
23 Dunnottar to Stonehaven and the Highland Boundary Fault

C. Gillen And N.H. Trewin

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Purpose

To examine Lower Old Red Sandstone sediments of the Stonehaven and Dunnottar Groups; the Highland Border Complex, and the Highland Boundary Fault.

Access

Stonehaven is situated 24 km (15 miles) south of Aberdeen and can be reached by the A92T road. The excursion involves walking along rough shores and clifftop paths, with occasional scrambling up and down fairly steep grassy slopes. A full day will be required to complete the excursion which can be divided into two parts with a lunch and refreshment stop at Stonehaven. Low tide is required for localities 2–5 and 6–10 (Figure 1). Localities 1 to 10 cover the Old Red Sandstone and can be visited in conjunction with excursions 21 and 22. Localities to the south of Stonehaven Harbour can be visited by parking at either Stonehaven Harbour or Dunnottar Castle (access off A92) If a driver is available a traverse from Dunnottar to Stonehaven can be arranged. A visit to the ruins of Dunnottar Castle is a convenient addition to this excursion. Localities 11 to 15 cover the Highland Border Complex and Highland Boundary Fault and could be visited in conjunction with excursion 18. The area is covered by Geological Survey 1:63,360 sheet 67 (Stonehaven) and O.S. 1:50,000 sheet 45 (Stonehaven).

Introduction

The Old Red Sandstone rocks at Stonehaven lie on the steeply dipping NW limb of the Strathmore Syncline, which is cut by the Highland Boundary Fault (Figure 1). The excursion begins in the Dunnottar Group of coarse conglomerates with subordinate sandstones and thin volcanoclastic horizons.

Dunnottar Group conglomerates and sandstones are underlain by the Stonehaven Group. This Group is subdivided into the lower Cowie Formation, (c. 730 m thick, Armstrong and Paterson 1970), containing a basal breccia, cyclic fluvial sandstones, shales and the *Dictyocaris* Member at the top. The upper, Carron Formation (c. 820 m), consists of sandstones of fluvial origin containing much volcanic detritus and including an agglomerate. The members of the Formation are formalized following Donovan in Armstrong *et al.* (1978). A Wenlock (mid Silurian) age has been assigned to the Stonehaven Group on the basis of spores (Marshall 1991, Welman 1993). The Stonehaven Group rests unconformably on the rocks of the Highland Border Complex. Clasts of the latter contribute to a basal breccia of

the Stonehaven Group. The Highland Border Complex at Stonehaven comprises sheared spilitic pillow lavas, black shale and jasper. Dalradian rocks are in tectonic contact with the Highland Border Complex along the Highland Boundary Fault. The contact is marked by a prominent dolomitic fault rock. The general geology of this part of the Highland Border has been summarised by Trewin and Thirlwall (2002), and Marshall *et al.* (1994) have discussed the burial history of the Old red Sandstone of the area.

Itinerary

Park either at Stonehaven Harbour [NO 878 856] or Dunnottar Castle car park [NO 876 838] for localities 1–5 (reverse order from Dunnottar). For localities 6–15 park at the swimming pool or on the seafront at Cowie. Parties can be picked up or set down at the layby at [NO 886 880] to save time. A path leads to the sea at Scatie Shore from this point and provides access to localities 14 and 15 if parties do not wish to walk the whole section.

Locality 1. Stonehaven Harbour [NO 877 854]

To the south of the harbour a near-vertical Carboniferous (probably Stephanian) dolerite dyke trending NE–SW forms the face of the cliff bordering the sailing club boat park above the beach. On the shore the dyke is seen to have a coarse central portion which is spheroidally weathered, and a finer-grained margin which is extensively brecciated and veined with calcite, probably due to later fault movement following the line of the dyke. Beyond the exposure of the dyke the sandstones of the Dunnottar Group are tuffaceous, medium- to coarse-grained and have pebbles both as pebble lags and isolated within sandstone. Cross-bedding is common with sets over a metre thick, and showing evidence of rapid deposition. Both tabular and trough cross-bedding are present and dewatering features disrupt the tops of several beds.

