Solid geology, Cainozoic of north-east Scotland

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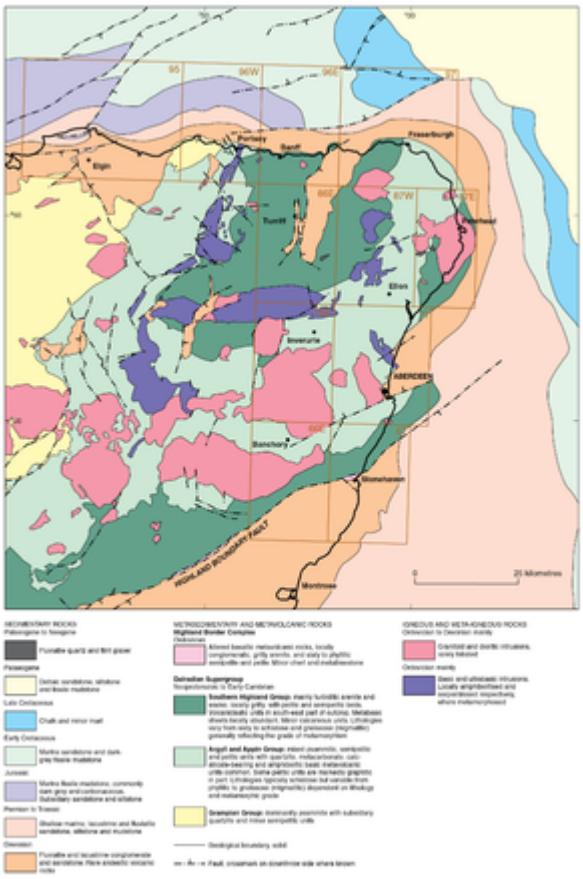
Solid geology



Solid geology of the district. P915249.

A simplified map of the solid geology of north-east Scotland is shown in P915249. The nature of the bedrock that underlies the Pleistocene deposits has exerted some measure of control on their development and form. The hardness of the differing types of bedrock, their weathering profiles, propensity to jointing, and overall response to subglacial deformation are all important factors that have controlled the pattern of glacial erosion and deposition. Resistant rock types such as granite and quartzite generally form positive topographical features that have diverted the ice, while readily releasing large erratic clasts into tills. The gabbros and ultramafic rocks generally form areas of negative relief, but like the granites, they have widely spaced joints and have readily yielded large erratics boulders, many of which were originally 'corestones' within saprolites. Their distribution can be used in the reconstruction of ice movement directions.

Easily fractured and finely jointed lithologies are also readily incorporated into ice sheets. Graphitic pelite and felsite are two examples of particularly common and widespread clasts, although neither are particularly resistant rock types. In general, the nature of the till in upland areas that formed beneath sluggish, possibly cold-based ice sheets strongly reflects the underlying bedrock.

The bedrock of the district ranges in age from late Precambrian to Early Cretaceous. Deposits of Palaeogene to Neogene age also occur. An outline of the solid geology is given below, but further details can be found in Stephenson and Gould (1995) and Craig (1991). A wider view of the Precambrian Dalradian succession may be found in Harris et al. (1994, pp.43–50).

Dalradian

A large part of the district is underlain by crystalline metamorphic rocks of the Neoproterozoic Dalradian Super-group. These metamorphic rocks represent original sedimentary rocks, now much altered by heat and pressure. Sandstones are thus represented by quartzites and quartzfeldspar-granulites (psammites), shales by various types of mica-schist and slate (pelites), and rocks intermediate between these two by quartz-mica-schists (semipelites). Limestones are now crystalline (marble), and originally muddy gritty sandstones have been weakly metamorphosed to become cleaved metagreywacke and schistose grit. The Dalradian sediments were deposited in a large intracontinental basin and later on a continental margin with small offshore oceanic basins.

