THE GEOLOGY AND LANDSCAPE OF MORAY

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SOLID GEOLOGY

Introduction

The geology of Moray consists of an ancient basement of metamorphic rocks, the Moine Schist and Dalradian Schist, intruded by a series of granitic igneous rocks belonging to the Caledonian episode of mountain building, then unconformably overlain by Old Red Sandstone sediments of the Devonian Period. Younger sediments, Permo-Triassic and Jurassic, are found along the coast, with Cretaceous rocks found only as ice-carried boulders.

The main structure-forming event to affect the area was the Caledonian Orogeny, around 500 million years ago, which caused folding and metamorphism of the older rocks. Molten granite magma was forced into these folded basement rocks and contributed to the elevation of the area as part of the Grampian mountains — a component of the Caledonian fold mountain chain which stretches from northern Norway through Shetland, then on via Scotland to Ireland and Wales. The last event in the Caledonian Orogeny was the formation of a fault system that includes the Great Glen Fault which runs parallel to the coastline of Cromarty and continues seaward into the Moray Firth.

Moine rocks

In Moray, the oldest rocks are referred to as the Moine Schists, which form the high ground in the south and west of the district. This group of crystalline rocks forming the basement is made of quartzite, schist and gneiss. Originally the rocks were laid down as sandy, pebbly or gritty sediments with thin muds and shales, probably in shallow water, carried down by rivers and deposited in a shallow sea. High pressure and temperature effects during folding converted these sediments into metamorphic rocks — quartzite and mica schist.

The Moine rocks of the area lying to the south-east of the Great Glen Fault are divided into two major units, an older Central Highland Division and a younger Grampian Division, the junction between the two being a zone of intense shearing known as the Grampian Slide (Fig.1.1). The Central Highland Division is found between Inverness, Forres and Aviemore. Mostly the rocks are coarse-grained quartz-rich gneisses, interbanded with belts of quartzite and mica schist. Schists forming the Streens of Findhorn were previously considered to be Dalradian but are now regarded as Moinian. The gneisses suffered high-pressure, high-temperature metamorphism and were involved in a long complex history of folding and partial melting. The Grampian Slide which separates the older

