# VIRVA

*Derek Flinn*

*OS Grid Reference: HU645921*

## Introduction

The site is bound to the east by a continuously exposed sea-cliff section revealing the base of the Vord Hill Klippe, a part of the Upper Nappe, the underlying thrust and the rocks below the thrust. Except at the south end of the site the cliffs are almost entirely composed of sheared and shattered serpentinite forming the cataclastic base of the Upper Nappe. In three places hornblendic rocks belonging to the underlying Middle Imbricate Zone are exposed. Both the hornblendic rocks and the overthrust ultramafic nappe are very well exposed and readily accessible. Hornblende schists are a characteristic feature of ophiolite complexes and are commonly found immediately beneath ophiolite nappes. They are conventionally interpreted as dynamothermal aureoles caused by the obduction of hot mantle nappes over basic volcanic rocks of the sea floor (Williams and Smyth, 1973). This interpretation has been applied to Fetlar by Gass *et al*., (1982), Prichard (1985) and Spray (1988), but has been rejected by Flinn on the basis of field evidence obtained from this site (Flinn *et al*., 1991; Flinn, 1993).

## Description

The sea cliffs northwards from Virva are formed of intensively shattered serpentinite lying immediately above the basal thrust of the Vord Hill Klippe of the Upper Nappe (Figure 2.16). The main body of the klippe to the west, underlying central Fetlar, is almost entirely formed of strongly ochrous-weathering metaharzburgite. However, one-quarter to one-half a kilometre west of the shoreline in Figure 2.16 the weathering colour changes eastward to white and the rocks become increasingly shattered and sheared. The change in weathering colour is due to the recrystallization of ochrous-weathering, relatively iron-rich lizardite serpentine to white-weathering, iron-poor antigorite serpentine and magnetite, a recrystallization that occurs along major shears in the metaharzburgite throughout the ophiolite. On the cliff face the serpentinite is seen to be intensely shattered and is coarsely sheared locally. Continuous fractures, many of which dip to the west, cut through this chaotically arranged assemblage. The condition of the serpentinite varies from a mass of fine powder to coherent blocks a metre or more across.

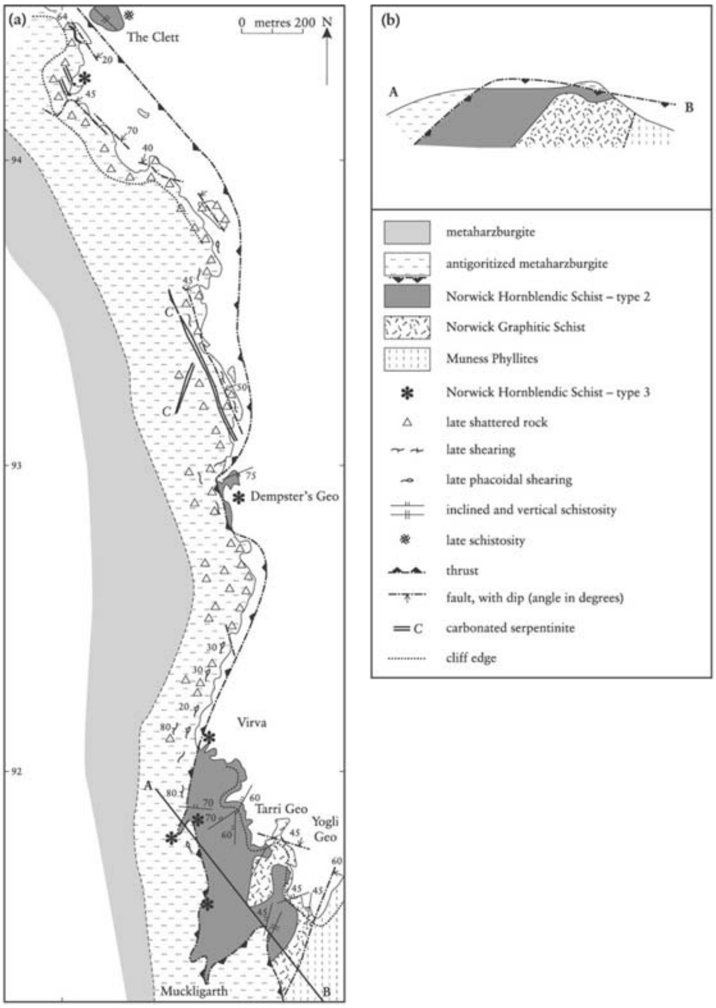


*Figure 2.16: (a) Map of the Virva area, Fetlar. (b) cross section*

North of Virva the thrust beneath the serpentinite is submerged beneath the sea at the foot of the cliff and is exposed only at Demptster's Geo. At Virva (Figure2.17) it is exposed as it passes inland to the south, where its course is marked by a very minor escarpment. The thrust plane is a thin zone of finely crushed and sheared rock a few centimetres thick. In the Virva area the base of the klippe adjacent to the thrust has been sheared into a crushed conglomeratic mass some metres thick and composed of phacoidal serpentinite blocks ranging up to half a metre in diameter.

