Sango Bay

[NC 406 681]–[NC 412 676]

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Introduction

Peach *et al.* (1907) recognized the importance of the Faraid Head and Sango Bay outcrops of Moine metasedimentary rocks and mylonites in that they lay distant from their main outcrop east of Loch Eriboll. The basal contact of these allochthonous units with the underlying substrate of Cambro-Ordovician Durness Group carbonate rocks is exposed in the Sango Bay area (Figure 5.14), just east of Durness village. Small sea stacks and crags in the bay also provide spectacular outcrops of 'Oystershell Rock', together with a range of less-deformed correlative units.

Sango Bay lies in a small fault-bounded wedge-shaped structural outlier that itself lies within the larger down-faulted Durness outlier (Figure 5.12), which preserves the Cambrian foreland sequence (see Faraid Head GCR site report, this chapter). The Sangomore Fault, whose fault scarp forms the south-east side of Sango Bay, drops down units of the allochthonous thrust sheet against these carbonate rocks. The site includes arrays of normal faults that relate to the main NNE- to NE-trending bounding faults of the Durness outlier. These faults form part of a complex set that probably relate to the formation of Devonian and Mesozoic offshore basins.

Since the work of the Geological Survey in the late 19th century, the Sango Bay area has been little studied, although the published patterns of the late normal faults have been used to link onshore with offshore basin tectonics (e.g. Enfield and Coward, 1987). Laubach and Marshak (1987) linked the coastal outcrops at Durness inland to explore how basement structures might have influenced the geometry of the fault system. Hippler (1989) investigated fault-rock evolution, particularly the structural overprinting of quartz mylonites by cataclasites associated with the faults (Hippler and Knipe, 1990). Her terminology of fault names is followed here. Most recently, Beacom (1999) has remapped the faults along the coast between Loch Eriboll and Cleit Dhubh as part of a regional study of brittle fracturing patterns in the Lewisian Gneiss Complex.

Description

The margins of the spectacular sandy Sango Bay site are defined by long, NNE-trending cliff-lines, developed along eroded fault scarps partially coated with cemented breccia largely derived from Durness Group carbonate rocks (Figure 5.14). The structurally highest rocks in the area now lie downthrown in the hangingwalls to these late normal faults.

Exposed on low skerries and stacks around [NC 410 676] are banded quartzofeldspathic and amphibolitic gneisses. These show characteristics of Lewisian or Lewisianoid rocks but contain penetrative greenschist-facies (chlorite, actinolite and epidote-bearing) assemblages, indicative of significant retrogression. Small chlorite- and epidote-rich shear-zones cut the gneisses. Westwards, the degree of retrogression and deformation appears to increase so that outcrops immediately below the public house [NC 408 677] are unrecognizable in origin. At these localities, small sea stacks are composed of crenulated chloritic phyllonite with small lensoid blebs of quartz. This is the 'Oystershell Rock' of Peach *et al.* (1907). Locally the quartz blebs contain a strong ESE-plunging mineral lineation. The phyllonites generally preserve an intersection lineation defined by the axes of the crenulations. These are dispersed around the quartz lineation. The crenulations themselves are generally extensional with respect to the early foliation and imply a top-to-the-WNW shear sense.

The basal contact of the 'Oystershell Rock' is found on the small peninsula at [NC 406 680]. It is clearly a thrust contact that emplaced the sheared and retrogressed Lewisianoid mylonites onto the Durness Group carbonate rocks. A 1 m-thick band of mylonitic quartzite lies along this thrust contact (Figure 5.15). The thrust can be mapped, offset by small faults, into the western coves of Sango Bay. It can be shown to have a gentle ESE dip and is everywhere above the carbonate rocks. Along the thrust contact the phyllonites are generally platy and do not show the crenulated texture that typifies them away from this contact. However, they do contain a locally strong ESE-plunging mineral lineation.