The base of the Downie Point Conglomerate of the Dunnottar Group is well displayed in the face of the quarried cliff where it rests erosively on the underlying sandstones. This conglomerate represents a dramatic influx of coarse material with rounded boulders up to a metre in size consisting mainly of contemporaneous lavas and also resistant quartzites. Follow the path back to Stonehaven Harbour and opposite the central harbour pier turn up Wallace Wynd and left up Castle Street (also signposted to Dunnottar Castle) Follow the path up the brae, past the information board mounted on a structure made from Ballachulish slate with pyrite cubes, and then follow the road to the first sharp bend where the path to Dunnottar leaves the road. Follow the path past the War Memorial to Strathlethan Bay.

Locality 2. Strathlethan Bay [NO 880 849]

Follow the cliff top path to the southern end of the bay. The top of the path down into the bay can be found about 20 m beyond the point where the main path to Dunnottar leaves the cliff edge and crosses fields. Descend the grassy path to the beach. The features to be seen are only well exposed at low tide on the wave cut platform. The bay is cut in sandstones of the Strathlethan Formation, a sandstone unit which overlies the Downie Point Conglomerate seen in the cliffs to the north of the bay. A thin unit of volcanic debris lies close to the junction and is exposed in the first sea cliff at the north end of the bay. The sandstones on the foreshore here show spectacular disruption features affecting a zone some 100 m wide. Disruption features are most intense at the base of the sandstone where much of the original fabric has been destroyed and sandstone blocks occur in a sandstone matrix which has a 'foliated' appearance with the matrix curving around partly rounded blocks of sandstone. Much of the rock has taken on a completely new streaky-foliated texture. The main part of the deformed zone contains large disoriented blocks of sandstone, some larger than 10 m, set in a sandstone matrix. The blocks tend to be more angular and the matrix less foliated than at the base of the deformed zone. The deformation features die out upwards (stratigraphically) and the top of the deformed zone is seen opposite the point where a small stream enters the bay. Here the disruption is less and is confined to a few separated areas, but again sand filled veins separate the disrupted strata.

The disruption clearly took place soon after deposition when the sandstones were very poorly lithified. The sand was in parts capable of liquefaction, but in other areas was partly cemented and remained coherent during the movement which took place. The movement may have been due to sediment failure on a slope induced by seismic shock due to earthquake or volcanic eruption. Movement was concentrated at the base of the sand unit and the upper part slid as one mass with little disruption.

Above the disrupted zone the main feature of the sandstone is the well developed trough cross-bedding, often at fairly low angles but in sets over a metre thick. Grain-size and set size of cross-bedding decrease up the succession and red mudstones are interbedded with the sandstones near the centre of the bay.

Locality 3. Strathlethan Bay [NO 880 847]

Return to the south end of the bay where the stack known as Carlin Craig is composed of andesite and some agglomeratic material and appears to be part of a lava flow, but it cannot be traced laterally.

Immediately south of the stack brick-red mudstones with green reduction areas are exposed; ripples and laminae of fine-grained sandstone are present within the mudstones. This sequence coarsens rapidly upwards through thin tuffaceous sandstone beds and plane-laminated sandstone, to sandstones and conglomerates with cross-bedding and

channels showing erosive bases. These conglomerates of the Dunnottar Castle Conglomerate contain mainly quartzite clasts but also include jasper and jasper-rich 'grit' pebbles typical of the Highland Border Complex. This coarsening-up sequence might represent progradation of the toe of an alluvial fan over alluvial plain sediments.

Return to the cliff top and follow the path across the fields (Figure 1) to Castle Haven. The Dunnottar Castle Conglomerate is over 1000 m thick and forms spectacular coastal scenery on the headlands.

Locality 4. Castle Haven [NO 880 842]

Descend the grassy slope into Castle Haven at the north end of the bay. Here the wave-cut platform shows typical features of the conglomerates with marked sorting and current imbrication of pebbles. Thin sandstones are also present which appear to represent the sandy 'tails' to gravel bars in a dominantly gravel bed river system. Cross-bedding determinations from these sandstones (Figure 1) indicate transport mainly from the NNE.

