

# Dalradian sedimentation, Grampian Caledonides

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Stephenson, D, and Gould, D. 1995. British regional geology: the Grampian Highlands. Fourth edition. Reprint 2007. Keyworth, Nottingham: British Geological Survey.

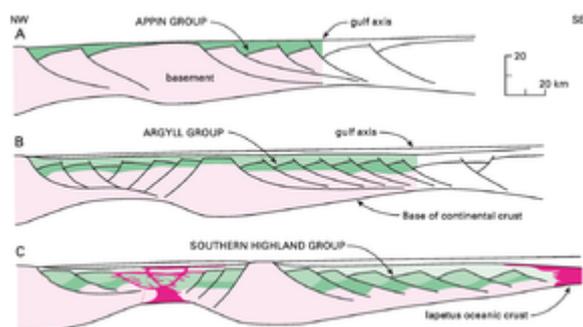
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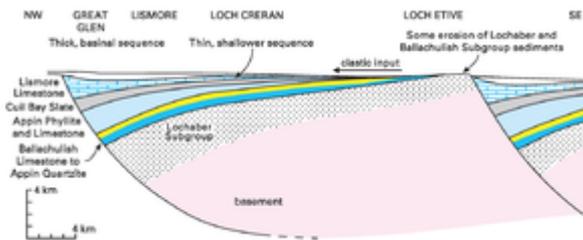
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## Dalradian sedimentation

Recent reviews of the Dalradian Supergroup conclude that the preserved outcrop, extending across the Grampian Highlands to the west coast of Ireland, represents a segment of a former very extensive continental shelf sequence (Anderton, 1985; Winchester, 1988). Sedimentation is thought to have commenced in a broad ensialic rift which opened north-eastwards to form a marine gulf. The Grampian Group was laid down on a relatively passive continental shelf on the north-west side of the rift (Winchester and Glover, 1988). Continued extension widened and deepened the rift and the sediments of the Appin and Argyll groups represent continuing deposition on the north-western shelf margin ([P915424](#)). Actual rupturing of the continental crust within the widening rift is indicated by the appearance of large volumes of volcanic material towards the top of the Argyll Group, with eruption continuing during deposition of the overlying Southern Highland Group. Faulting, related to the progressive lithospheric stretching across the rift, has been recognised as a principal control on Dalradian sedimentation.



Schematic evolution of the Dalradian terrane in the South-west Highlands (from Anderton, 1985). [P915424](#).



Deposition of the Appin Group in a 'trapdoor' basin defined by listric faults between the Great Glen and Loch Etive. P915425.

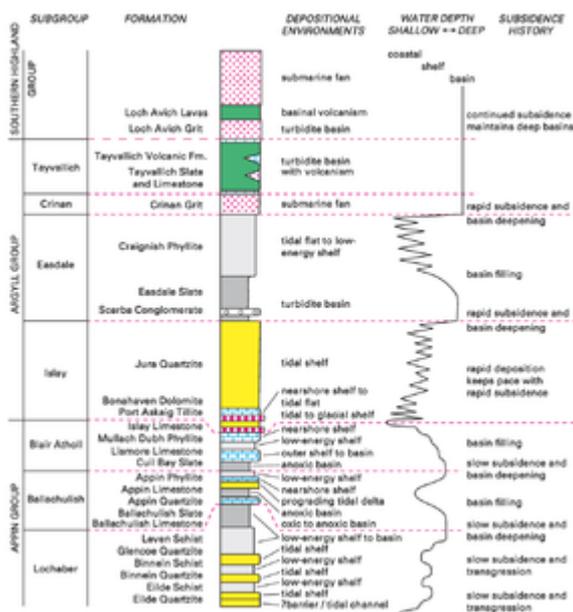
Anderton (1985) envisaged the area of deposition to be divided into a series of developing, SE-dipping fault blocks bounded by 'scoop-shaped' listric faults which delimited individual sedimentary basins on the continental shelf (P915425). These early fault-systems thus had a direct influence on both the composition and shape of the sediment pile, and ultimately affected the morphology of the regional folds. The faults also acted as controls for submarine volcanic activity, and perhaps also for the subsequent emplacement of late igneous intrusions.

## Grampian Group

The Grantown Formation, at the base of the Grampian Group, is regarded as a sequence of shallow-marine shelf sediments which were deposited in local depressions on the continental shelf.

Accelerated, uneven subsidence along the shelf was accompanied by an increase in the supply of immature sediment leading to the deposition of fining-upward turbidite sequences which thicken to the east and south-east where they dominate the Grampian Group succession.