An almost continuous succession from the upper part of the Grampian Group to a high level in the Southern Highland Group is exposed along the Moray Firth coast between Buckie and Macduff. The lowest part of the succession, assigned to the Grampian Group, consists of well-bedded quartzite and psammite that is mostly thickly bedded (Cullen Quartzite Formation), and was deposited in shallow water. The succeeding Appin Group was also deposited under shallow marine conditions, but the amount and grain size of the clastic material progressively decreased, and increasing quantities of limestone and organic material were deposited. The Lochaber Subgroup is represented by thinly bedded, flaggy psammite and semipelite; it becomes more calcareous upwards, eventually passing into conspicuous tremolite-rich semipelites, calc-silicate rocks and impure limestones (Findlater Flag and Cairnfield Flag formations). The overlying Ballachulish Subgroup consists of semipelite and pelite, commonly graphitic, interbedded with limestone units up to 35 m thick (Mortlach Graphitic Schist and Tarnash Phyllite and Limestone formations). The Blair Atholl Subgroup is represented by the Fordyce Limestone Formation, another interbedded pelite and limestone.

The Islay Subgroup at the base of the succeeding Argyll Group is marked by a discontinuous bed of metadiamictite, the 'Boulder Bed', which records a glacial event correlated with the widespread Neoproterozoic Varanger glaciations of the North Atlantic region. Associated psammite and quartzite units (Arnbath and Durn Hill formations) are succeeded by mixed semipelitic, pelitic and

calcareous rocks (Easdale Subgroup: Castle Point Pelite and Portsoy Limestone formations), and then by striped, thinly bedded psammites and semipelites (Crinan Subgroup: Cowhythe Psammite Formation). The overlying Boyne Limestone Formation (Tayvallich Subgroup) includes a 200 m-thick unit of 'relatively pure' limestone exposed on the coast section, surrounded by calc-silicates and calcareous semipelites.

The Southern Highland Group is locally unconformable on the Argyll Group west of Whitehills. The basal White-hills Grit Formation is characterised by calcareous psammites and semipelites, while the overlying Macduff Slate Formation consists of micaceous semipelite and pelite with abundant units of gritty psammite. The group is characterised by turbidites, and was deposited from density currents in deeper water than the rest of the Dalradian Supergroup. The group includes the Macduff Boulder Bed, which preserves a record of distal glaciomarine sedimentation in the form of ice-rafted dropstones and related bedding-deformation structures (Stoker et al., 1999). The Macduff Slate Formation may extend from the Neoproterozoic into the Cambrian and possibly even Ordovician, but the evidence for this is contradictory and inconclusive.

To the east of Macduff and in the more southerly parts of the district, only the Southern Highland Group (Collieston, Glen Effock and Glen Lethnot formations) and the upper part of the Argyll Group (Aberdeen, Ellon and Strichen formations) are represented. The rocks are dominantly psammites and semipelites, with rare calcsilicate beds. Significant areas of limestone outcrop (Deeside Limestone Formation) are confined to the area immediately south-east of Banchory.

Caledonian orogeny and magmatism

The Dalradian rocks were folded and metamorphosed during the Caledonian orogeny, which reached its acme at about 490–470 Ma. Four phases of folding and deformation, D1 to D4, are recognised, but are rarely all present in any one place. In the district, the large-scale effects of the earliest phase, which produced the Tay Nappe, are seen in the Collieston area and south of Aberdeen, where the strata are regionally inverted. The abundant upright, open to tight, northerly plunging early folds on the Banffshire coast section may also relate to this early phase. The large-scale structure of the area north of Aberdeen and east of Portsoy is dominated by the later 'open', upright northnorth-east-trending Turriff Syncline and the parallel Buchan Anticline to the east. They are D3 or possibly D4 in age. South of Aberdeen, gently dipping, inverted strata of the Southern Highland Group are tilted to the vertical along the Highland Border Downbend. This is a late regional east-north-east-trending monoform; its axial trace runs a few kilometres north of the Highland Boundary Fault. Major zones of ductile shearing occur both west of Portsoy (probably a continuation of the Keith Shear Zone), and in and just east of Portsoy (the Portsoy Shear Zone). They are also found between Inzie Head and Ellon, and along the northern and southern boundaries of the Insch basic intrusion. The Keith Shear Zone is associated with early granite intrusions and may itself reflect an early, Proterozoic structure. Other shear zones are closely associated with the emplacement of the basic and ultrabasic intrusions and are probably of early Ordovician age, although they may also reflect older lineaments in basement gneisses at depth.