Locality 5. Castle Haven [NO 880 840]

Near the southern end of Castle Haven a marked change in clast composition is seen in a conglomeratic unit exposed near H.W.M. The clasts are not as well rounded and are composed of low-grade metamorphic rocks with a spaced cleavage. The coarser lithologies contain partly flattened quartz and feldspar clasts. These clasts are indistinguishable from the rocks of the Dalradian Southern Highland Group as seen to the north of the HBF at locality 12 of this excursion. This conglomerate unit marks the first appearance of Dalradian derived clasts in the ORS sequence, and is unusual in having a sparry calcite cement which is clearly displacive and brecciates the slaty clasts. This carbonate was probably formed soon after deposition as 'caliche' type carbonate typical of soil profiles. Sparse current direction data indicate transport from the WNW.

The next unit in the succession is also distinctive in consisting largely of red weathered lava boulders and pebbles. The conglomerates between here and the Castle also contain clasts of apparent Dalradian origin. If the identification of the Dalradian clastic material is accepted, then it can be concluded that the Grampian Block was in place and shedding some material south in early Gedinnian times. This is in contrast to the view of Bluck (1984) who did not recognise proven Dalradian clasts in this part of the ORS. The real paucity of such Dalradian clasts and the abundance of quartzites require further explanation. Possibly a considerable quartzite conglomerate cover existed on the Grampian Block and Dalradian bedrock was unavailable for erosion prior to the deposition of the beds at this locality, and only small areas of Dalradian bedrock remained available through the rest of the time of ORS deposition.

A visit can be made to Dunnottar Castle at this point in the excursion. Return to Stonehaven by the clifftop path.

Locality 6. Cowie Harbour [NO 881 867]

From Stonehaven Harbour drive through Stonehaven main street and turn right to Cowie and the swimming pool where coaches can be parked [NO 877 866]. Transport can be left here with the party returning along the shore, or by the cliff top path after completing the excursion. An alternative is to send transport on to wait at the large layby at [NO 886 880] Den of Cowie, just before the 'no entry' sign. A path signposted to 'Skatie Shore and the Highland Boundary Fault' leaves the road close to the 'no entry' sign. The foreshore exposures of the Cowie Formation are accessible only at low tide and are most conveniently examined at the old jetty of Cowie Harbour [NO 881 867] where there is a geological information board featuring *Pneumodesmus newmani*. This millepede, discovered by Mike Newman in 2003 possessed spiracles, and hence 'breathed' air, and is the oldest known truly terrestrial animal. The succession is composed mainly of sandstones with thin shale and mudstone interbeds. At the end of the concrete remains of the jetty the Volcanic Conglomerate Member is seen. In this conglomerate the clasts are almost exclusively volcanic in origin, comprising andesites and rhyolites. Clasts are generally up to 10 cm but a few are boulder size. There is considerable variation along the strike in the conglomerate which appears to be of fluvial origin, but derived from a local contemporaneous volcanic source.

Seaward of the conglomerate are medium-grained sandstones (Red Sandstone Member) with some cross-bedding showing derivation from the NE (Figure 1) but many beds are parallel-laminated. Deposition was possibly by braided streams. Finer-grained, thin rippled sandstone, green shales and mudstones with rare

calcareous nodules constitute the Dictyocaris Member which includes the Cowie Harbour fish bed. Fish remains considered by (Westoll 1951; list in Cameron and Stephenson 1985) to be of Pridoli age (late Silurian) have been found but are very rare. Plant debris and fragments of the arthropod *Dictyocaris slimoni* are occasionally found. However more recent palynological studies by Marshall (1991) and Wellman (1993) have concluded that spores indicate a Wenlockian (mid Silurian) age. Near here the fossil millepede *Pneumodesmus newmani* (Wilson and Anderson 2004) was discovered. **There is a display related to this discovery at the Harbour museum in Stonehaven (open from 4th April to 1st October, 1.30pm to 4.30pm, except Tuesdays).**

