The Lower Old Red Sandstone of New Aberdour

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Purpose

This excursion covers sections in the Crovie Group of the Lower Old Red Sandstone at the eastern side of the Turriff Basin and demonstrates the irregular nature of the sub-Devonian surface. Features of Dalradian metamorphism (andalusite zone) and structure are also seen.

Access

New Aberdour is situated on the B9031 coastal road 12 km (7 miles) west of Fraserburgh and 10 km (6 miles) east of Gardenstown. Take the minor road to New Aberdour beach (Figure 1) and (Figure 2) which leaves the main road a little west of New Aberdour village at [NJ 884 636]. Ample parking is available at the beach. The beach (Figure 1) is backed by cliffs and grassy slopes, and at half to low tide a rock-cut platform is exposed. Details of the sedimentology are best seen where the platform is abraded by wave action at the foot of the pebble beach. Low or half tide is essential for examination of the wave cut platform and in calm weather it is possible to do the entire excursion at or near beach level, but some rock clambering is required between Localities 1 and 3 and around the point at Locality 5. At higher states of the tide the points cannot be rounded but the cliff top is accessible and the field boundary can be followed by an indistinct unmarked path. The going is rough in places with deep vegetation in summer. Take care crossing fences. Descent to Locality 1 from the cliff top can be made with care by a grassy gully which can be slippery when wet. Walking distance is 3–4 km. The area is covered by Geological Survey 1:63,360 sheet 97 (Fraserburgh), and O.S. 1:50,000 sheet 30 (Fraserburgh). Half a day should be allowed for this excursion.

Introduction

The Old Red Sandstone of the Turriff Basin is slightly more than 1 km thick (Ashcroft and Wilson 1976) mainly comprising conglomerates and red sandstones. The Lower ORS Crovie Group, which is seen on this excursion comprises sandstones, marls and conglomerates which are faulted against, or rest unconformably on the Dalradian. Conglomerates of the Middle ORS Findon Group unconformably overlie the Crovie Group. The unconformity is seen on the Pennan excursion (Trewin 1987, and AGS website version). Further details are given in the introduction to the Gamrie excursion (Trewin and Kneller 1987), and by Sweet (1985) who describes the sedimentology of this section.

The succession is generally well exposed, but is divided by the Dundarg Fault into two major blocks, and thicknesses are difficult to measure. The Localities described (Figure 2) are treated in ascending stratigraphic order with the possibility of some repetition or absence of strata by faulting. Generalised stratigraphic sections are shown in figure 3. More detailed logs are given by Sweet (1985) and Donovan *et al*. (1978).

For further details on Dalradian metamorphic and structural features (Localities. 13–15) refer to the Macduff to Whitehills Excursion (Hudson 1987,also Hudson and Johnson on AGS website) and the Geological History section (Kneller 1987) of the Aberdeen geological excursions guidebook.

Itinerary

Locality 1 [NJ 898 652]

Proceed by the shore or cliff top from the parking area to Locality 1. This magnificent exposure shows the basal unconformity with the eroded surface of the Dalradian andalusite schists and psammites overlain by coarse ORS breccias (Figure 4).

The basement consists of andalusite schists of the Rosehearty-Fyvie 'Group' in which relict andalusite crystals up to 1 cm long are largely altered to micaceous aggregates and deformed by a later foliation which is axial planar to folds in this area. The folds have axes generally trending north to NE and may plunge gently either north or south. At Locality 1 the original bedding in the schist group is clearly seen, the rocks are inverted and occur on the overturned limb of an anticline trending NE. The original sediments of the Rosehearty-Fyvie 'Group' (part of the Southern Highland Group) were similar to those described for the Southern Highland Group at Macduff (Trewin 1987, and AGS website). The sequence comprises alternations of thick-bedded, massive pebbly greywackes, sometimes with grading, and mudstone-shale sequences (now the andalusite schists) with thin turbidites showing grading and Bouma sequences of structures. These lithofacies represent channel and interchannel deposits of a turbidite fan.