The fault rocks associated with the normal faults in Sango Bay are very different to the mylonites and phyllonites along the low-angle thrust. The freshest outcrops are found on the north-west face of the little peninsula at [NC 406 680], where a fault scarp in brecciated carbonate rocks is spectacularly exposed. This fault can be seen to have a throw of about 8 m. The carbonate fault-breccias show composite angular fragments (less than 0.5 mm to 5 cm) that are themselves composed of cataclasites. Micro-veining and carbonate cementation are ubiquitous, including patchy development of pink-stained iron-rich carbonate precipitates. The micro-veins show network textures on a millimetre- to centimetre-scale. The matrix to the breccias is a combination of carbonate rock flour and cement.

Cataclasis also affects the ductile shear fabrics of the thrust contact. Hippler (1989) and Hippler and Knipe (1990) described microfracturing and brecciation on all scales in the quartz mylonites at the late fault contacts. Optical and transmission electron microscopy show that fracture patterns on a grain scale can be influenced by the earlier microstructure of the mylonite.

Interpretation

Peach *et al.* (1907) interpreted the low-angle thrust contact that carries quartz mylonites, 'Oystershell Rock', and recognizable Lewisianoid gneisses in its hangingwall as the Moine Thrust. Kinematic indicators clearly show a WNW-directed sense of emplacement onto the upper part of the Durness Group. Holdsworth *et al.* (2001) contested this nomenclature, suggesting that the contact in Sango Bay is a lower structure than the Moine Thrust as they inferred that the 'Oystershell Rock' was derived from Lewisian gneisses that were once overlain by Cambrian rocks (see Clèit an t-Seabhaig GCR site report, this chapter). Regardless of these debates it is clear that the thrust contact carries allochthonous mylonites and their less-deformed equivalents from the east of Loch Eriboll out onto the foreland succession. Peach *et al.* (1907) and subsequent workers used this inference to deduce a minimum displacement on the base of the allochthon in excess of 15 km, the distance between exposures of the Moine Thrust Belt rocks on Faraid Head and Sango Bay and those east of Loch Eriboll.

The late faults that drop down the allochthonous sheets against their footwall of Durness carbonate rocks, show complex histories of brecciation and veining. They are probably of Devonian age and show evidence of cyclic movement and cementation during quiescent periods, typical of cataclastic fault-zones. Clearly the fault zones represented transient fluid pathways during movement, as indicated by the complex nature of the veins and the differing iron contents of the cements.