Locality 7 [NO 8810 8685]

At the end of the seawall past the concreted sewage pipe are some normally clean exposures of medium- to coarse-grained sandstones forming part of the Brown and Grey Sandstone Member. The sandstones are trough cross-bedded and show examples of distortions of the lamination due to dewatering of the sandstone shortly after deposition (fluidisation or quick-sand features). These are fluvial channel sandstones and the bases of the channels contain clasts of both mudstone and calcareous concretions which were eroded by the current. These clasts acted as nuclei for the further precipitation of carbonate cement. Ghosts of diagenetic concretions can also be seen but the original carbonate has now been largely dissolved out.

Locality 8. Quartz-porphry dyke [NO 8815 8690]

An irregular quartz-porphry dyke is exposed on the shore and in the cliffs at the back of the beach. The rock contains phenocrysts of idiomorphic feldspar together with quartz and biotite. The dyke appears to be intruded into a fault line, the rocks to the south of the dyke being fractured.

Locality 9. Fluvial cycles [NO 884 871]

The sandstones and mudstones between localities 8 and 9 comprise a series of fining-up cycles of sedimentation and are part of the Castle of Cowie Member of the Cowie Formation. A log of a typical cycle is shown below in (Figure 9).

Trough and planar cross-bedding are characteristic of the sandstones at the base of each cycle. Individual cross-bed sets seldom exceed 60cm in thickness and the larger sets tend to show disruption structures at the bed top. The base of each cycle is sharp and represents erosion at the base of a fluvial channel, with the cross-bedded sandstones being the deposits of sand bars within the channel. Central parts of cycles show smaller scale cross-bedding and ripple lamination which in some instances shows excellent climbing-ripple sets.

These rocks were deposited in lower energy conditions near channel margins. Some units of planar - laminated sandstone might represent deposition during higher energy flood conditions. The tops of the cycles mainly comprise red mudstone and thin ripple-laminated fine sandstones which were probably deposited on an alluvial plain as overbank deposits from the channels. The presence of polygonal mud cracks shows that the muds frequently dried out due to exposure. A few surfaces display small (c. 3 mm) vertical sand-filled burrows possibly produced by small arthropods. The burrow sections frequently appear to be paired and the burrows may have been U-shaped. Current directions in this area are variable from cycle to cycle, indicating that the river channels had moderate sinuosity. Current directions are dominantly from the NW (Figure 1).

Locality 10. The unconformity [NO 8865 8725]

The irregular unconformity of the Cowie Formation on the Highland Border Complex is exposed in the cliffs below the ruins of St. Mary's Church. The unconformity is best seen by looking west at the SE end of Ruthery Head cliffs. ORS sediments dip to the south at 70–80°, whereas the HBC rocks have a penetrative cleavage which dips steeply to the NW.

A few metres above the unconformity the strata are thin-bedded, dominantly sandstone and contain small scale planar and trough cross-bedding with sets generally less than 30 cm thick.

The cross-bedded units are typically coarse sandstone with a few small pebbles. Interbeds of sandstone are plane laminated or rippled and desiccation cracks affect both sandstone and red mudstone. A thin andesitic lava flow is present within the sandstones. Current directions in the sandstone (Figure 1) appear to be from the WNW based on cross-bedding measurements. This is probably a local feature related to topography close to the unconformity, and the rocks could also have suffered some rotation adjacent to the HBF. The general nature of the unconformity and overlying sediments indicate that local relief was low with gentle slopes. Clearly there was no nearby mountainous source area for large volumes of detrital material.

Locality 11 [NO 888 874]

Follow the high water mark round the corner into the next bay to the north. If the tide is low, go as far east as possible out onto the small promontory and look westwards onto the pillow lavas, which have clear outlines. They are half to one metre long and appear to young northwards. **Please do not hammer the pillows.**

Most of the lavas at this locality are badly sheared and do not display pillow structures. The rocks are usually termed 'greenstones' owing to the fact that they have been altered to chlorite schists. See Brown (1983, p. 174–5) for a discussion of the geochemistry of igneous rocks in the Highland Border Complex.

