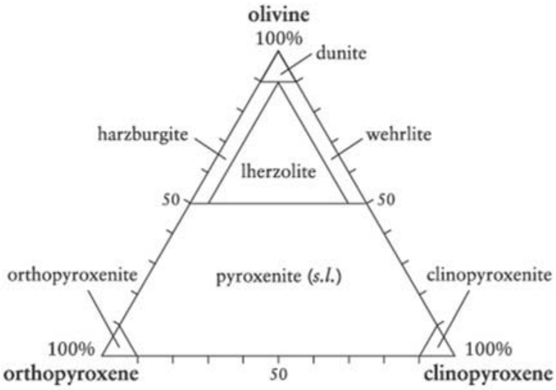

Figure 2.3: Descriptive nomenclature for ultramafic rocks in terms of their relative content of olivine and pyroxene.

The larger wehrlite–clinopyroxenite masses, those measured in tens of metres, form mound-like exposures rising a metre or two above the enclosing metadunite. The presence in them of abundant, fresh, large clinopyroxene grains makes the wehrlite–clinopyroxenite more resistant to erosion than the enclosing serpentinized dunite and clinopyroxene-bearing metadunite. As a result the wehrlite–clinopyroxenite masses form the characteristic protuberant features that commonly carry an enhanced vegetation cover, probably due to the fertilizing effect of the Ca in the clinopyroxene. The low ground between the wehrlite–clinopyroxenite masses is occupied by their metadunite and clinopyroxene-bearing metadunite host rocks which, in the coastal exposures, can be seen to contain smaller wehrlite–clinopyroxenite xenoliths. The wehrlite–clinopyroxenite masses are only well exposed on the coast where it is apparent that they are formed of wehrlite, olivine-clinopyroxenite and clinopyroxenite complexly interbanded and intergraded on a scale ranging from several centimetres to several decimetres. The bands are much less rectilinear than those in the metaharzburgite and the metagabbro and can rarely be followed for more than a metre; some occurrences exhibit disruption and contortion of the banding.

The contact between the metadunite layer and the lower metagabbro layer to the south is seen in only one small exposure in Unst and that is at 610 054, outside the area of Figure2.8. However, the contact is closely confined by exposures on either side for considerable distances in several places and everywhere it can be followed by magnetometer since it gives rise to a very steep ground-magnetic gradient. The contact thus sharply defined lacks transitional lithologies and is curvilinear and unsheared. In the upward succession it marks the incoming of feldspar and the exit of olivine (fresh or serpentinized) except in xenoliths. This creates the most profound lithological change in the succession and is therefore considered to represent the geophysical Moho.

The lower metagabbro is as uniformly hydrated as the metaharzburgite and the metadunite (see The Punds to Wick of Hagdale GCR site). The clinopyroxenes have been replaced by single-crystal plates of colourless to pale-green amphibole and the feldspars have been altered to very low birefringence, very fine-grained pseudomorphs. As a result the rock weathers to a speckled pale-green and white pattern. Relict clinopyroxene is rare. Twinned, fresh albitic plagioclase occurs sporadically, associated with the altered plagioclase. The metagabbro contains no evidence of having ever contained olivine. Fresh interstitial grains of brown hornblende occur as a sparsely distributed original accessory. The early uniform hydration, as in the metaharzburgite, was followed by a later low-grade metamorphism closely related to shearing.

The metagabbro is characterized locally by regular alternations of pyroxene-rich and feldspar-rich ungraded bands, each several centimetres thick (Figure2.9). South of the geophysical Moho in the coastal section (south of (648 076); Figure2.8), this banding is seen to be repeated continuously for several hundred metres but most occurrences are small patches or even single bands. The attitude of the bands varies considerably but generally the dip direction is between east and south.

Figure 2.9: Rhythmic banding in metagabbro (HP 647 077). (Photo: D. Flinn.)