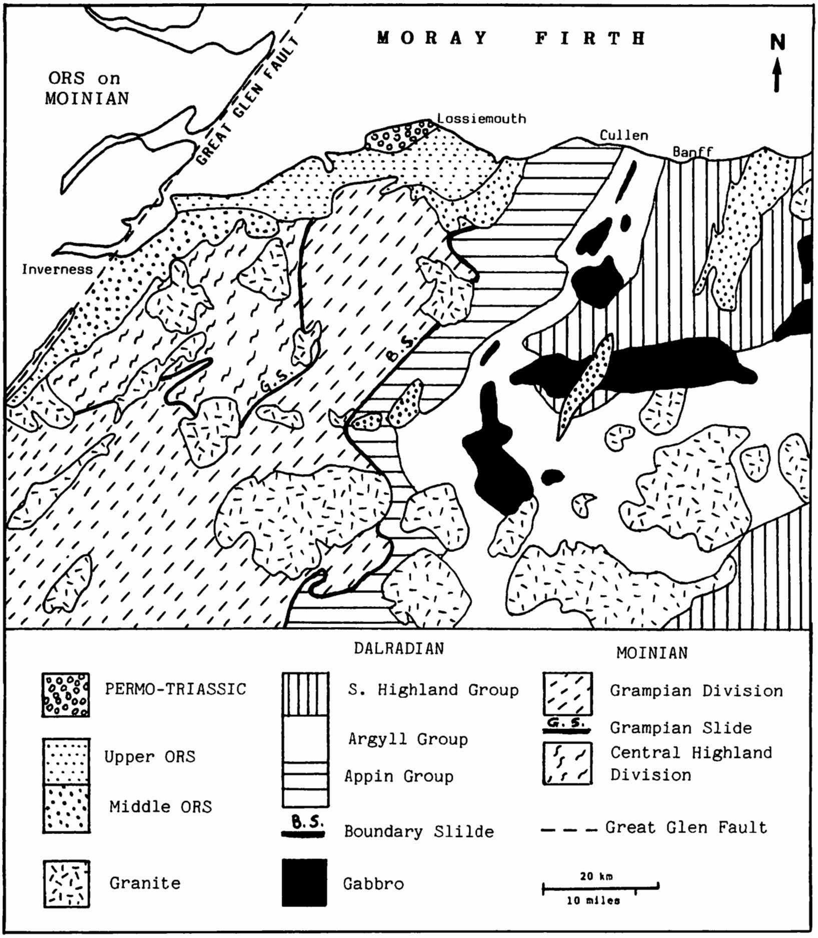

Fig.1.1 Geological map of Moray and adjacent areas.

rocks from the overlying younger Grampian Division stretches from south of Forres to Lochindorb, Grantown and Aviemore. Rocks of the Grampian Division are mostly quartz-rich metamorphosed sediments, originally sandstone with subordinate shale and limey mudstone, deposited in shallow-water marine conditions. They are finer-grained, less metamorphosed and less deformed than the rocks of the older Central Highland Division and contain fairly common sedimentary structures.

Complexities in the fold history and metamorphism of the Moine rocks make it difficult to unravel their geological history, although some radio-

Groups	Subgroups	Formations	Rock types
Southern highland (600 m.y.)		Macduff Slates Boyndie Bay group U. Whitehills group	slate, greywacke schist, greywacke schist, grit
Argyll (650 m.y.)	Tayvallich	L. Whitehills group Boyne Limestone	calc flags, schist, grit limestone, mica schist
	Crinan	Cowhythe Gneiss	biotite gneiss
	Easdale	Portsoy group	schist, limestone, quartzite
	Islay	Durnhill Quartzite	quartzite, mica schist
Appin (> 700 m.y.)	Blair Atholl	Sandend group Garron Point group	limestone, mica schist schist
	Ballachulish	Crathie Point group Findlater Flags	calc-biotite flags micaceous flags
	Lochaber	West Sands group Cullen Quartzite	garnet-mica schist quartzite

Grampian Division of the Moines (> 750 m.y.)

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Central Highland Division of the Moines (1000 m.y.)

Fig.1.2 Dalradian stratigraphy of the Moray-Buchan area.

metric dates are available.[1] The age of the deformation and metamorphism of the Central Highland Division is around 1000 million years, implying that the original sediments must be somewhat older than this. Pegmatites in the Grampian Slide zone yield an age of 780-730 m.y. (million years). The younger Grampian Division shows no evidence of any events at 1000 m.y. and would therefore appear to have been deposited in the interval 1000-750 m.y. Near Tomintoul the Grampian Division passes up into the base of the younger Dalradian rocks without a break.[2] Central Highland Division rocks were affected by the Grenville mountain-building event (or orogeny) at around 1000 m.y. ago.

Dalradian rocks

Dalradian rocks account for the most extensive outcrops in the district. Technically they are referred to as the Dalradian Supergroup, which is divided into three Groups and a number of Formations (Fig.1.2). The rocks, which form part of the Caledonian mountain chain, were laid down in shallow seas around 700-600 million years ago and deformed in the period 530-440 m.y. ago. Igneous activity in the orogenic belt is marked by gabbro intrusions at 490 m.y. ago and granites at around 410 m.y. ago. Dalradian rocks form an enormously thick pile of sediments (at least 10 — 15 km, possibly up to 25 km thick: but this is the total thickness and does not imply that this amount of sediment was ever deposited at one particular place), the oldest found around Cullen, then progressively younger rocks eastwards from Portsoy to Banff and Fraserburgh. Most, if not all, the Dalradian rocks were deposited in Precambrian times. Sedimentation evolved as a progression from shallow water marine sands, deposited in a stable slowly subsiding shelf, to deep water muds, deposited by turbulent submarine mud flows set off by earthquake shocks in an area that was by now unstable and sinking rapidly. Faulting was taking place while sediments were being laid down, the result being a series of adjacent fault-bounded basins, each with its own separate thick pile of sediments.