Continue into Craigeven Bay where the position of the HBF is marked by exposures of the fault rock on the shore. It is a distinct yellow-coloured rock and can be seen across the bay, dipping to the NW at 70°–75°. It is a silicified dolomitic limestone, extensively brecciated and recemented and cut by numerous thin carbonate veins. No bedding structures are present in the fault rock, and it is considered to be a highly altered serpentinite body that was emplaced along the line of the HBF.

Locality 12 [NO 888 876]

Walk round to Craigeven Bay and examine the exposures at the base of the grassy cliffs and on the foreshore below the golf course. Here the rocks are Southern Highland Group Dalradian grits and phyllites. A number of open folds plunging gently to the SW can be seen, together with a number of small kink bands. The rocks are fractured and veined by quartz along this shore section. Grading in pebbly greywackes gives way-up evidence. The rocks possess a spaced cleavage and in the coarse beds the quartz and feldspar grains are flattened. The rocks here and from locality 15 should be compared with the clasts of presumed Dalradian origin in the ORS at locality 5 (Dunnottar).

Locality 13 [NO 890 875]

At the NE end of Craigeven Bay, the fault rock is well exposed and shows deep irregular erosion hollows. In the lowest of these is a block of dark green to black rock which may be a serpentinite pod. Just east of the HBF and fault rock are sheared lavas, black shales and cherts with thin seams of sulphide. The HBC rocks here dip at around 70° to the NW, cleavage being parallel to bedding.

Locality 14 [NO 893 877]

Climb up the steep grassy slope to the top of the cliff and walk around the edge of the golf course past the ruined coastguard hut (Only a concrete base now remains) down to Garron Point. Highly altered serpentinite pods occur here, adjacent to the fault rock. Eastwards the carbonate 'dyke' thins out, and eventually the Highland Border Complex and the Dalradian grits are in direct faulted contact. Schistose spilites of the HBC are crushed and folded, and in places are cut by thin veins of fault rock. The fault surface can be seen at the extremity of Garron Point [NO 895 877] where a steep plane dips at 80° to the NNW.

Locality 15 [NO 891 878]

Dalradian grits on Skatie Shore show intense effects of movement on the HBF. They are sheared, buckled and kinked and many of the narrow fractures are filled with quartz. Bedding can be picked out on the basis of grain size, and larger grains have been flattened in the cleavage which is more intense than in Craigeven Bay. Depending on vehicular arrangements return to Cowie Harbour along the shore or by the cliff top path. Do not take short cuts over the golf course, and avoid annoying the golfers. Alternatively continue north along the path at the back of Scatie Shore past two narrow gaps marked by old tank traps and take the path up the cliff to Den of Cowie. The path goes beneath the most northerly arch of the railway viaduct. Cross the main track that contours the hillside and continue on the path to the layby at [NO 886 880].

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Figures

(Figure 1) Locality map Dunnottar to Garron Point with simplified stratigraphic section (part modified from Armstrong and Paterson 1970). Abbreviations as follows. DCC Dunnottar Castle Cong.; SS Strathlethan Sst.; DPC Downie Point Cong.; D Dictyocaris Member; R Red Sst. Member; V Volcanic Cong. Member; B Brown and Grey Sst. Member; C Castle of Cowie Member; P Purple Sst. Member; B Basal Breccia Member; HBC Highland Border Complex; Dal Dalradian. Rose diagrams are based on dip of cross-bedding foreset lamination at the localities indicated.

(Figure 2) Strathlethan Bay (Locality 3) from the south.

(Figure 3) Castle Haven (Locality 4), showing near vertical conglomerates on shore and in cliffs.

(Figure 4) Castle Haven (Locality 4), sandstone lenses within conglomerate on shore and in cliffs beyond.

(Figure 5) Castle Haven (Locality 5). Dunnottar Conglomerate with abundant volcanic clasts.

(Figure 6) Castle Haven (Locality 5). Dunnottar Conglomerate with clasts sourced from the Dalradian of the Grampian Block (phyllite with folded spaced cleavage), and the Highland Border series (red chert).