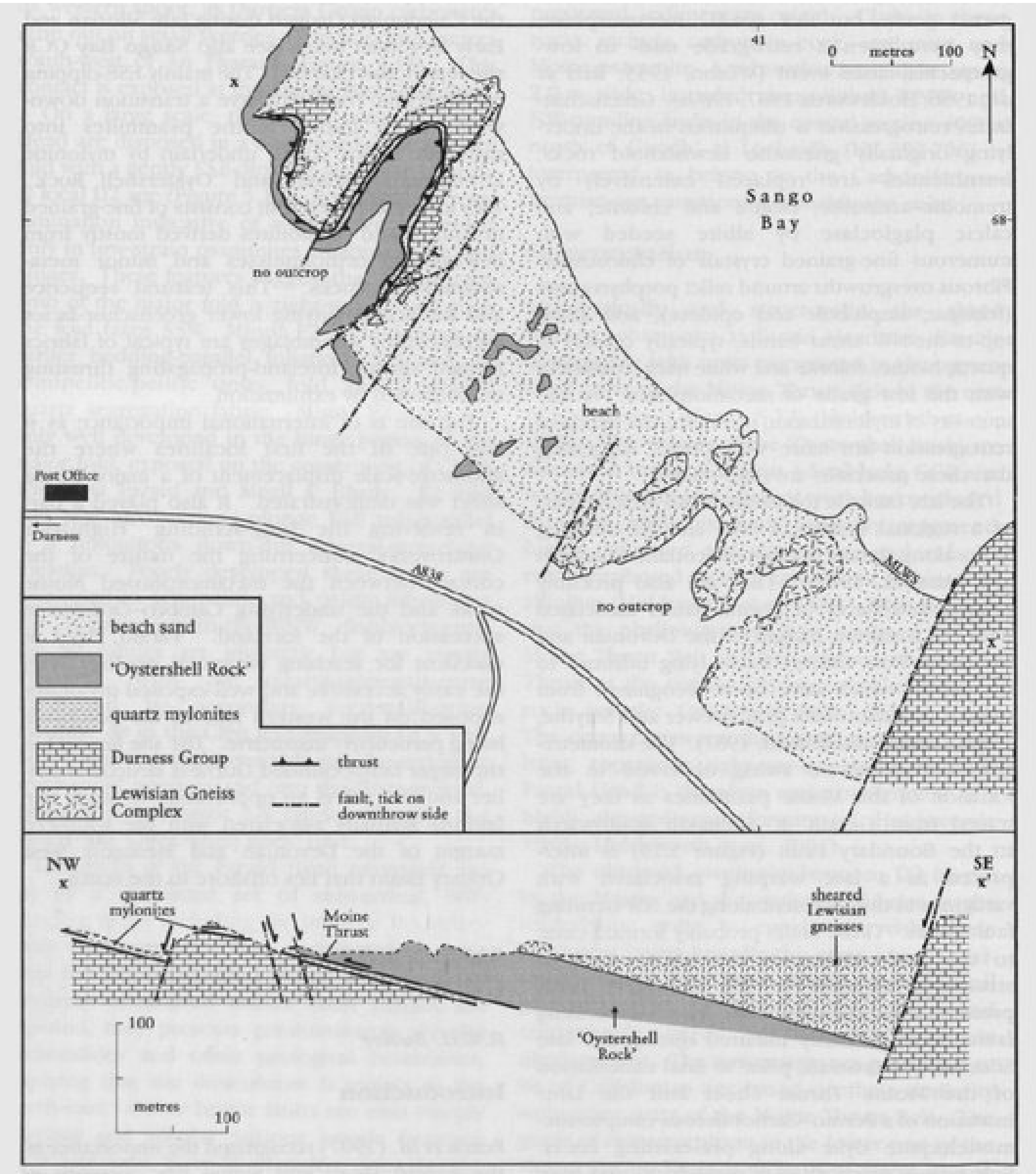
On a larger scale, the Sango Bay outcrops raise important issues concerning the relationship between the post-Caledonian normal faults and the Caledonian and earlier structures. Using offshore seismic data, several workers have proposed that the normal faulting utilized Caledonian structures (e.g. Brewer and Smythe, 1984; Enfield and Coward, 1987). Laubach and Marshak (1987) suggested that the Durness fault patterns were influenced by Precambrian structures of the foreland, although the subsequent work of Beacom (1999) suggested that this proposal is invalid. Although the latter controversy cannot be resolved at Sango Bay, the Caledonian influence can be assessed. Microstructural investigations have suggested a granular control on fracture processes exerted by the fabrics in the quartz mylonites (Hippler, 1989; Hippler and Knipe, 1990). However, it is highly unlikely that these controls operate on a larger scale through such a varied rock sequence (e.g. Beacom, 1999). Further, the normal fault array in Sango Bay clearly cross-cuts the Caledonian thrusts and shows no evidence of having reactivated the simple thrust contacts nor even of having been refracted along them. Thus, at this locality, there is no support for models involving the reactivation of Caledonian structures or their fabrics to influence later basin formation.