The Grampian or early Caledonian Orogeny

The Grampian Orogeny is a term used to describe a related sequence of events that affected Dalradian and Moinian rocks during the period 550-475 million years ago. Original sediments were folded, flattened, stretched, sheared, heated and metamorphosed to produce schist, gneiss, quartzite and marble. Later they were intruded by granites and affected by overthrusting and faulting, then uplifted to form the long, narrow, slightly sinuous Caledonian mountain chain. Relatively high-grade metamorphic rocks are found on the coast from Portsoy eastwards. It has been suggested that the intrusion of large bodies of gabbro, such as the Portsoy, Huntly, Cabrach, and Insch masses during the peak of folding brought in sufficient extra heat to produce these unusual high-grade rocks. These gabbros are around 500 million years old and were forced into the rocks during the third fold episode (out of four). Shortly afterwards, the gabbro bodies were sheared and disrupted; there is ample evidence for this around Portsoy (Fig.1.3).[3]

Grampian region is well-known for its abundant granites, many of which lie in or on the boundaries of Moray (Fig.1.4). The granites are Silurian to Devonian in age (404-415 m.y. old) and were intruded into the Caledonian mountains after the main folding and metamorphism of the Dalradian rocks. Two groups of granites are recognised, an older suite that includes Moy, Ardclach, Grantown and Ben Rinnes, and a younger group that includes Findhorn (Tomatin), Monadhliath, Cairngorm and Glen Gairn.

Modern views on the origin of the Caledonian mountain chain, developed in the last few years, are based on the recognition of the importance of large faults with a left-handed slip movement, such as the Great