(Figure 7) Dunnottar Castle built on vertical Dunnottar Conglomerate.

(Figure 8) Information board at Cowie Harbour (Locality 6) with details of the fossil millipede *Pseudodesmus newmani*.

(Figure 9) Typical features of fluvial fining-upward cycles seen at Locality 9.

(Figure 10) Fluvial cycles in Stonehaven Group at Cowie Shore (Locality 9).

(Figure 11) Ripple lamination in fluvial sandstone, Cowie Shore (Locality 9).

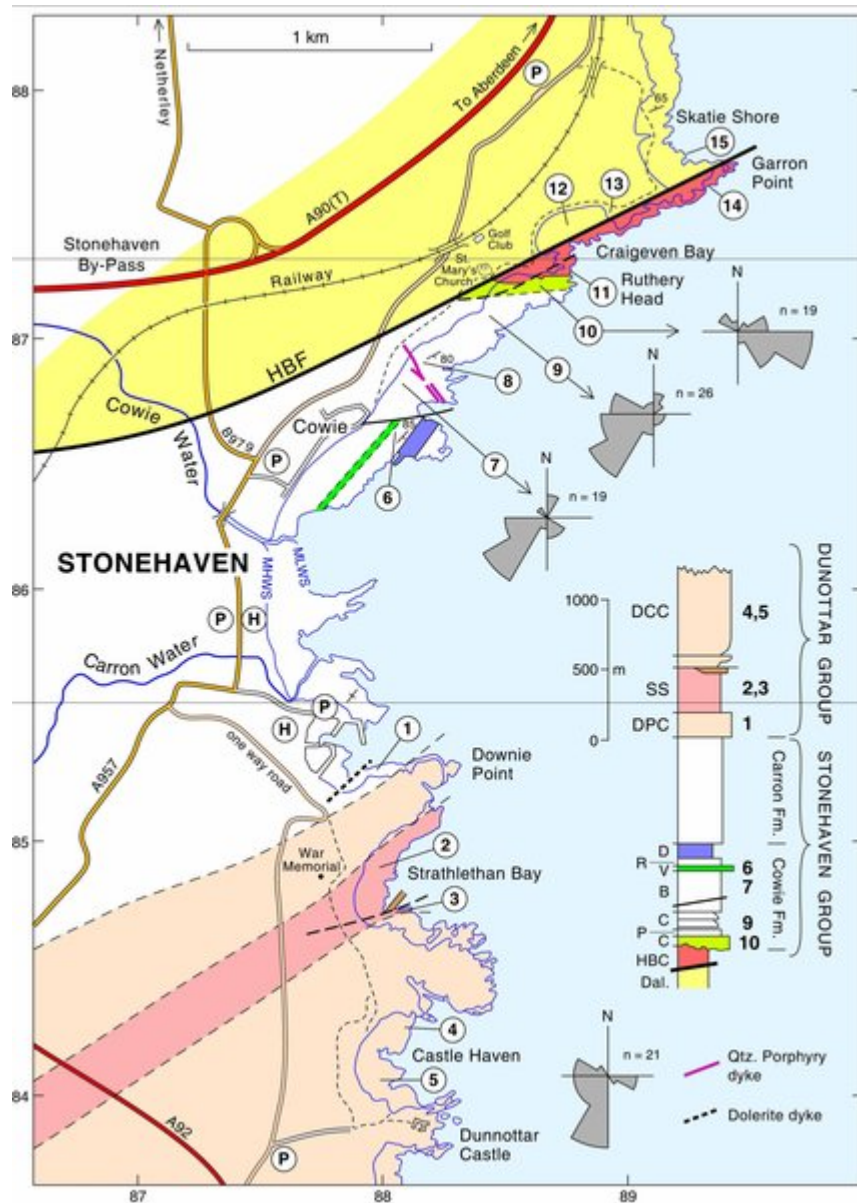
(Figure 12) Rapid transition from breccia to laminated sandstone at the base of the Stonehaven Group above the unconformity with the Highland Border Series (Locality 10).

