Excursion 3 Stoer Group at Stoer Peninsula

Maarten Krabbendam

Purpose: To examine the stratigraphy and sedimentology of the late Mesoproterozoic Stoer Group, and its unconformable relationships with the underlying Lewisian gneiss and overlying Torridon Group.

Aspects covered: Basal unconformity with breccia and neptunic dykes; fluviatile and lacustrine deposits (Clachtoll Formation), fluviatile sandstone (Bay of Stoer Formation) and volcaniclastic Stac Fada Member. The upper part of the Stoer Group is best studied at Enard Bay (Excursion 4).

Maps: OS: 1:50,000 Landranger sheet 15 Loch Assynt; 1:25,000 Explorer sheet 442 Assynt and Lochinver. BGS: 1:50,000 107W Point of Stoer.

Terrain: Mainly coastal outcrops with relatively easy access. Most outcrops can be visited at any state of the tide, with some exceptions (e.g. Locality 3.1). Many boulders and bedding planes can be extremely slippery, especially below high tide mark. The excursion is not recommended during stormy conditions.

Time: A full day allows leisurely study; if pressed, a half day would suffice.

Access: There are no access constraints for this excursion, but it is largely on or near crofting land and care must be taken with livestock – dogs should be kept on a lead at all times. Please note that this is a very popular excursion, and that the outcrops should not be hammered.

Locality 3.1 Bay of Clachtoll: Stoer Group – Lewisian Gneiss Complex unconformity (low tide only). [NC 0404 2702]

Park in the car-park near Clachtoll beach [NC 0395 2730)], which has public toilets and a Ranger Hut with a small display on the local natural history. A' Chlach Thuill (the 'Split Rock') is visible on the shore to the south-west. From the car-park, walk across the dunes and then the beach in a southerly direction (Figure 29).

At the southern end of the beach, cobbly breccio-conglomerate – the basal Clachtoll Formation — overlies Lewisian gneiss via a sharp unconformity. Note the strong subvertical east–west foliation of the Lewisian gneiss, which lies within the Stoer Shear Zone (similar to the Canisp Shear Zone – see Excursion 2). Towards the north-west, the conglomerate passes laterally into brick-red muddy sandstone, indicating much quieter depositional conditions. The depositional setting has been interpreted as an apron of debris-fans (bajada) fringing a lake (Stewart, 2002).

If the tide is low, follow the beach south-east to a wide sandy gully, and follow this south to a small bay at [NC 0405 2674]. If the tide is high, walk to the south-east corner of the beach and ascend towards a fence. Turn right and follow a faint path along the fence, which it crosses and re-crosses, and walk south past a ruin to a small bay at [NC 0405 2674].

Lewisian gneiss occurs on the east of this little bay, while sandstone occurs to the west; the bay marks a fault. From here, climb over the gneiss knoll to the east, following an old fence, turn right through a gap and right again to a small south-east-facing cliff.

Locality 3.2A Stoer Group – Lewisian Gneiss Complex unconformity. [NC 0412 2672]

The small cliff of Lewisian gneiss shows numerous veins of red mudstone and locally fine sandstone, injected into cracks and fractures. Locally, the gneiss is brecciated, with angular blocks surrounded by a matrix of injected mudstone. Some of the most photogenic examples occur in loose boulders below the cliff. In the gully below the cliff, a small stream marks the boundary between a mafic Scourie Dyke and brecciated, faulted Lewisian gneiss. On the far (western) side of the cliff, subhorizontal slickensides (suggesting a component of strike slip movement) occur in mudstone, plastered against

gneiss. The cliff and gully mark a fault, which operated during Stoer Group deposition; Beacom e*t* al*.* (1999) showed that deposi-tion occurred during sinistral transtension.