The unconformity surface dips at angles from 45° to close to vertical and shows weathering alteration and reddening as well as downturning of the schists at the contact. The less resistant schists are frequent as clasts only for a short distance from the unconformity surface. Most blocks in the breccias are psammitic lithologies of the local Dalradian together with occasional vein quartz and pink felsite. Granitic debris is absent and all clasts are of local origin. Close to the unconformity blocks up to 8 m long are found with their long axes parallel to the strike of the ORS. The large blocks acted as a framework which was filled with red sand and gravel by water flowing through the deposit. It appears that this very coarse breccia mantles an irregular topography on which resistant greywacke beds stood up as ridges as can be seen along the present day coastline. The very coarse breccia is about 10 m thick at this point.

Locality 2 [NJ 897 651]

Tracing the unconformity to the SW, towards Locality 2, the basal breccias can be seen to pinch out and are overlain by sandstone with conglomeratic lenses which then directly overlie the basement.

Granitic debris in the form of angular quartz and feldspar grains 2–5 mm in size occur here close to the unconformity above the locally derived basal breccia. One can imagine the early land surface having been mantled with rock fall and mass flow derived breccias which were later overtopped by finer grained sediments when the local topography became more subdued.

Locality 3 [NJ 898 650]

Follow the unconformity round into a small inlet, probably representing a small gully on the Devonian land surface, as interpreted by Sweet (1985). On the south side a fault is seen affecting breccias, conglomerates and sandstones resting on the basement. The steep walls on the eastern side of the inlet are mantled with angular breccia. On the foreshore the unconformity can again be seen and is overlain by red, pebble-free sandstone showing trough cross-bedding with transport to the NW. Sweet (1985) recorded transport to the SW and great local variation is present. The cross-bedded sandstones are probably the deposits of bar forms migrating within fluvial channels. Minor fault disturbance does occur along the unconformity but sufficient is preserved to illustrate its varied dip and the great variety of lithologies immediately above the surface. Clearly the basal conglomerates, breccias and sandstones reflect the covering of the irregular slopes, hollows and rises of the Devonian landscape by the deposits of debris flows, and of streams draining local bedrock.

Locality 4 [NJ 8965 6490]

With increasing distance from the unconformity, a greater uniformity is seen in the sediments. The incoming of abundant granitic debris in typically coarse red conglomeratic sandstones, with much angular feldspar and quartz and a grain size of 2–10 mm, is seen between Localities 4 and 5 (equivalent to the offshore reef of Locality 2). The conglomeratic sandstones consist of irregular beds up to 1 m thick which frequently have erosive bases with concentrations of pebbles and some boulders up to 50 cm in diameter. All the coarse pebbles are of local Dalradian rock types together with felsite, vein quartz and granite. Rounding is generally poor indicating a short transport distance. Channel structures up to 2 m deep are present, filled with crudely cross-bedded conglomerate.

Locality 5 [NJ 8955 6490]

On the east side of the promontory on which Dundarg Castle stands, a wide channel is filled with low- angle cross-bedding in which individual beds are each about 10 cm thick and crudely graded. Many of the sandstone beds are structureless and have 'floating' pebbles (matrix supported). These beds were deposited by rapid intermittent transport of sand and gravel possibly by flash floods. The exceptionally poor sorting and rounding, presence of matrix supported boulders and pebbles, lack of abundant cross-bedding and other structures seem to rule out a fluvial environment with permanent streamflow. The conglomeratic sandstones are part of alluvial fan structures over which violent flash floods deposited their sediment load. The abundant granitic debris comes from the Strichen Granite which is exposed 4 km inland. The granite was undergoing deep weathering and granular decomposition in Devonian times, but not providing many pebbles or boulders. The local felsites and quartz veins were more resistant to weathering and are abundant in the pebble population.

Locality 6 [NJ 894 649]

At Locality 6 a marked change in sedimentation occurs with the deposits becoming finer grained.

Large and small pebbles reduce in abundance and are succeeded by 2 m of red finely-laminated sandstone with some ripple- lamination. Isolated boulders are still present and the lithology reverts upwards to 12 m of sandstones with some minor conglomeratic beds and channel fills as before. A more permanent return to fine-grained deposition occurs a few metres further on in the middle of the bay, opposite a small isolated cliff west of the cliff top wall. Over a few metres maximum grain-size diminishes rapidly and channels and their conglomeratic fills become thinner and finer. The following 13 m of sandstones consist of beds up to 30 cm thick which show parallel-lamination, small-scale cross-bedding and ripple lamination. Concentrations of sorted granitic wash are present throughout with a few clasts up to 10 cm in size. The large burrow *Beaconites* occurs sporadically in some sandstone beds, but it is better seen further up the succession. The marked fining-up of the sequence records the passage from a coarse fan through fan-toe and on to an alluvial plain or playa surface.