(Figure 13) Pillow lavas in the Highland Border Complex at Locality 11. Hammer for scale.

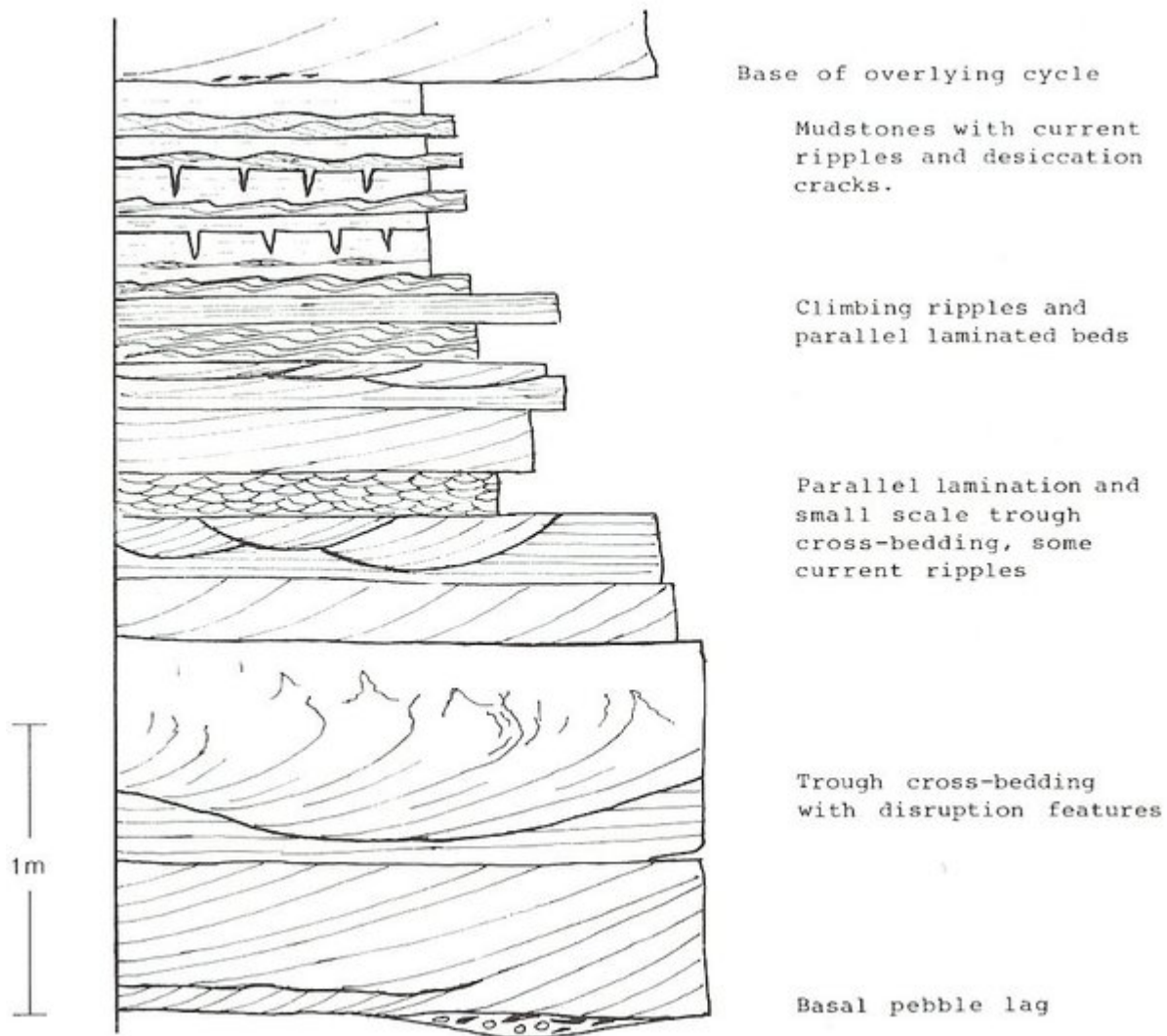
(Figure 14) Dalradian cleaved phyllites and grits. Craigeven Bay (Locality 12).