Locality 3.2B Basal Stoer Group breccio-conglomerate. [NC 0412 2666]

Cross the stream and follow a sheep path for *c*.50 m to the south, then clamber over some gneiss until you see an outcrop of conglomerate. This conglomerate is the basal part of the Clachtoll Formation. It is confined to a smallpalaeovalley(noticethelargeknollofgneisstotheeast; (Figure 30)).The unconformity is sharp and does not show signs of weathering. The breccio-conglomerate contains clasts of mafic and intermediate gneiss, metadolerite, ultramafic rock, and vein quartz that can be matched with the adjacent Lewisian gneiss, all within a gritty matrix. Together with locality 3.2A, this shows that the base of the Stoer Group was deposited during extension with locally high palaeorelief.

Locality 3.3 A' Chlach Thuill ('Split Rock'). [NC 0384 2673]

Retrace your steps for about 100 m and then head west over grass towards a prominent rocky knoll on the peninsula. This is A' Chlach Thuill ('Split Rock'; (Figure 31)). Most of the peninsula consists of the brick-red, massive muddy sandstone of the Clachtoll Formation, well exposed to the north and south of A' Chlach Thuill. The knoll marks the sudden incoming of pale, pink cross-bedded medium-coarse sandstone of the Bay of Stoer Formation (Figure 32). Stewart (2002) reports horizons of dessicated limestone laminae within the mudstone of the upper part of the Clachtoll Formation, but the outcrops are difficult to find and in hazardous locations.

Retrace your steps to the beach of Bay of Clachtoll. Looking north, note the clear change of landscape that coincides with the unconformity between Lewisian gneiss and the Stoer Group: the characteristic, rough 'cnoc-an-lochan' landscape has developed on the gneiss, whilst to the east the Stoer Group underlies a gentler landscape with good pasture.

Locality 3.4 Bay of Clachtoll beach: Clachtoll Formation. [NC 0405 2715]

The large knoll in the middle of Bay of Clachtoll beach consists of thick bedded, red muddy sandstone, typical of the Clachtoll Formation. From here, make your way to the white building on the north-west side of the bay – this is the Salmon Bothy, and contains a small exhibition illustrating the history of salmon fishing in Clachtoll.

Outcrops at high-water mark just north of the Salmon Bothy show thinner bedded muddy sandstone, locally with desiccation cracks on bedding surfaces, indicating periods of subaerial exposure.

From here, follow the coast north to a monument to the Reverend Norman MacLeod, founder of the Normanite Presbyterian movement. The monument is made from Ledmore Marble (see Excursion 10). Follow the 'walkers' signs through the various gates and stiles past the croft of Clachtoll Cottage. Beyond the croft follow a path over grass, then turn west to a patch of boulders with low outcrops.

Locality 3.5 Aird na Mòine: Bay of Stoer Formation. [NC 0361 2726]

The low outcrops here comprise medium-coarse pink sandstone (Bay of Stoer Formation) and show trough cross-bedding, indicating flow along a north-south axis. Dewatering structures and other soft-sediment deformation structures indicate rapid deposition. These sandstones were deposited in a fluviatile environment, possibly in braided rivers or alluvial fans.

Work your way northwards, following the top of the outcrops, past a perched erratic of Lewisian gneiss. Extensive, sloping bedding planes alternate with small cliffs; head towards the second of these.

Locality 3.6 Sgèir na Tràghad: Bay of Stoer Formation. [NC 0358 2751]

A series of mudstone–sandstone alternations (*c*.10 cm scale beds), bounded at top and bottom by thicker bedded sandstone, are seen at this locality (Figure 33). The mudstone (locally siltstone) contains both planar and ripple laminations. The sandstone sharply overlies the mudstone intervals and contains pebbles of vein quartz. Small-scale, syn-depositional extensional faulting disrupts the beds. This facies has considerable lateral extent (see also Locality 3.8) and this suggests a lacustrine interval within an overall fluviatile sequence. In total, five mudstone–sandstone cycles occur in the Bay of Stoer Formation (Stewart, 2002)

Continue northwards past An Dun, a ruined Iron Age broch, to the cobble beach of Bay of Stoer. Continue along the beach to reach outcrops at sea level on the north-west side of the bay.