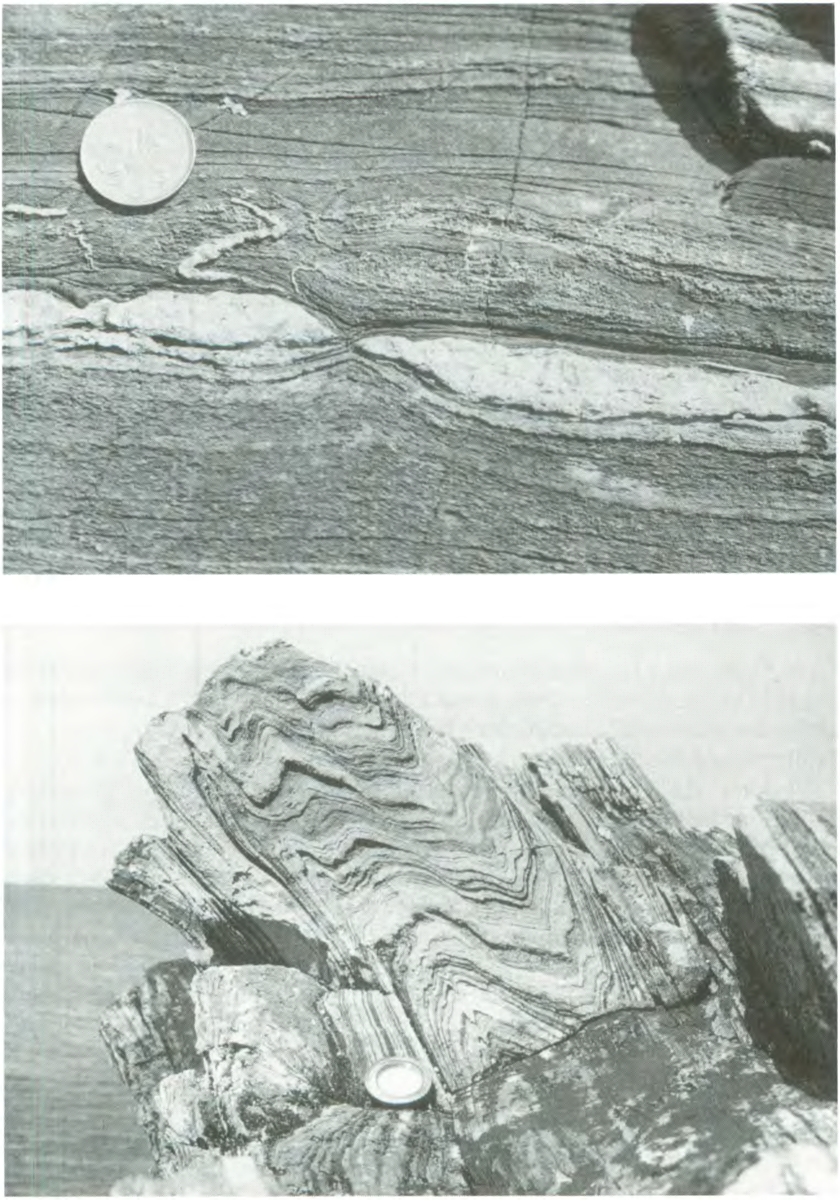

Fig.1.3 Deformation structures in the Dalradian. (a) Pull-apart structure (boudinage): white marble stretched in weaker impure limestone, Sandend; (b) fold in impure limestone, Portsoy.

Fig.1.4 Cairngorm granite plateau; Moinian in foreground.

Glen Fault and Highland Boundary Fault. Between these major faults lie segments of continental crust termed 'terranes' which may have formed in quite distant locations and were brought together by slipping along the faults during the early Devonian around 410 m.y. ago.[4]

Between the Great Glen Fault (GGF) and the Highland Boundary Fault lies the Grampian terrane consisting of Dalradian rocks which were compressed during the Grampian Orogeny (500 m.y. ago), then uplifted between 460 and 410 m.y. ago. Prior to 500 m.y. ago, the Northern Highlands terrane was probably remote from the Grampian terrane. The two blocks were then brought together at 460-410 m.y. ago, and any older units that originally lay between the two terranes were over-ridden. There is evidence of several unassigned units along the length of the Great Glen. The boundary between the two terranes must lie partly along the Fault (Fig.1.7).

Old Red Sandstone

Old Red Sandstone rocks were deposited as thick continental sediments at the end of the Caledonian Orogeny. Rapid uplift of the mountain chain was matched by equally rapid river erosion. The sediments were spread out in river valleys at the foot of the young high mountains and some merged into lake deposits of the inland Orcadian basin which encompassed Shetland, Orkney, Caithness and the Moray Firth. When these rocks were