The alluvial plain or playa sediments comprise 32 m of red and green mudstones and shales with limestones. The limestones comprise; bands of carbonate nodules, generally 1–20 cm in diameter which occur only a few centimetres apart; some nodule beds which are up to 50 cm thick and laterally continuous limestones up to 15 cm thick are also present (Figure 5). In thin section displacive growth of calcite and replacement of detrital grains by calcite is seen. Several generations of calcite deposition are marked by cross-cutting veins. Continuous limestone beds are sometimes formed by coalescing nodules, and sharp crested ridges, 'tepee structures', are developed where adjacent edges have been forced upwards. In some instances polygonal desiccation cracks appear to control the development of the carbonate nodules. The range of structures present are typical of incipient (type I) to mature (type IV) calcretes where carbonate nodules coalesce to produce limestone beds (Machette 1985). These are likely to indicate deposition in a semi-arid climate and would require significant periods of geomorphic stability to form. Interbedded with the mudstones and limestones are thin laminated and ripple-laminated sandstone beds with oscillation ripples whose axes generally trend NE–SW.

The presence of oscillation ripples indicates the presence of a standing body of water in which waves could rework the sediment surface. A setting such as a shallow lake can be envisaged which would also be consistent with the low energy environment required for the settling of fine grained material to form the mudstones. Desiccation cracks indicate that this was only an ephemeral lake, termed a playa, and the presence of calcretes hint at the aridity which may have led to its regular desiccation. The fining-up sequence passed through between Locality 1 to here could represent a transition from the conglomeratic facies of an alluvial fan, through a sandy fan margin into a mud and sand flat which had a temporary water cover in wet seasons but was subject to desiccation in dry seasons.

Locality 7 [NJ 839 649]

The fine-grained succession comprising mudstones and further calcretes continues to Locality 7 on the wave cut platform where coarse-grained sediment again appears in the succession in the form of thin beds with coarse-grained (to 5 mm) erosive bases sometimes with small scale cross-bedding, primary current lineation (N–S), current ripples and oscillation ripples (E–W).

The marl and cornstone lithologies continue interbedded with the coarser material. A surprising feature is the presence of pink felsite pebbles and boulders up to 60 cm in diameter, set in fine- grained laminated sandstone and even within mudstone beds (Figure 6). These are unlikely to have travelled far and may have slid gently from an adjacent outcrop onto the mud and sand flat. A more likely interpretation is that the boulders were washed in during high energy floods, and subsequently lower energy floods combined with aeolian deflation removed the finer grained sediment that surrounded them. The boulders are frequently sub-rounded but many have angular edges and etched and pitted faces; some appear to be ventifacts shaped by wind action, but they were finally deposited in water-lain strata.

Another striking feature in this part of the succession is the appearance of the trace fossil burrow *Beaconites* (Figure 7) at the same time as the coarser material appears in the succession. The *Beaconites* burrows are 8–13 cm wide and can be traced for over a metre on bedding surfaces. Short vertical examples are also present. The horizontal burrows sometimes appear to end at a vertical burrow. The animal responsible for the burrows does not seem to have favoured any particular lithology, since these large burrows with their backfill structures are found in fine sandstone, coarse pebbly sandstone and also in the mudstones, where they may be replaced by carbonate (calcretes nodules). A few indistinct walking traces (*Beaconichnus*) similar to those described from Gamrie (Trewin and Kneller 1987) are present and may have been made by the same animal that produced the burrows. The animal was probably an arthropod which burrowed for protection, and to conserve moisture in the same way as do modern scorpions. *Beaconites* occurs through at least 15 m of strata usually in the coarser beds.