Locality 3.7 Bay of Stoer: Clachtoll – Bay of Stoer formation boundary. [NC 0379 2834]

Take care at this locality as the bedding planes can be very slippery. The outcrops forming the wave-cut platform are in the Clachtoll Formation and show muddy sandstone with desiccation cracks and ripple marks (Figure 34). Locally pebbly, gritty sandstone occurs, possibly indicating sheet floods. At the west end of the wave-cut platform is a small cliff of sandstone, marking the sharp, locally erosive, change into the Bay of Stoer Formation, characterised by thick-bedded and cross-bedded sandstone with local contortions.

Go a short distance to the east and ascend a grassy slope towards a wall; follow the path to the west along the wall. At the end of the wall, go through the gate; after about 50 m cross a small stream.

Locality 3.8 [NC 0355 2853]

The same thin mudstone–siltstone beds are exposed here as at Locality 3.6, showing considerable lateral extent. From here, continue west along the path to a rocky promontory.

Locality 3.9 Stac Fada: Stac Fada Member. [NC 0333 2854]

The promontory marks the Stac Fada Member (Figure 35). This consists of a *c*.12 m thick massive deposit of greenish, poorly sorted muddy sandstone, full of angular dark green or black volcanic fragments (max. 5 cm. long), including pumice and (now devitrified) volcanic glass. At the top of the unit are round pea-sized spheres or accretionary lapilli (better preserved at Locality 4.9). The geochemistry of the volcanic fragments points to a mafic volcanic source (Young, 2002). Sanders and Johnston (1989) report folded vesicle trails up to 3 m long within the member.

There appear to be two volcaniclastic units in the area (although Stewart [2002] suggests that these are the same unit repeated by faulting). The upper, thickest unit is seen in the north to be wedged in with sandstone; some metres above this lies a raft of sandstone some 20 m long. Smaller rafts, some of which are contorted, occur to the south. The sandstone below the lowest unit is locally strongly warped, especially in the south.

A number of different interpretations have been proposed for the exact genesis of the Stac Fada Member. All interpretations have to take into account the fact that the underlying sediments were unlithified, and deformed and fragmented by the emplacement of the unit. This therefore suggests some sort of mass-flow, flowing at fairly high speed and covering a wide area. The presence of vesicle trails suggests that (at least at Stac Fada itself) emplacement was hot enough to produce gas or steam from underlying wet sediment, as the unit was emplaced. Lawson (1972) suggested an origin as an ash or pyroclastic flow. Sanders and Johnston (1989, 1990) suggested the unit had a peperitic origin (as a mixture of magma and wet sediment), with the lowest unit at Stoer representing the feeder. A difficulty with this interpretation is that peperite normally develops at the margins of large sills or at the base of lava flows, and that having the feeder exposed would be something of a coincidence. Young (2002) suggested that there are at least three units, representing three individual volcanic mudflows, some with opposing palaeocurrent indicators, suggesting different sources. However, Stewart (1990, 2002) favours the interpretation of a single volcanic mudflow. Most recently, Amor *et al*.(2008) have recognised grains of shocked quartz in the Stac Fada Member and have proposed that it is not volcanic in origin, but that it represents a proximal ejecta blanket formed by the impact of a meteorite into the underlying Stoer Group

sandstones. This theory is difficult to reconcile with the evidence for mafic volcanic fragments (Young, 2002), which could not have been sourced from the local country rocks, and so the origin of the Stac Fada Member remains controversial.

In all cases, the presence of accretionary lapilli, which are formed as airborne ash particles coalesce into 'volcanic hailstones', suggests a component of direct ash fall, since lapilli are relatively fragile and are unlikely to survive redeposition. Such ash falls would, in all cases, follow the main depositional event, be it peperitic, mud flow, pyroclastic flow, or impact-related.

West of Stac Fada, the remainder of the Stoer Group stratigraphy can be seen: first stratified mudstone, followed by massive mudstone with rounded outcrops (Poll a' Mhuilt Member). At the western end of the bay steeper cliffs mark the start of the sandstone strata of the Meall Dearg Formation. These outcrops can only be studied at low tide and access is treacherous. The detailed stratigraphy of the section is described by Stewart (1978, 2002).