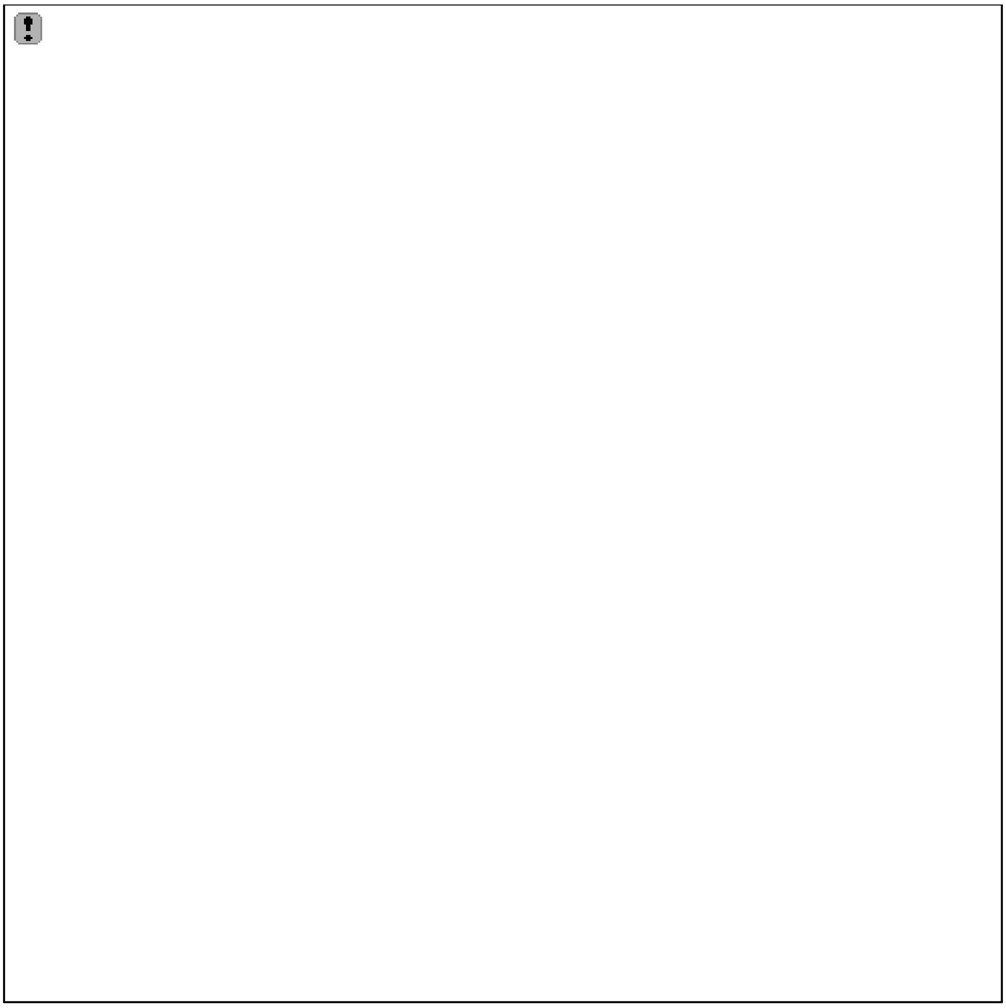

*Figure 2.17: Virva from the north, showing the outcrop of the thrust below the Upper Nappe and the underlying hornblendic rocks. NHS, Norwick Hornblendic Schist (Photo: D. Flinn.)*

The hornblendic rocks beneath the nappe are equivalent to hornblendic rocks in Unst which occupy a similar tectonic position and were named the Norwick Hornblendic Schists byRead (1934). Three types of Norwick Hornblendic Schist have since been distinguished byFlinn (1993) of which two occur in the Virva site; these have been named Norwick Hornblendic Schist – type 2 and Norwick Hornblendic Schist – type 3 and are described below.