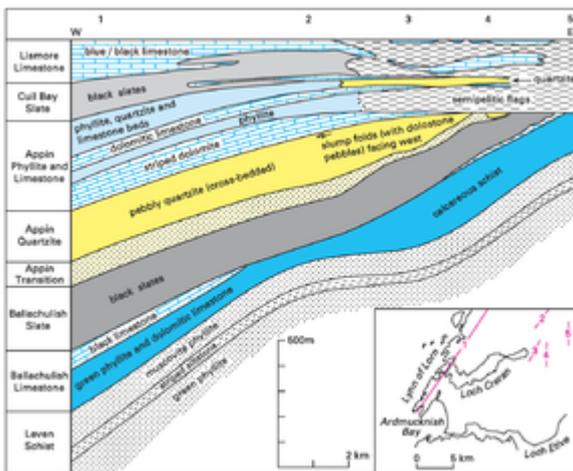
The lithological variation in the upper part of the Grampian Group is attributed to regional shallowing with intertidal and estuarine sedimentation (Glover and Winchester, 1989). The deposited sediments became more mature but are chemically distinct from those of the overlying Appin Group. A marine regression of the shelf locally exposed the Grampian Group sediments prior to renewed subsidence at the start of the Appin Group. Throughout the sedimentation of the Grampian Group there was a constant supply of detritus from a 'granitic' source in the northern land mass (Hickman, 1975; Glover and Winchester, 1989).



Interpreted depositional environments of the Appin, Argyll and Southern Highland groups (after Anderton, 1985). P915426.

## Appin Group and lower Argyll Group

Wright (1988) concluded that during Appin Group times sedimentation occurred on a tidal shelf overlying a gently subsiding crust. As in the preceding Grampian Group the supply of sediment was from a north-western landmass, although palaeocurrent indicators show that the sediment was distributed along the shelf by tidal longshore currents. According to Anderton (1985) conditions fluctuated between an open-marine oxidising environment and stagnant euxinic lagoons to produce quartzite/black pyritic shale sequences (P915426). In south-western parts of the Lochaber Subgroup outcrop, deltaic deposits occur over a distance of about 40 km with facies varying from proximal at Appin to distal at Glen Roy (Hickman, 1975). The various quartzite formations (the Eilde, Binnein and Glencoe quartzites) are interpreted as tidal sand bodies (Wright, 1988).



Appin Group facies changes in the Loch Creran area, based on correlation of strike sections and estimation of pre-tectonic thicknesses. P915420.

The blue limestones and black shales of the overlying Ballachulish Subgroup extend from Banff to Donegal and indicate that deposition took place on an extensive, shallow, probably lagoonal shelf with considerable along-strike continuity of facies (Wright, 1988). Nevertheless the shelf must also have been relatively narrow to explain the rapid down-dip facies changes seen, for example, between Lismore and Glen Creran (P915420) (Litherland, 1980). The Ballachulish Slate is interpreted as a prodelta clay deposit and encroachment of fine quartz sands from the delta into deeper water produced the overlying quartzites such as the Appin Quartzite (Wright, 1988). At intervals during Blair Atholl Subgroup times sediment supply exceeded shelf subsidence so that local nondeposition due to emergence is marked by incomplete stratigraphical sequences.

A dramatic climatic change took place at the beginning of Argyll Group times to produce the widely distributed Port Askaig Tillite Formation (and contemporaneous glacial deposits recognised around the world). The tillites, at the base of the Islay Subgroup, were probably deposited on a shallow-marine shelf by successive pulses of grounded ice, possibly advancing from the south-east. The tillites are thickest on Islay but show similar features, where present, throughout the Dalradian outcrop. Intrabasinal sedimentary rocks were first eroded by the glaciers and then covered by marine tills in which extrabasinal granitoid debris becomes increasingly common upwards. Evidence

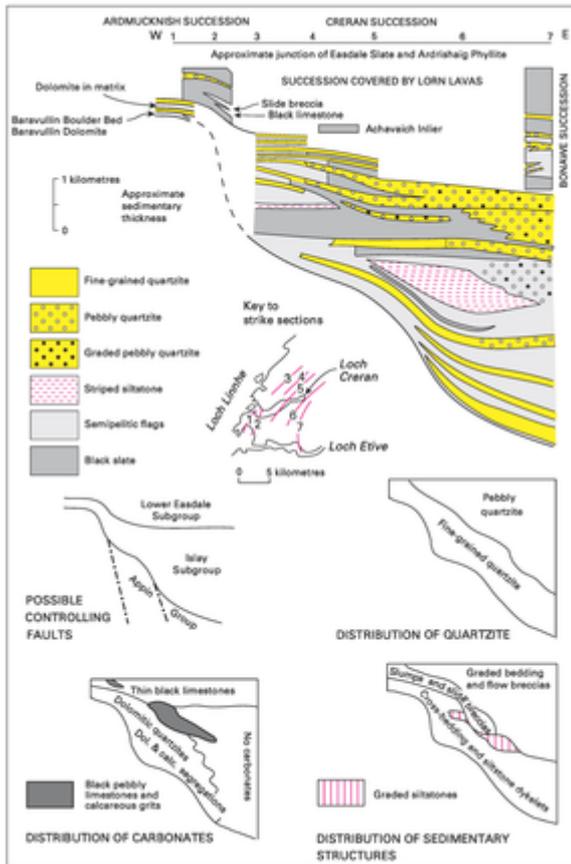
for 17 separate glacial advances is recognised from interbedded marine sediments within the tillite formation (Spencer, 1971). Isolated dropstones in varved siltstones infer local flotation of the ice sheet but large-scale deposition from ice rafts and reworking by downslope mass-flow, as suggested by Eyles and Eyles (1983), is rejected by Spencer (1971). Periods of emergence and periglacial weathering between the glacial cycles are suggested by polygonal sandstone wedges, interpreted as ice wedges (Eyles and Clark, 1985). Beach conglomerates then herald the start of a marine transgression followed by the next glacial advance. Dolomitic limestones with stromatolites, suggestive of warm water, were deposited during some of the interglacial periods and palaeomagnetic results indicate that the Port Askaig Tillite Formation was deposited in low latitudes (Tarling, 1974). This evidence would seem to be in conflict with having an ice sheet at sea level, but as yet there has been no satisfactory explanation for this paradox.