Near low tide mark on the seaweed covered ledges forming the succession above the beds with *Beaconites*, the sediment coarsens again and beds contain abundant angular felsitic debris in a sand matrix. Occasional thin mudstones and calcretes are still present but form only a minor part of the succession. The large boulders of the *Beaconites* beds appear to be absent. The succession is terminated by the Dundarg Fault which is thrown down to the west and controls the headland position at the west end of the bay.

Locality 8 [NJ 889 647]

Between the Dundarg Fault and the central unexposed area of New Aberdour Bay the typical conglomeratic sandstone lithology (Figure 8) continues without interruption. At the east side of the bay at Locality 8 it has been eroded into a spectacular series of arches and tunnels. In the western wall of the central tunnel at its seaward end, the edge of a channel 1.5 m deep and filled with conglomerate and eroded in coarse sandstone can be seen (Figure 9). This represents the limit of lateral migration of a channel on an alluvial fan surface. The steep sided nature of this channel margin suggests that the coarse sands into which it is cut were forming a coherent substrate at this time, possibly due to minor early carbonate cementation.

Localities 9-12 [NJ 886 648] to [NJ 882 650]

On the western side of the bay at Locality 9 the same lithology continues but between this point and the end of the bay a fine-grained sequence similar to that previously described is present. The succession exposed between Localities 9 and 10 is illustrated in (Figure 3). At the base a well-developed fining-upwards sequence is seen commencing with the conglomeratic sandstones with channels and erosive bed contacts. The sequence continues with 4 m of laminated red sandstone with finer grained conglomerate lenses and fine-grained parallel and ripple-laminated sandstone. Mudstones with thin rippled sandstones and calcrete beds complete the upward-fining sequence. Oscillation ripple axes are oriented NE–SW.

The succession continues, with minor faulting, through about 70 m of purple and red marls, with calcrete nodules and beds increasing in abundance upwards. Occasional thin rippled sandstone beds occur and one thin, laterally impersistent, development of arkosic grit with *Beaconites* is present. At Locality 10 more grit and conglomerate beds occur in the succession with channels and cross- bedding. *Beaconites* burrows again appear at two levels along with this coarse material, but whereas at Locality 7 the *Beaconites* beds were succeeded by conglomeratic sandstone with abundant felsite clasts they are here followed by more than 10 m of red mudstones. West of the fault at Locality 10 the foreshore consists of faulted blocks of mudstones with the coarser beds containing *Beaconites* exposed again at Localities 11 and 12.

Current directions recorded on cross-bedding, channels and primary current lineation are generally to the north and NW. Orientations of oscillation ripple axes are highly variable but generally N–S at the top of this section in the *Beaconites* beds.

Interpretation of Devonian sequence

The faulted nature of the succession makes correlation difficult. It is possible that the two fine-grained sequences described on either side of the Dundarg Fault are roughly equivalent and are repeated by faulting. Even if this is the case rapid lateral variation must occur as can be seen by the difference in facies (mudstones and conglomeratic felsite-rich sandstone) that overlie the prominent *Beaconites* bearing lithologies. Considerable lateral variation is certainly present near the unconformity and probably continues up the succession. The thickness of conglomeratic sandstone between the unconformity at Locality 1 and the first fine grained unit is about 100 m, whereas the thickness seen below the second unit (Localities 9–10) is about 500 m assuming no significant faulting is present. If the two fine-grained units are correlated the conglomeratic sandstone must thicken rapidly westwards. Total thickness of this Lower ORS succession is at least 600 m and possibly as much as 800 m. Although similar facies sequences are present in the two sections there is little evidence for any facies boundary correlations as suggested by Sweet (1985).

The lithologies seen include basal breccias which mantle the Devonian land surface, filling hollows and valleys. The conglomeratic sandstones probably formed by flash floods on alluvial fans issuing from the local topography. Finer-grained lithologies include outwash sandstones at fan margins and sandstones deposited by gentle currents in shallow water to give current ripples. Mudstones were deposited in areas of quiet sedimentation which may at times have been temporary playa lakes. Waves in shallow water lakes produced the parallel crested ripples. The nodular and bedded limestones record periods of low sedimentation rate and geomorphic stability during which carbonate was deposited in soil profiles similar to present day calcrete deposits of hot semi-arid areas. The angularity of the pebbles and preponderance of local rock types indicate short transport distances for the sediment. The sketch block diagram of (Figure 10) is an attempt to account for the features seen in the Devonian sedimentary rocks of New Aberdour.