To the east of Portsoy and to the north of Aberdeen, the regional metamorphism was of a relatively low-pressure type (Buchan metamorphism), and the characteristic minerals formed in pelites and semipelites were andalusite and cordierite. To the west of the Portsoy Shear Zone and south of Aberdeen, regional metamorphism took place at higher pressures, and the characteristic minerals to form in pelitic rocks were garnet, staurolite and kyanite.

Large volumes of basic magma were intruded into the Neoproterozoic metasedimentary rocks at about 470 Ma. It crystallised as several large layered bodies of basic and ultrabasic rock. The Insch,

Haddo House, Arnage, Maud, Belhelvie and Portsoy masses lie within the district, and the nearby Huntly and Knock masses have also provided erratics to the till of the area. The commonest lithologies are serpentinite (derived by hydration of ultrabasic rocks), olivine gabbro, olivine norite, and gabbros and norites (both cumulate and granular types). Troctolite, monzonite and syenite are more restricted in outcrop. Contact metamorphism associated with the basic intrusions produced hornfelses rich in sillimanite and cordierite, and also produced characteristic 'contaminated' and 'hybrid' rocks such as cordierite-bearing norite. Locally these metamorphic effects appear to have reinforced the regional pattern giving rise to areas of semipelitic and psammitic gneisses.

A phase of late Neoproterozoic (about 600 Ma) acid plutonic intrusion produced the Windyhills and Boggierow granitic intrusions, which now lie along the Keith Shear Zone, and are deformed by it. Acid magmas were also intruded about 470 Ma and at 425–395 Ma. The earlier intrusions, confusingly termed the 'Older Granites', are grey muscovite-biotite granites (S-type) and are typically foliated. This group includes the Aberchirder, Strichen, Forest of Deer, Kemnay, and Aberdeen granites. The later intrusions show calc-alkali differentiation trends (B-type) and are more voluminous. They comprise an earlier group of quartz-diorites, tonalites and granodiorites, typically grey in colour, which include the Torphins, Crathes, Balblair and Clinterty intrusions, and a slightly later group of biotite-granites, generally pink and in some cases megacrystic, which show a highly evolved geochemistry. These include Peterhead, Bennachie, Hill of Fare and Mount Battock. The distant Cairngorm, Ballater and Glen Gairn plutons also belong to this suite.

A suite of minor intrusions is associated with the 420–390 Ma plutons. They are widely distributed, but their outcrops are too small to be shown on smaller scale maps. The principal lithologies are felsite, microgranite, quartz-feldspar porphyry, microdiorite, and the lamprophyres, spessartite and vogesite. The more acid lithologies can form hard and resistant blocks that have yielded erratics and, in places, form a conspicuous though minor component of sand and gravel deposits.

Ordovician, Devonian and Carboniferous

A very narrow, discontinuous strip of early Ordovician rocks, the Highland Border Complex, crops out just north-west of the Highland Boundary Fault. They include metabasalts, slaty pelites, gritty psammites and rare impure limestones.

Devonian rocks formed in arid intermontane basins following the Caledonian orogeny. They are found as outliers in the East Grampian area to the north of the Highland Boundary Fault, around Elgin, in the Turriff basin and in several smaller outliers including one found recently on the Moss of Cruden, near Peterhead.