Take the path back, and keep following tracks past a white cottage left of the beach to meet the tarred road. Go left for 100 m then turn right on the tarred road towards Stoer Burial Ground (the upper, older cemetery; a newer cemetery lies to the south). Just past the cemetery is a gate, and behind this is Locality 3.10.

Locality 3.10 Stoer cemetery: basal Stoer Group conglomerate. [NC 0411 2842]

Basal breccia and conglomerate, with gneiss cobbles up to 60 cm. across, directly overlie gneiss. The gneiss does not show signs of weathering. Notice the strong pre-Stoer Group topography.

Return to the road, go left and follow the road back to Clachtoll Beach car-park.

Locality 3.11 Culkein – Port Feadaig: Stoer Group /Torridon Group unconformity. [NC 042 329]

From Clachtoll, drive north through Stoer, take the first left towards the lighthouse, then continue north towards Culkein. As you approach the sea, park in a lay-by approximately 50 m before (east of) a white cottage. There is a parking place for one or two minibuses at [NC 0431 3275]. Walk west past the white cottage and descend north across a field (use the gate) to a small bay, Port Feadaig. In decent weather there is a good view to the north-east toward Scourie and the quartzite mountains of Arkle and Foinaven.

On the eastern side of the bay are strata of the Stoer Group, dipping *c*.25–30° to the west, whilst on the western side are gently dipping strata of the Torridon Group. Note the large hill of Lewisian gneiss (Cnoc na Buaille) to the south-east, again showing considerable relief in the pre-Stoer and pre-Torridon Group topography.

On the eastern side of the bay [NC 0426 3291] the Stoer Group sandstone is thickly bedded, medium- to coarse-grained, and locally cross-bedded, and probably fluviatile. These outcrops belong to the Bay of Stoer Formation (the thin cyclic muddy sandstone–mudstone cycles as seen at Localities 3.6 and 3.8 occur just east of Port Feadaig).

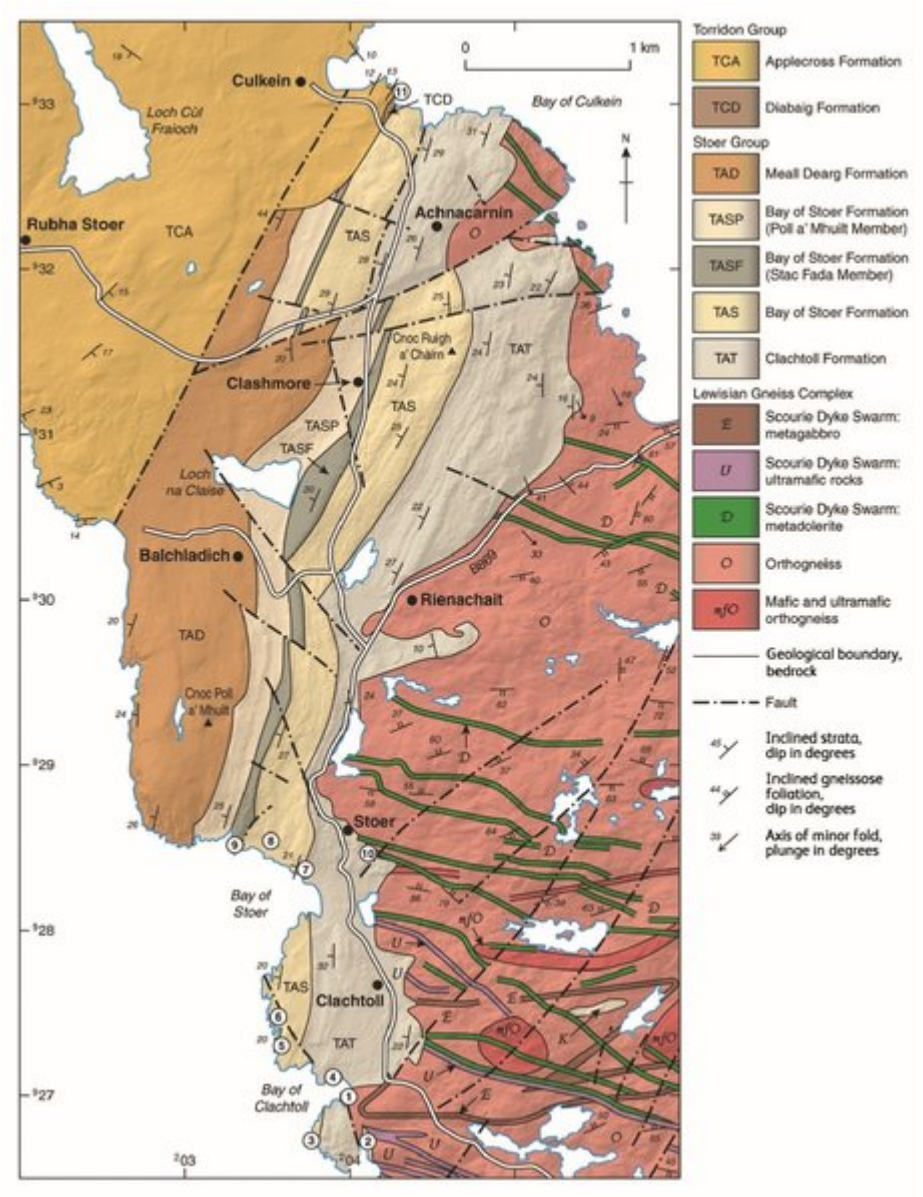
Also in this area are large metre-sized boulders (not *in situ*) of conglom-erate, mainly with rounded clasts of Lewisian gneiss in them, suggesting moderate transport distance. The boulders are presumably derived from the basal Torridon Group conglomerate, and are remnants of the unconformity between the Stoer and Torridon groups, which would have occurred just above the present-day erosion surface.