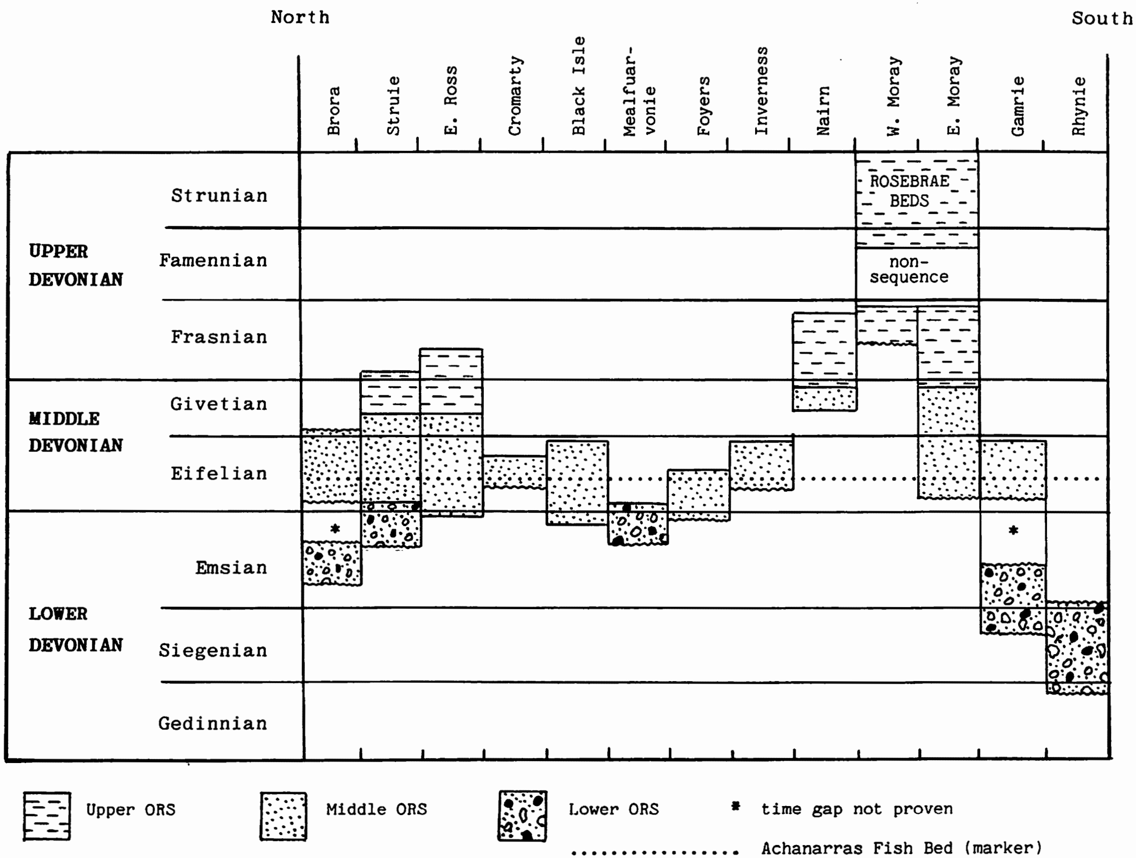

Fig.1.5 Devonian and Old Red Sandstone around the Moray Firth. ORS sub-divisions do not coincide with Devonian time divisions. Based on Rogers et al. 1989.

forming 360-400 m.y. ago, Scotland lay in the centre of a large continent consisting of Britain, Scandinavia and North America. The latitude of the Orcádian basin then was around 20° south of the equator and the climate was semi-arid.

The sediments were deposited in alluvial fans, rivers and lakes, unconformably on top of an eroded landscape of Moine and Dalradian rocks surrounding the Orcadian basin. Alluvial fans built out from high uplands to the NW and S, producing thick, coarse conglomerate sequences. Cross-bedded sandstones were produced by rivers flowing across the alluvial plains.

Lower Old Red Sandstone (ORS) sediments occur in a number of isolated outliers at Aberdeen, Tomintoul, Rhynie, Cabrach and Turriff (Fig.1.7). The Rhynie outcrop is famous for its fossil chert, a silicified peat deposit containing perfectly preserved primitive land plants and the earliest known insects. Deposition in this area was mainly in alluvial fans or temporary lakes. Coarse breccias and conglomerates occur at the base of the Lower ORS, containing pebbles and boulders of Dalradian rocks.

The Middle Old Red Sandstone crops out extensively between Rothes and Buckie, and as small outliers SW of Elgin. The Middle ORS of the Orcadian Basin varies from being mainly cyclic lake deposits in Caithness, to mainly river sediments south of the Moray Firth. Fossil fish beds occur at Gamrie and Fochabers (the Tynet Burn), which probably represent an interruption of river sedimentation by an unusually large extension of the Orcadian lake.[5]

A considerable thickness of Upper ORS overlies the Middle ORS around Elgin and Rothes. The sequence consists of grey and red cross-bedded sandstone with thin conglomerate, subordinate mudstone and several fish beds (Fig.1.5). These sediments are the deposits of northward flowing braided streams and meandering rivers which drained into a basin to the north of the Moray Firth. In the west of the region, the highest unit, the Rosebrae Beds, oversteps older formations and rests directly on Grampian Group Moine rocks. The top of the Rosebrae Beds could possibly be as young as lowermost Carboniferous (i.e. around 355 m.y. old).