The Lower Devonian Crovie Group crops out mainly along the eastern side of the Turriff Basin. It consists of sandstones and conglomerates deposited on river floodplains and alluvial fans. The conglomerates underlying parts of Aberdeen are also assigned to the Lower Devonian. The unconformably overlying Middle Devonian rocks belong to the Inverness Sandstone Group. In the Turriff Basin, they form the Gardenstown Conglomerate Formation. This consists of a sequence of breccias and conglomerates, but also includes the Findon Fish Bed. Inland, the conglomerates are commonly deeply weathered. To the southeast of Elgin, and in outliers as far east as Deskford, the Spey Conglomerate Formation at the base of the Inverness Sandstone Group comprises a basal breccia overlain by a conglomerate with rounded cobbles mainly of quartzite set in a loose sandy matrix. It is overlain by red-brown and purple-brown flaggy sandstones of the Fochabers Sandstone Formation, which also contains beds of red- and purple-brown and green-grey mudstone. The unconformably overlying Upper Devonian Nairn Sandstone Formation, a gritty to pebbly arkose with scattered clasts of micaceous mudstone, crops out in the Alves–Elgin area.

To the south of the Highland Boundary Fault, between Edzell and Stonehaven, there is a thick sequence of late Silurian to early Devonian mainly fluviatile rocks that was deposited adjacent to the rising Highland block. The basal Stonehaven Group consists largely of sandstones with some siltstone and a thin andesitic lava flow. The Dunnottar–Crawton and Arbuthnott–Garvock groups here consist largely of conglomerate, derived partly from older metamorphic and igneous rocks and partly from contemporaneous lavas. Flows of andesite and mugearite are conspicuous in the coastal section. The uppermost Strathmore Group consists of sandstones and siltstones, some notably red, interspersed with fans of conglomerate, where large Devonian river systems drained the embryonic Highlands.

A suite of east–west-trending quartz-dolerite dykes of latest Carboniferous age occur throughout the district, though they are most abundant in the southern part. The dykes are typically wider than an earlier felsite to lamprophyre suite of Siluro-Devonian age, and large blocks are commonly found as erratics close to these dykes.

Mesozoic

Mesozoic sedimentary rocks are widely preserved offshore and reflect the stability of the land masses in the East Grampians and adjacent sea areas since Permian times. Permian and Triassic rocks are preserved only in the extreme north-west of the district, in a strip from Burghead to Lossiemouth. The Upper Permian to Lower Triassic Cutties Hillock and Hopeman sandstones comprise aeolian sandstones with large-scale dune-bedding and sparse fluviatile deposits. The overlying fluviatile sandstones and conglomerates of the Burghead Beds are succeeded by the Upper Triassic Lossiemouth Sandstone, which is also of aeolian origin. This grades upwards into the Stotfield Cherty Rock, a calcrete-dominated sandstone with chert concretions. Jurassic rocks have been proved at depth near Lossiemouth. They consist of basal calcareous mudstones (or marls) overlain by a rhythmic sequence of sandstones, siltstones and mudstones, and succeeded by coarse-grained, kaolinitic sandstones. A hitherto unknown outlier of Lower Cretaceous glauconitic sandstone has been found recently on the Moss of Cruden (Hall and Jarvis, 1994). No Upper Cretaceous rocks are known in north-east Scotland, but evidence of a Late Cretaceous transgression is given by the presence of nodular flints at the base of the Buchan Ridge Gravel Member, which contains abundant flint pebbles yielding Cretaceous fossils.

A thick and more complete succession of Mesozoic rocks occupies the Moray Firth basin. Triassic sandstones rest unconformably on sandstones and conglomerates of the Old Red Sandstone and are overlain by sandstones, black shaly mudstones and siltstones of Early Jurassic to Early Cretaceous age. The Lower Cretaceous rocks also include glauconitic and calcareous sandstones. Upper Cretaceous chalk and calcareous mudstones crop out on the sea bed at the eastern end of the Moray Firth and parallel to the North Sea coast some 15 km offshore from Peterhead.

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