Dalradian metamorphism and structure

Locality 13 [NJ 882 649]

Lower ORS is juxtaposed against Southern Highland Group Dalradian by a fault throwing down to the NE, trending about 140° with a steep NE dip. There is considerable associated brecciation, and the Dalradian is extensively fractured along this stretch of shore-line. These rocks lie within the andalusite zone of regional (east Buchan) metamorphism, the andalusite and cordierite isograds occurring two to three km to the west, where they are obscured by down-faulted ORS. The Dalradian at this Locality is thus at a fractionally lower grade than that at Localities 1 to 3.

The Southern Highland Group here is of similar sedimentary character to that at Gamrie Bay (Trewin and Kneller 1987) with rippled and/or graded thin-bedded siltstones and pelites, occasional well- sorted thin sandstone beds and amalgamated greywacke units, though it lacks the coarser detritus found further west (the maximum detrital grain size decreases eastwards (down the succession) from the axis of the Turriff Syncline). Pelitic rocks here have phyllitic character, with ovoid, xenoblastic 'knots', up to about 5 mm in length, of andalusite and cordierite. The typical mineral assemblage in the pelites is quartz + plagioclase feldspar + white mica + biotite + andalusite + cordierite, +/– (chlorite) the last four being present as porphyroblasts. Garnet is relatively common in the andalusite-free semi-pelitic rocks (originally matrix-rich greywackes) in the andalusite zone, usually as tiny dodecahedra. The distinction of andalusite and cordierite in the field is often difficult at this grade, and some xenoblasts actually consist of both minerals. In general, andalusite tends to be paler, more resistant to alteration (and hence to weathering) and of better crystal form, though this is not invariably so.

At this Locality the dominant lithologies are cross-laminated and graded pelites and fine sandstones, usually in beds 1-10 cm thick. Differential porphyroblast development clearly picks out compositional variation within and between pelites. Within individual graded beds, andalusite and cordierite porphyroblasts are sometimes concentrated in the iron-, magnesium- and aluminium-rich fraction towards the top of the bed, reflecting the original segregation of detrital clay minerals, chlorite and mica. This feature can be used to identify graded bedding (Figure 11). The relative abundance of andalusite and cordierite varies from bed to bed. In some particularly aluminous bands, abundant, large andalusite crystals occur, up to 2 cm in length, showing good prismatic form. These crystals weather proud of the matrix. Other bands are particularly rich in xenoblastic, blue-grey cordierite, generally weathering with negative relief to an orange-brown colour, accompanied by stubby prisms of porphyroblastic biotite. Some areas of early (diagenetic) calcareous cementation are picked out by greenish, epidotic patches.

Locality 14 [NJ 883 648]

Eastwards, the first conspicuous promontory is created by an amalgamated sandstone unit folded by a large D3 antiform, with a typical steep western limb. Quartz veins developed near the hinge (which trends about 020°, plunge about 10°) are disposed in a crude fan about the axial plane. An axial- planar crenulation cleavage (S3) is locally well-developed in adjacent pelites. The D3 folds are asymmetric with a consistent westerly vergence, axial planes and associated S3 cleavage dipping east or ESE at a moderate angle. Much of the fracturing here can be attributed to the proximity of the fault bounding the ORS, along which a thick fault generated breccia is developed.

Locality 15 [NJ 884 648]

Small scale structures are well displayed. The andalusite and cordierite porphyroblasts are seen in thin section to overgrow an early cleavage (S1) which is more or less parallel to bedding in these exposures. This cleavage has been interpreted by Fettes (1970) as the same cleavage as that found in the nonporphyroblastic pelites of the Macduff Slates. It is crenulated by a later (S3) fabric, which is axial-planar to the prominent local (D3) folds, and post-dates porphyroblast growth. The S3 crenulation cleavage is usually the most obvious structure in pelites at this Locality, and dips east at about 20°. Note the lithological control on cleavage development — psammites are almost devoid of a tectonic fabric, at least to the naked eye.