Shelf sedimentation resumed after the final retreat of the ice, resulting in the deposition of the Islay, Jura and Schiehallion quartzites. The closest shoreline remained north-west of Islay and Jura with at least 100 km of open sea to the south-east. The local absence of the Schiehallion Quartzite from the shelf sequence may be due to contemporaneous erosion rather than non-deposition (Pantin, 1961). A change to a tidal, shallow-water environment at the top of the Islay Subgroup was probably caused by a combination of source area uplift and a tectonically induced marine transgression.

## **Upper Argyll Group**

An initial shelf-deepening event at the start of the Easdale Subgroup resulted in fault-controlled, steep shelf-slope sedimentation. The base of the subgroup is generally marked by a rapid change to fine-grained sediments showing features of deep-water sedimentation and turbidity currents, with local incursions of very coarse-grained, mass-flow deposits (as seen in the Scarba Conglomerate Formation). The sediments were probably deposited in a series of fault-controlled marginal basins having a general NE-SW trend (Anderton, 1985; 1988). The interbasinal highs are marked by local thinning, facies changes, erosion or non-deposition; they commonly coincide with long-lasting major lineaments trending north-east or north-west (Fettes et al., 1986; Graham, 1987). Syngenetic barium and base metal mineralisation is attributed to ponding of exhalative brines in local basins adjacent to active faults, which in turn controlled sea-water infiltration into buried sediments (Coats et al., 1984). A variety of lower Easdale Subgroup facies are recognised along the strike length with, for example, volcanic rocks and turbiditic quartzites exposed in the Perthshire area.

Shallow-water shelf and tidal flat sedimentation returned during upper Easdale Subgroup times due to infilling of the local basins with fine-grained sediments to produce, for example, the Craignish and Ardrishaig phyllites in the South-west Highlands. Minor volcanism is recorded by various tuff layers such as the Farragon Beds.



Variation in thickness and lithology over a possible fault-controlled basin margin, lower Argyll Group of Benderloch. P915423.

A further rapid shelf-deepening and basin-forming event at the start of the Crinan Subgroup induced turbidite deposition, with soft-sediment structures preserved in the Crinan Grit, attributed to contemporaneous earthquakes. Major faulting caused slope failure and reworking of buried but poorly lithified sediments.

The sediments of the shelf became more distal in character during the interval between the Islay and Crinan subgroups; the deltaic or shallow-marine sands, which probably supplied the clastic sediments involved in the turbidite flows, being more distant from the axis of deposition (Harris and Pitcher, 1975). The marked thickening of the Crinan Grit from 600 m to over 3000 m along a line running along Loch Awe (the Loch Awe axis) is parallel to, but displaced several kilometres south-east from, the underlying major thickening seen in the Islay Subgroup (P915423). As the sediments in the Crinan Subgroup fine overall from south-west to north-east across Scotland, a major input from the south-west seems likely.

The change to carbonate sedimentation at the start of the Tayvallich Subgroup to form the major limestone sequences such as the Loch Tay Limestone, implies that either the shelf became starved of clastic detritus or that off-shelf carbonate supply became dominant. Facies and thickness changes along and across-strike have been used to identify volcanic centres, such as in the Tayvallich-Loch Awe area, as well as major morphological features, such as submarine canyons.

## Southern Highland Group

Preserved sedimentary structures within the dominantly psammitic turbidites of the Southern Highland Group are consistent with deposition within major submarine fans on a subsiding

continental shelf ([P915424](#)). The turbidites are relatively enriched in feldspar and high-grade metamorphic and granitic rock fragments when compared to earlier Dalradian turbidites, features that were originally taken to indicate a newly emerged, immature source area to the south-east, the north-western continent being by this time too distant beyond a wide shelf (Harris and Pitcher, 1975; Harris et al., 1978). However, palaeocurrent directions and facies changes in the sequence all suggest a dominant flow towards the south-east with minor north-eastward and south-westward axial flows. Isotopic studies do not reveal any significant differences between the Southern Highland Group turbidites and the lower units in the Dalradian (O’Nions et al., 1983). Hence, the composition of the Southern Highland Group turbidites may reflect an erosional evolution of the north-western source area caused by stripping of a cover sequence to reveal a Lewisian-type granitoid basement (Plant et al., 1984; Anderton, 1985). The Loch Avich Lavas represent a final phase of lithospheric stretching in the Dalradian Basin; both the Tayvallich and Loch Avich lavas are thickest in the Loch Awe area.

## **Full list of references**

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