(Figure 15) The Highland Boundary Fault crossing Craigeven Bay, viewed looking south from the path up the cliff at the northern end of the bay. Yellow dolomitic fault rock in foreground (Locality 13).

(Figure 16) Aerial Photo of Garron Point clearly showing the Highland Boundary Fault



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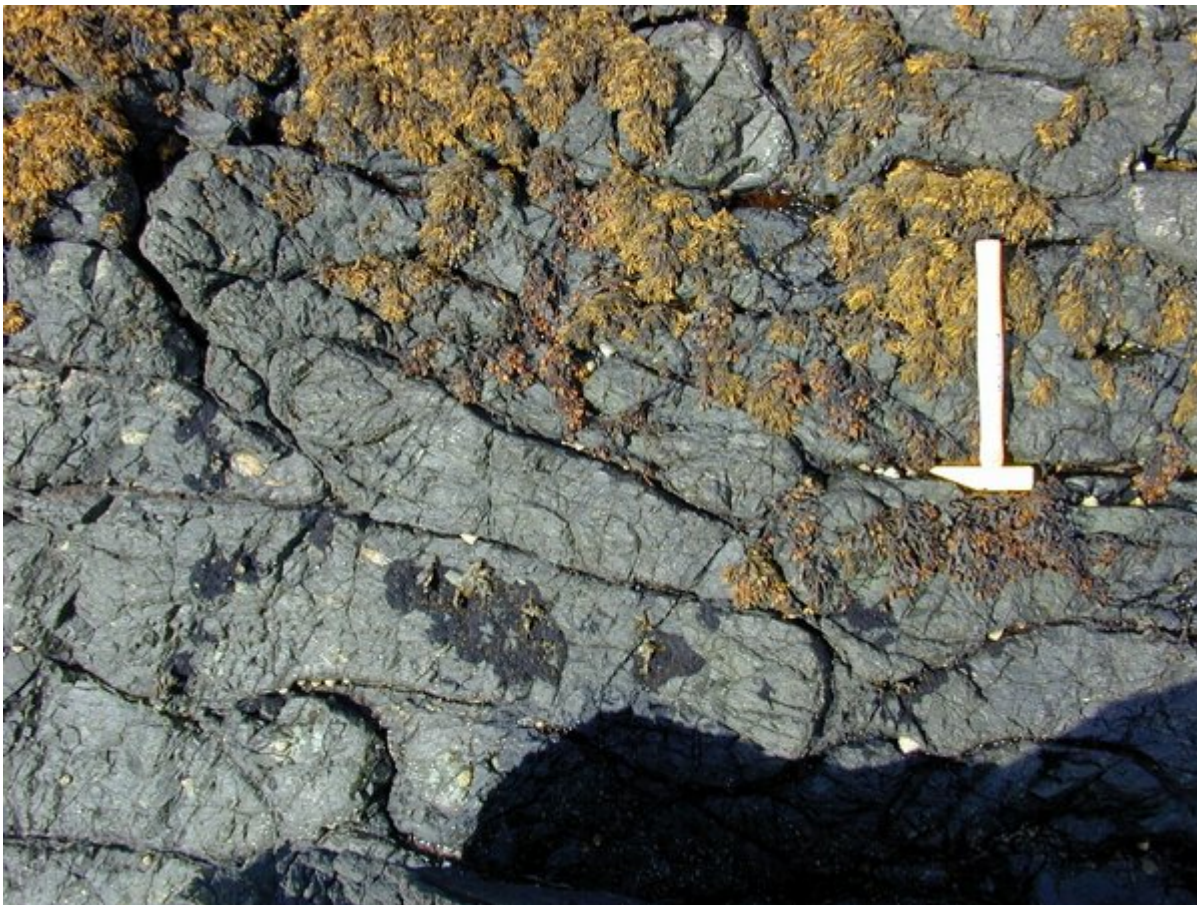
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