Alignment of andalusite and cordierite porphyroblasts within the S1 planes forms a lineation roughly parallel to D3 fold axes, and to the S1/S3 intersection (a fine crenulation), normally plunging gently to the NE. These structures can be seen on the numerous surfaces roughly parallel to bedding. Abundant grading and cross-lamination demonstrate that the rocks are right-way-up at this Locality. The Dalradian section is brought to an end by a fault trending about 025°. This truncates the NW trending fault and throws down to the east.

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Figures

(Figure 1) View west along New Aberdour beach showing rock-cut platform, Locality 1 in far distance.

(Figure 2) Locality map of the New Aberdour area.

(Figure 3) Diagrammatic logs of eastern and western sections at New Aberdour, with Locality numbers as in (Figure 2).

(Figure 4) Basal breccia of the Lower Old Red Sandstone dipping steeply NW and resting unconformably on andalusite schists of the Rosehearty-Fyvie 'Group' in the foreground.

(Figure 5) Nodular and bedded carbonate forming incipient to mature calcrete intervals within the red mudstones observed at Locality 6.

(Figure 6) Felsite boulder in fine sandstone, Locality 7.

(Figure 7) *Beaconites* burrows exposed on a bedding surface with wave generated oscillation ripples. Locality 7.

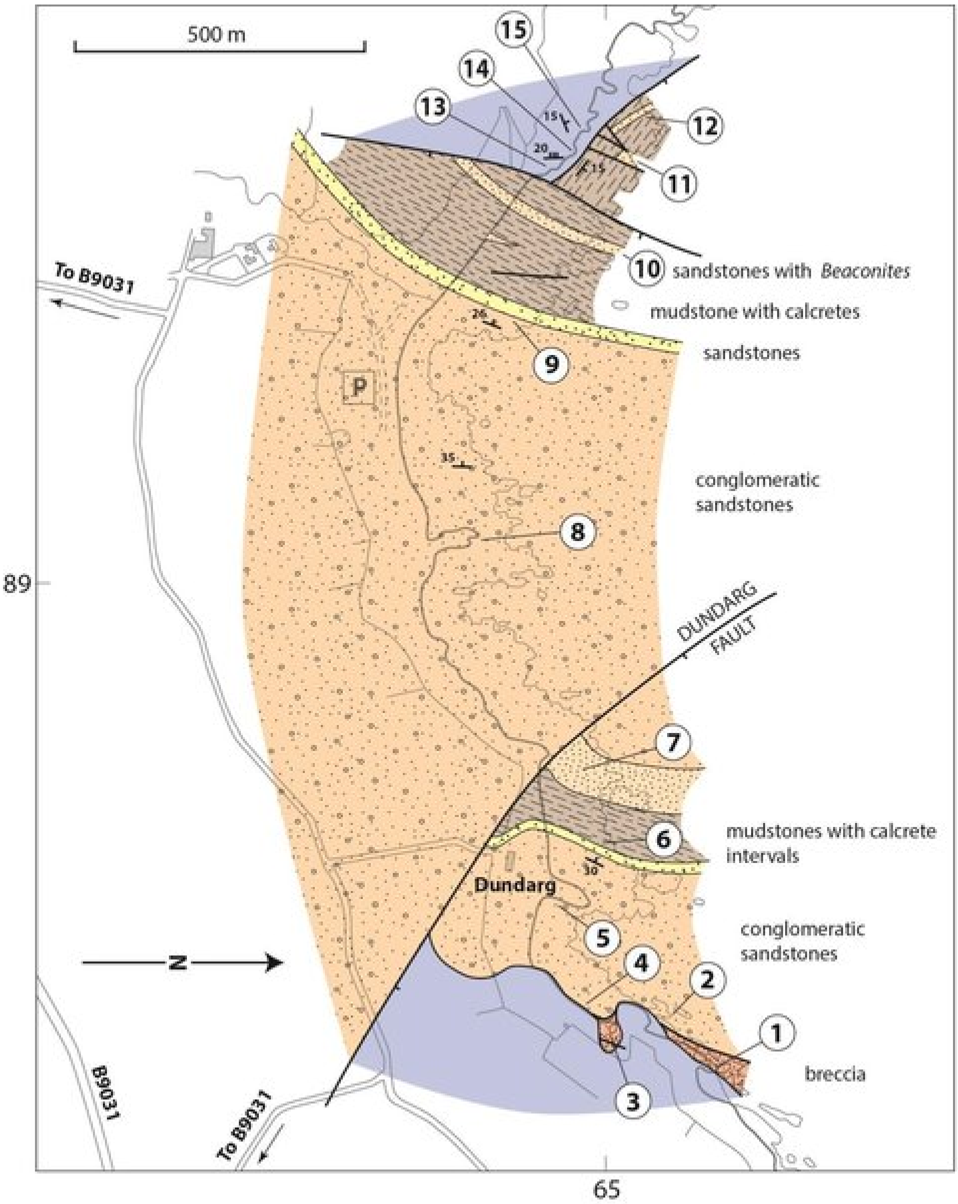
(Figure 8) An example from locality 8 of the textures within the poorly sorted and only vaguely bedded pebbly and conglomeratic sandstones described from locality 5.