The Norwick Hornblendic Schist – type 2, here referred to as hornblende schist, is composed largely of green hornblende with the grains elongated parallel to the c-axes and arranged in the plane of the schistosity making them S-dominant tectonites with little sign of a lineation. The maximum grain size is rarely more than one millimetre. The schistosity is often emphasized by closely spaced, feldspar-rich, fine lenticular laminations. The schists contain epidote and chlorite in variable amounts, often associated with low-grade alteration. Titanite is a very common and often abundant accessory.

The Norwick Hornblendic Schist – type 3, here referred to as hornblende granofels, is a hornblende-clinopyroxene-garnet granofels with a grain size of several millimetres. It generally appears as black and homogeneous and the garnet and clinopyroxene grains can only be clearly discerned in the polished exposures near sea level. The hornblendes are brown and have a weak optical preferred orientation. The hornblende grain boundaries form a granoblastic polygonal mosaic indicative of recrystallization under isostatic conditions. The boundaries of the clinopyroxene grains cut across this hornblende mosaic showing that pyroxene replaced hornblende. Garnet (as grains generally about 2 mm in diameter), titanite, ilmenite, apatite, rutile and small amounts of quartz occur as accessories together with minor amounts of recrystallized (albitic) feldspar.

The relationship of the two types of Norwick Hornblendic Schist to the serpentinite nappe are best displayed at Virva. There, Gass *et al*., (1982) and Spray (1988) described a contact between the serpentinite and a clinopyroxene-garnet-hornblende rock (the granofels) which grades east (away from the serpentinite) through hornblende schist into greenschist. As described above, the mineral constituents of the granofels can only be identified in the field at the cliff-foot, where it has been scoured by the sea. Thin sections reveal that in fact the granofels grades to both east and west into chilled margins, a metre or more wide, against the adjacent rocks. In its outer part the chilled margin consists of fine-grained (less than 0.1 mm) aggregates of chlorite containing scattered opaque grains and very rare grains of clinozoisite 0.2–0.3 mm across. This contact facies passes into an inner zone dominated by closely packed anthophyllite needles in a matrix of chlorite but including rounded spots of pure chlorite about 0.3 mm across. This in turn passes through a random mixture of amphiboles, chlorite, epidotes, albite, ilmenite, and titanite, into the high-grade hornblende granofels.

At Virva (6445 9208) the hornblende-garnet-clinopyroxene granofels (Norwick Hornblendic Schist – type 3), with its chilled margins, extends along the coast for some 40 m from the thrust. The hornblende schist (Norwick Hornblendic Schist – type 2) cropping out immediately east of the granofels contains widely scattered lenticular streaks of clinopyroxenite, albite pegmatite, and quartzo-albitic leucosome; some tens of metres farther east it also contains two thin lenses of apparently psammitic, garnet-biotite gneiss. Several hundred metres east of the basal thrust the hornblende schist becomes almost unrecognizable due to crushing and late retrograde metamorphism.

Several other localities within the Virva site show important aspects of the granofels and schist. Chilled hornblende granofels can be seen welded to serpentinite in small exposures on the hillside south of Virva, at 6446 9157 and (6442 9185). At the latter exposure the granofels invades the serpentinite in a metre-wide dyke-like apophysis with a south-westerly trend. Hornblende schist forms the sea stack at Dempster's Geo and, between the stack and the serpentinite of the nappe in the adjacent cliff, fragments of chilled hornblende granofels occur among the shattered rock. Farther north, at the base of the cliff opposite to The Clett (640 943), two or three south-dipping intrusive sheets, less than a metre thick, consist of chilled hornblende granofels. At the southern margin of Figure 2.16, to the south of the coast at Virva, the basal thrust of the klippe can be seen to cut across the Norwick Hornblendic Schist into the underlying graphitic phyllite layer of the Middle Imbricate Zone.

## Interpretation

Williams and Smyth (1973) showed that hornblende schists are a characteristic component of ophiolite complexes and used the Norwick Hornblendic Schists, as described by Read (1934), as one of a number of examples. Williams and Smyth interpreted the ophiolitic hornblendic rocks as a 'dynamothermal aureole' produced as hot harzburgitic mantle was obducted over basic rocks of the sea floor which were thus heated and thermally metamorphosed. Gass *et al*. (1982) applied this model to the Shetland Ophiolite. They showed that at Virva the grade of the hornblendic rocks decreases downwards from the basal thrust, stating that 'A thin zone of garnet-clinopyroxene amphibolite grades into amphibolite and then greenschist facies away from the contact'. However, farther west the base of the nappe overlies sheared, shattered and antigoritized serpentinite and to the east the greenschist, into which the amphibolite grades, is retrogressively metamorphosed amphibolite. These relationships do not fit readily with the simplistic interpretation of thermal metamorphism by an obducted, hot mantle slab.