The term 'Old Red Sandstone' is used in the sense of a description of rock types, rather than rock ages. In fact, the ORS was deposited mostly during the Devonian period, but Lower, Middle and Upper ORS do not correspond to the divisions of Lower, Middle and Upper Devonian time. An important rock unit used to date rocks is the Achanarras Fish Bed. The fish bed at Tynet Burn near Fochabers belongs to this same marker horizon and has yielded many examples of fossil fish in the past (Fig.1.6).

Great Glen Fault

Although Moray is rather far to the east of the Great Glen, the Fault has had such a profound effect on the shaping of the Moray Firth that a few

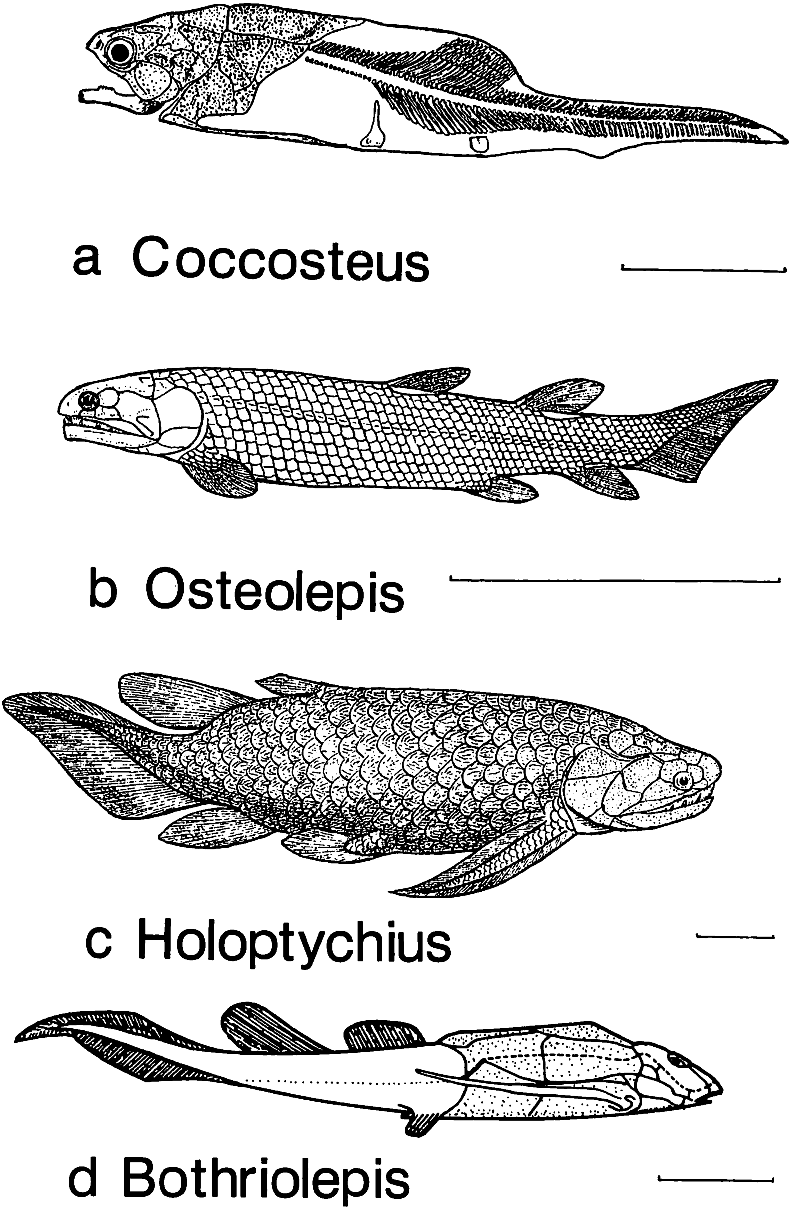

Fig.1.6 *Fossil fish reconstructions; Old Red Sandstone of the Moray Firth basin. Scale bar = 50 mm.*

words on the origin and history of the Fault will not appear out of place here. The GGF can be traced offshore from Mull through the Great Glen and north towards Shetland, where the Walls Boundary Fault is probably a splay off the GGF. The GGF has controlled the shape of the Black Isle and Tarbat Ness peninsula coastlines. Much controversy has surrounded the magnitude, age and direction of movements on the GGF.[6] The fault initiated as a late-Caledonian vertical structure, with around 80 km (50 miles) left-handed slip taking place before the start of Lower ORS deposition. Post-ORS lateral movements were right-handed in sense and 25-29 km (15-17 miles) in direction (Fig.1.7). During the Mesozoic, the GGF