Conclusions

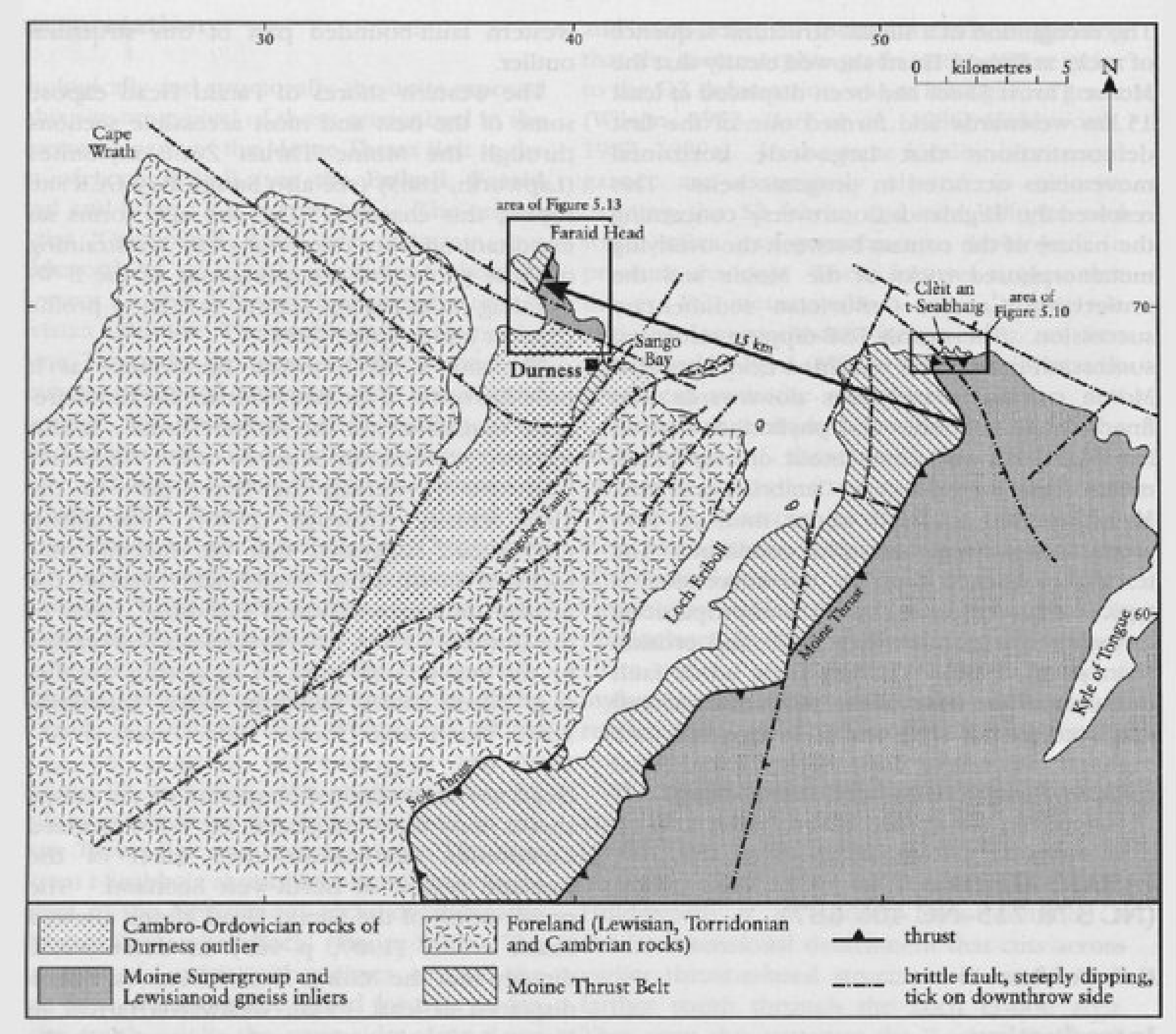
The Sango Bay outcrops are critical for establishing minimum displacements on the base of allochthonous, mylonite-bearing thrust sheets in northern Scotland. This was first recognized by the original surveyors in the late 19th century, and hence the GCR site is of considerable historical importance. The outcrops are clean and readily accessible, making them admirably suited for study, unlike some other parts of the Moine Thrust Belt. Further, there is an excellent array of outcrops that show the progressive retrogression and shearing of Lewisianoid gneisses related to the thrusting. The kinematic indicators in the high-strain 'Oystershell Rock' are particularly clear and imply a consistent WNW-directed emplacement direction.

The site also contains exceptional exposures of post-Caledonian (probably Devonian) normal faults with spectacular carbonate-rich fault rocks. These show complex cyclic histories of brecciation and cementation that are characteristic of seismogenic faults. This is also one of the very few places where Caledonian thrusts are clearly cut by post-Caledonian normal faults with the overprinting of the earlier mylonites by later cataclasites clearly demonstrated. Although some workers have inferred that Caledonian thrusts have been preferentially reactivated during post-Caledonian normal faulting, in the Sango Bay outcrops this type of behaviour is not seen in the exposed, shallow crustal-level faulting.