(Figure 9) Steep channel margin in conglomeratic sandstones, Locality 8.

(Figure 10) Diagrammatic view of sedimentary environments of the Lower ORS of New Aberdour. (1) Basal breccias and conglomerates. (2) Alluvial fans of conglomeratic sandstones. (3) Sandy fringe to alluvial fans. (4) Fine-grained deposits of playa lake flats.

(Figure 11) Graded psammite with sharp base overlain by parallel and ripple lamination grading to pelite. Porphyroblasts of cordierite increase into the pelitic portion of the bed which also shows cleavage oblique to bedding.

(Figure 1) View west along New Aberdour beach showing rock-cut platform, Locality 1 in far distance.



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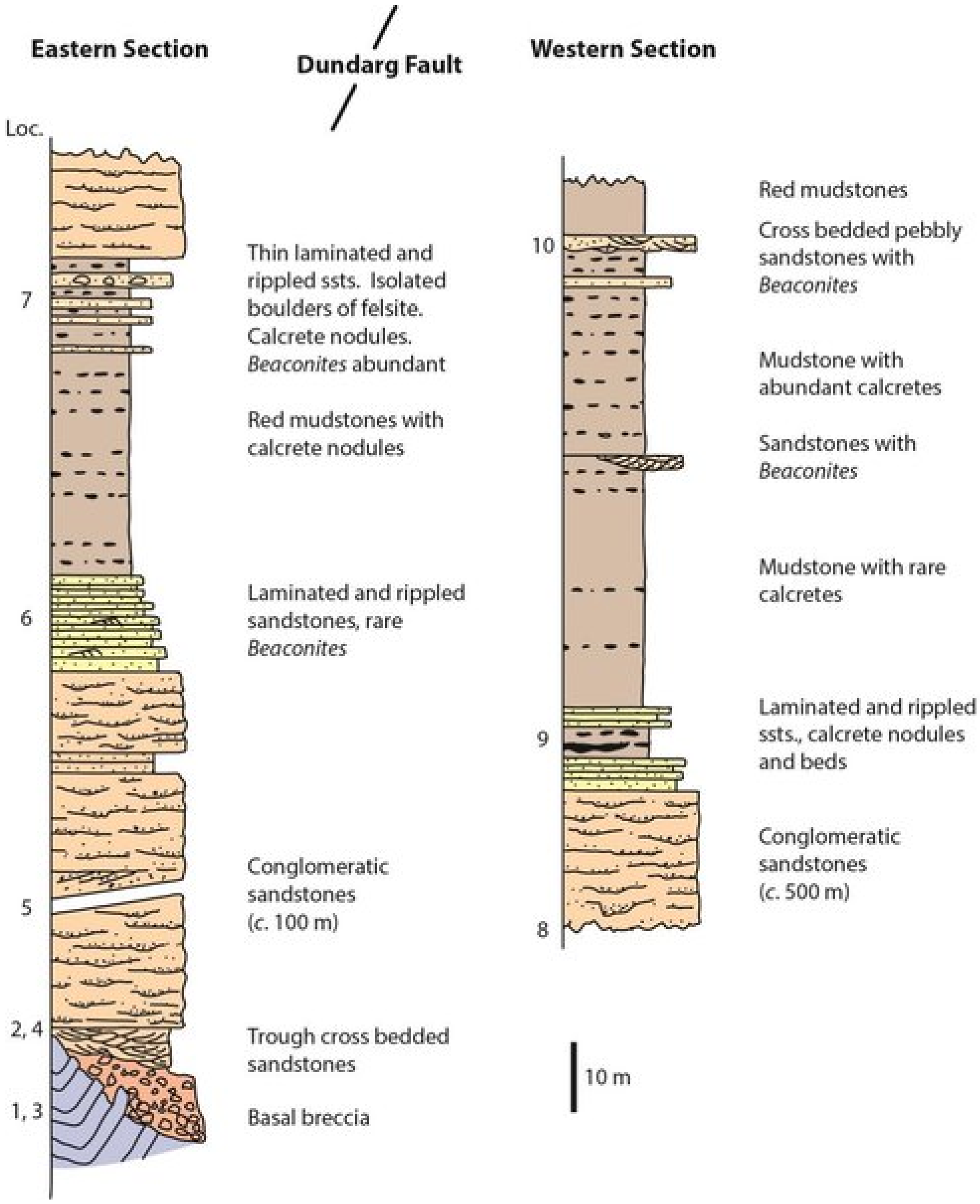