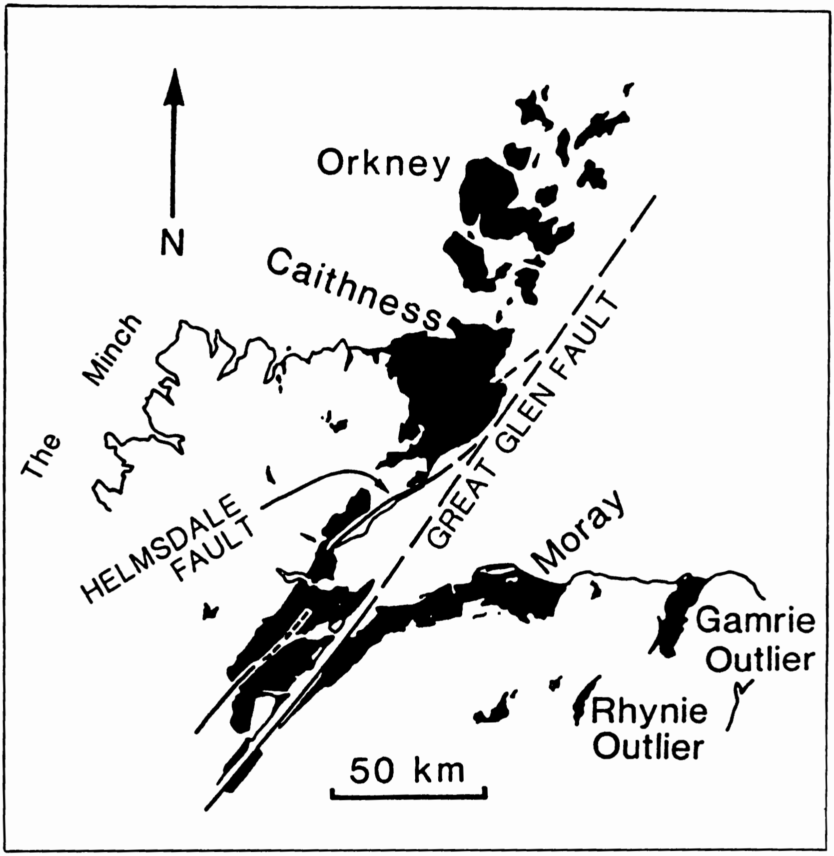

Fig.1.7 Original configuration of ORS rocks in the Orcadian basin, i.e. movements on GGF restored. After Rogers et al. 1989.

became reactivated as a vertical fault with downthrow to the SE. Fault movements during sedimentation allowed great thicknesses of sand and shale to be deposited in the Moray Firth basin.