Just west of the centre of the bay is a somewhat overgrown outcrop with gently north-east dipping strata of laminated siltstone, mudstone and sandstone, belonging to the Diabaig Formation of the Torridon Group. On the north-west side of the bay [NC 04205 3296] are coarse pebble beds, with round clasts of vein quartz and red chert, forming the lowest parts of the Applecross Formation of the Torridon Group. Massive, thick-bedded (up to 5 m thick) pebbly sandstones with conglomerate occur higher up.

Further north, the Applecross Formation rests directly on west-dipping sandstone of the Bay of Stoer Formation and the Diabaig Formation is not present, suggesting the existence of a small palaeovalley in the centre of the bay. The unconformity itself can only be seen at low tide.

To the east of Port Feadaig is a good section through the Stoer Group, which shows considerable lateral facies changes compared with the sequence at Clachtoll and Stoer. Details can be found in Stewart (1978, 2002).

References



(Figure 29) Geological map of the Stoer area (after British Geological Survey, 2002b), showing the localities described in Excursion 3.

(Figure 30) Basal breccia of the Stoer Group in a palaeovalley (centre) resting unconformably against Lewisian gneiss on both sides. (BGS photograph P524833, © NERC)

(Figure 31) A' Clach Thuill, the Split Rock, formed of sandstone of the Bay of Stoer Formation. (BGS photograph P661223, © NERC)