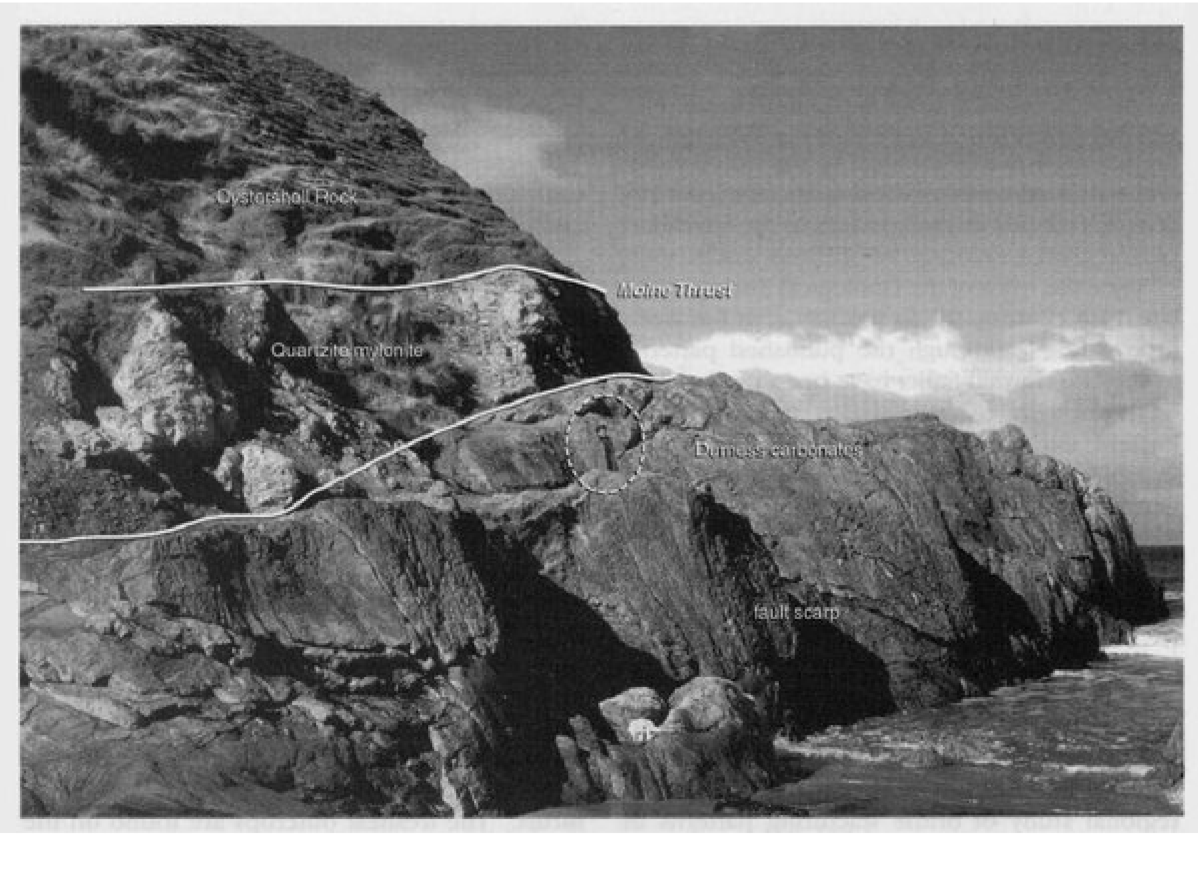
References



(Figure 5.14) Map and cross-section (x—x') of Sango Bay, Durness.



(Figure 5.12) Map showing the relationship between the Moine Thrust Sheet and the Durness Klippe. Arrow drawn parallel to regional thrust transport direction (290°) shows minimum displacement of 15 km required along Moine Thrust due to preservation of Faraid Head klippe. Areas of Figures 5.10 and 5.13 are indicated.



(Figure 5.15) Thrust contact at Sango Bay, emplacing 'Oystershell Rock' over quartz mylonite and Durness carbonate. This thrust was interpreted by Peach et al. (1907) as the Moine Thrust. (Photo: R.W.H. Butler.)