Large areas of the metagabbro have been intensively brecciated but subsequently healed. The metagabbro fragments, each no more than several centimetres across, have all been slightly rotated relative to each other but the rock is as resistant as the unbrecciated variety and the fractures are not apparent in thin section. Such brecciation occurred earlier than the more common and widespread late shattering and shearing. This healed brecciation makes rhythmic banding difficult to detect.

At Geo of Bakkigarth (6475 0765), 200 m south of the geophysical Moho in Figure2.8, there is a small xenolithic mass of wehrlite-dominated wehrlite–clinopyroxenite associated with some late shearing. This is one of a series of xenoliths, each up to several tens of metres across, composed of wehrlite–clinopyroxenite and clinopyroxene-bearing metadunite. These occur within the metagabbro close to its western boundary with the metadunite, but otherwise outside the area covered by Figure 2.8. Some are associated with swarms of pyroxenite fragments up to 10 cm across. Rhythmic banding in the metagabbro close to these blocks varies more widely than in the general mass of the metagabbro. All these wehrlite–clinopyroxenite masses are indistinguishable from those in the metadunite layer and like those are considered to be xenoliths.

Interpretation

In Shetland the succession above the petrological Moho takes the form of two distinct layers, each several kilometres thick, one of metadunite and the other of metagabbro. Both these layers contain fragments of a disrupted, coarsely crystalline and intensively banded wehrlite–clinopyroxenite layer. In the metadunite layer these xenoliths have been partly assimilated so that they are surrounded by metadunite containing isolated interstitial clinopyroxene grains.

The metadunite layer with its xenoliths of wehrlite–clinopyroxenite has been presented hitherto as ultramafic cumulates in which 'dunite grades into wehrlite and then pyroxenite'. This description is generally accompanied by idealized sections showing separate successive layers of dunite, wehrlite and clinopyroxenite (Gass *et al.*, 1982; Prichard, 1985; Lord *et al.*, 1994). While this representation is not wholly inappropriate, it hides the full sequence of relationships: wehrlite–clinopyroxenite xenoliths are enclosed in contamination aureoles of clinopyroxene-bearing metadunite suspended in an intrusive metadunite layer. Recently, the obvious absence in the field of continuous layers of wehrlite and clinopyroxenite has been explained as the result of tectonic disruption by NE-trending sinistral faults (Lord *et al.*, 1994). However, the absence of any evidence on the ground or on aerial photographs of such faults, together with the unfaulted continuity of the nearby metagabbro–metadunite boundary (as proved by magnetometery – see above), casts doubt on this interpretation.

Prior to the emplacement of the dunite layer it is possible that the wehrlite–clinopyroxenite masses formed a continuous unit that rested on the mantle and formed *in situ*, as cumulates from an early magma chamber, on the Gass (1980) model. This continuous unit was later disrupted and lifted piecemeal to a higher level, first by the arrival of the intrusive dunite layer and later by the gabbro.

The nature of the geophysical Moho, so clearly revealed in this area, is particularly relevant to the long-running volume problem in serpentinization. Serpentinization of an olivine-rich rock results in a decrease in density of about 20% and, according to petrographic calculations, either an increase in volume of about 45% (*c.* 13% linearly) or a loss of magnesia and silica of about 35% by weight (O'Hanley, 1992). In the past, serpentinization has been accepted as occurring with conservation of volume and loss of material to the surrounding rocks by metasomatism, or with conservation of material and volume increase taken up in bounding faults, with or without internal fracturing. Unst is unique in providing evidence that no expansion has taken place across the serpentinite–metagabbro contact and that no metasomatic transfer has occurred, despite the serpentinization of an olivine-rich rock. The problem remains an enigma.

Conclusions

The Skeo Taing to Clugan GCR site is of international importance in that it provides an accessible and almost continuously exposed coastal section through the geophysical Moho; a traverse across the boundary between the underlying ultramafic rocks and the overlying basic rocks in the ophiolite succession. However, the relationships revealed show that it is intrusive contacts that are involved and not compositional divisions within a continuous series of related rocks formed in a magma chamber. This controversial aspect adds to the overall value of the site in terms of ophiolite research.

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