Spray (1988) accepted the Gass *et al*. (1982) interpretation and drew further conclusions. He showed that the composition of the hornblendic rocks (supposedly the ocean floor overthrust by the ophiolite nappe) is significantly different both to that of the basic sheets of the quasi-sheeted-dyke complex and to that of their fine-grained upper metagabbro host (as exposed in Unst). On the basis of compositional comparisons with other ophiolite complexes he argued that the hornblendic rocks originated as true ocean floor whereas the Shetland Ophiolite was formed as the floor of a small basin marginal to that ocean. The marginal basin was envisaged as opening while the true ocean floor was subducted beneath it.

Flinn *et al*. (1991) and Flinn (1993) have argued that the Shetland ophiolitic nappes were already serpentinized when they were obducted and were thus too cool to have metamorphosed basic volcanic rocks of the ocean floor to form hornblende schist. It was also suggested that the protolith of the hornblende granofels was not basaltic oceanic floor but basic magma adiabatically melted from the mantle and segregated in the initial fracture arising from decoupling at the onset of obduction. The hornblende schist may have originated in a similar manner but somewhat earlier so that it served to lubricate the thrust during movement and thus became schistose as it cooled and crystallized.

Spray (1988) reported six K-Ar ages for hornblendes separated from four hornblendic lenses beneath the nappes. The oldest age obtained, 479 ± 6 Ma, was from the Virva occurrence (6445 9208) and the remainder ranged up to 465 ± 6 Ma. Spray interpreted this range of different ages as resulting from diachronous accretion of the hornblende schist during obduction. However, the widespread retrogressive metamorphism in the hornblende schists, leading to partial loss of radiogenic argon, makes these dates unreliable. A more dependable date is the $^{40}$Ar-$^{39}$Ar step-heating age of 498 ± 2 Ma for hornblende separated from a Virva sample of the hornblende granofels (Flinn *et al*., 1991). In view of the likely low temperature of the nappe when obducted, the hornblende would not have taken long to cool to the closure temperature. This age is therefore regarded as a good estimate of the date of obduction of the Upper Nappe.

## Conclusions

The coastal section north of Virva, Fetlar, provides an accessible and extensive view of the basal thrust of the Upper Nappe. This allows examination of the thrust's relationship to the underlying hornblendic granofels and schist. It is a crucial locality in the controversy surrounding the origin of these rocks and their relationship to the obduction of the Shetland Ophiolite and is of international significance. In particular, the site provides evidence that these hornblendic rocks cannot be a part of a thermal aureole formed as hot mantle was thrust over basic volcanic rocks of the ocean floor, following the conventional interpretation of hornblende schists found associated with ophiolites. Instead, a preferred interpretation is that the hornblendic rocks formed from basic magma which was intruded, from deep in the mantle, into the basal thrust of the ophiolite as it was obducted.

## Reference list

Flinn, D. (1993) New evidence that the high temperature hornblende-schists below the Shetland ophiolite include basic igneous rocks intruded during obduction of the cold ophiolite. *Scottish Journal of Geology*, **29**, 159–65.
Flinn, D., Miller, J. A. and Roddam, D. (1991) The age of the Norwick hornblendic schists of Unst and Fetlar and the obduction of the Shetland ophiolite. *Scottish Journal of Geology*, **27**, 11–19.
Gass, I. G., Neary, C. R., Prichard, H. M. and Bartholomew, I. D. (1982) The chromite of the Shetland ophiolite. A report for the Commission of the European Communities. Contract 043-79-1-MMP U.K.
Prichard, H. M. (1985) The Shetland ophiolite. In *The Caledonian Orogen – Scandinavia and Related Areas* (eds D. G. Gee and B. A. Sturt), Wiley, Chichester, pp. 1173–84.
Read, H. H. (1934) The metamorphic geology of Unst in the Shetland Islands. *Quarterly Journal of the Geological Society of London*, **90**, 637–88.
Spray, J. G. (1988) Thrust related metamorphism beneath the Shetland Islands oceanic fragment, north-east Scotland. *Canadian Journal of Earth Sciences*, **25**, 1760–76.
Williams, H. and Smyth, W. R. (1973) Metamorphic aureoles beneath ophiolite suites and Alpine peridotites: tectonic implications with west Newfoundland examples. *American Journal of Science*, **273**, 594–621.