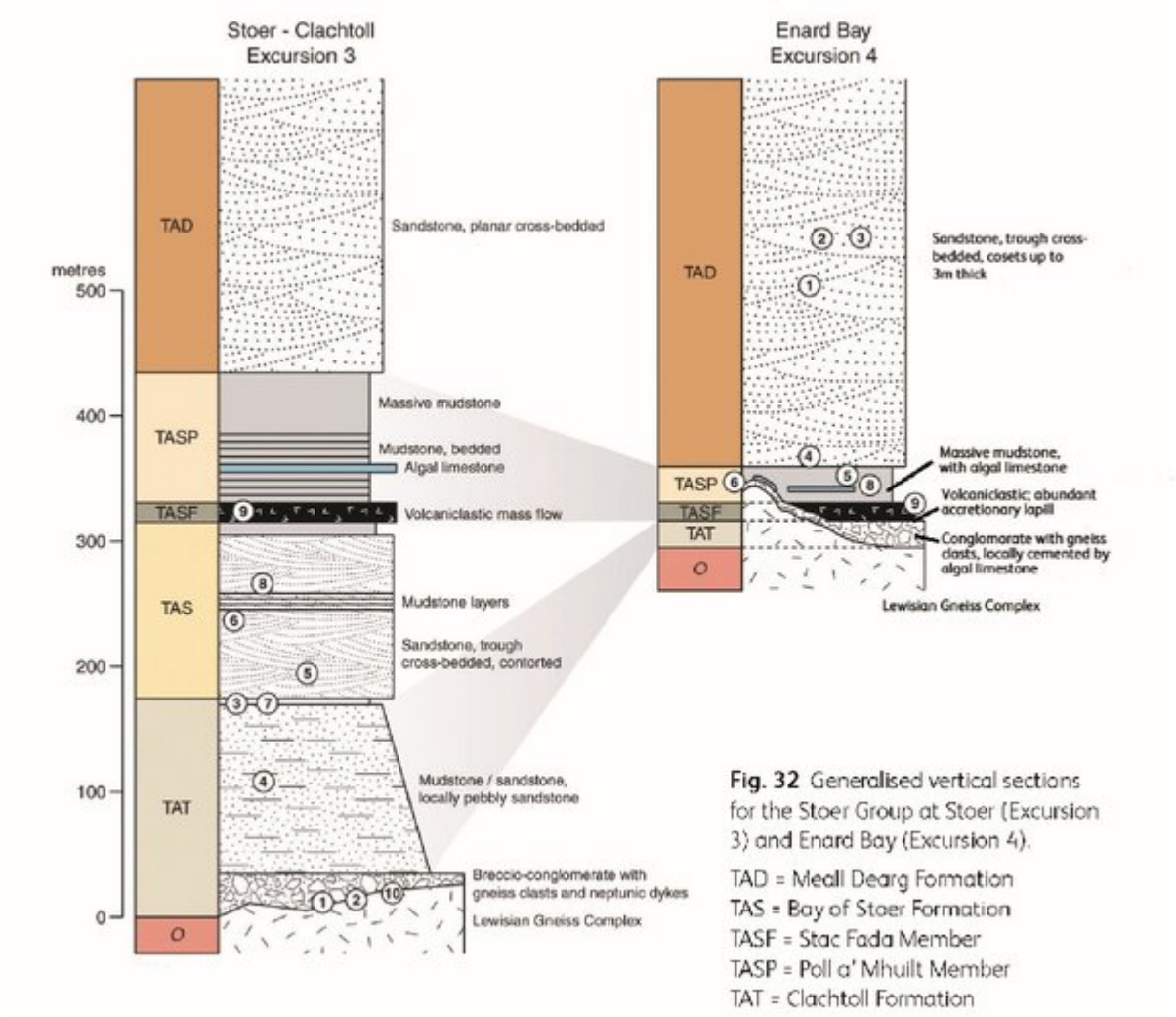


Fig. 32 Generalised vertical sections for the Stoer Group at Stoer (Excursion 3) and Enard Bay (Excursion 4).

TAD = Meall Dearg Formation
TAS = Bay of Stoer Formation
TASF = Stac Fada Member
TASP = Poll a' Mhuilt Member
TAT = Clachtoll Formation

(Figure 32) Generalised vertical sections for the Stoer Group at Stoer (Excursion 3) and Enard Bay (Excursion 4). TAD = Meall Dearg Formation TAS = Bay of Stoer Formation TASF = Stac Fada Member TASP = Poll a'Mhuilt Member TAT = Clachtoll Formation

(Figure 33) Outcrops of the Bay of Stoer Formation, containing alternating mudstone and sandstone beds, at Locality 3.6. (BGS photograph P518638, © NERC)

(Figure 34) Rippled sandstone surface in the Clachtoll Formation, Locality 3.7. (BGS photograph P518651, © NERC)

(Figure 35) Outcrops of the Stac Fada Member on the Stac Fada peninsula. (BGS photograph P512723, © NERC)