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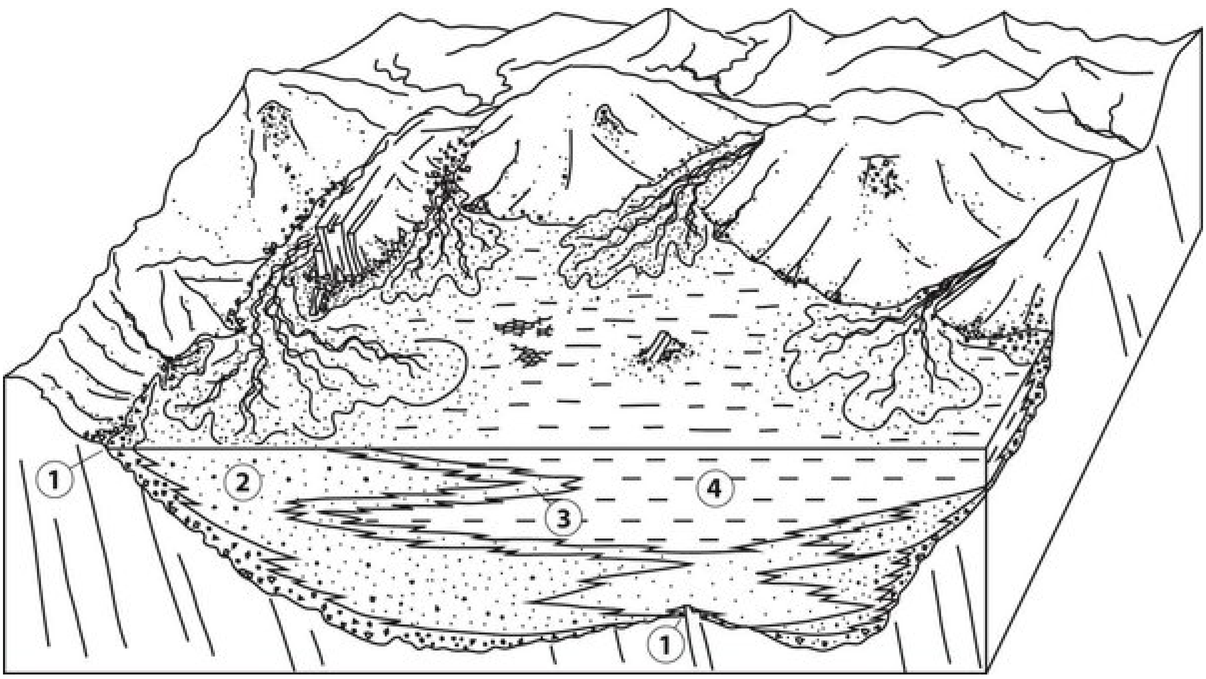

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(Figure 11) Graded psammite with sharp base overlain by parallel and ripple lamination grading to pelite. Porphyroblasts of cordierite increase into the pelitic portion of the bed which also shows cleavage oblique to bedding.