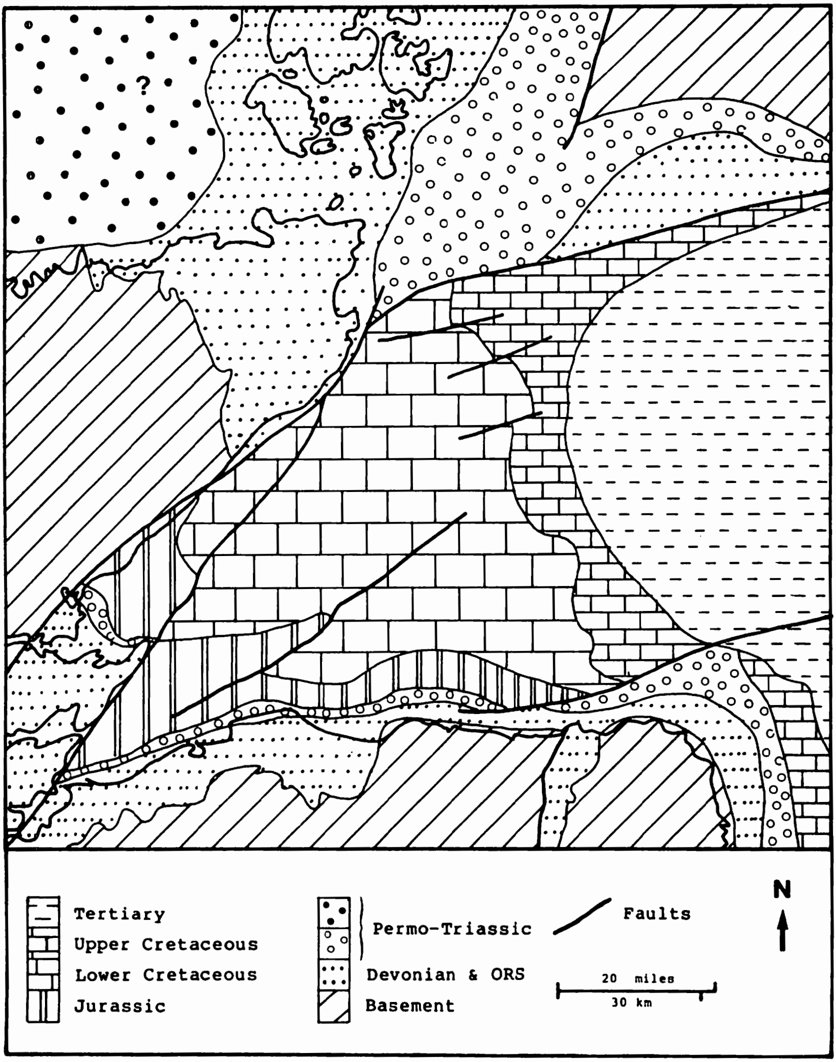

Fig.1.8 Offshore geology of the Moray Firth.

Permian and Mesozoic Rocks

Narrow outcrops of Permian, Triassic and Jurassic rocks occur along the Moray Firth shores, from Burghead and Hopeman to Elgin and Lossiemouth. Much greater thicknesses are found in the Moray Firth Basin and northern North Sea (Fig.1.8) and are the source of the oil and gas deposits.

Permo-Triassic ('New Red Sandstone') sediments are unconformable on or faulted against Old Red Sandstone, and like the latter they consist of red beds where the colouration is due to iron oxide (haematite) in the cement around quartz sand grains. The red beds are mainly continental in origin and contain few fossils, apart from the famous reptile skeletons and footprints near Elgin and Hopeman (Fig.1.9). The oldest formation onshore is the Hopeman Sandstone, consisting of dune-bedded desert sandstones containing wind-faceted pebbles. It is unconformable on the ORS, but the two rocks look so similar that they were mistaken at first until reptile finds proved a late Permian or Triassic age. The overlying Burghead Beds are unfossiliferous Middle Triassic yellow, cross-bedded river deposits (Fig.1.10). Above lies the third unit of the New Red Sandstone, the Late Triassic Lossiemouth Sandstone, Sago Pudding Stone and Cherty Rock. The aeolian (wind-blown) Lossiemouth Sandstone contains a reptilian fauna.[7] Fossils from Moray are well displayed in the Elgin museum.

Older rocks are found offshore: the Early Permian Rotliegendes, consisting of 500 m (1800 ft) of fluvial and aeolian sandstones, mudstones and evaporites, and the overlying Late Permian Zechstein Group — 1500 m (4900 ft) of marine carbonates and evaporites. Oil has been found in these Permian rocks, principally in the Zechstein carbonates. The Permo-Triassic sandstones offshore are 300-500 m (1000-1800 ft) thick SE of the Great Glen Fault. They are unconformable on the ORS and are themselves unconformably overlain by Jurassic rocks. A very narrow outcrop of Lower Jurassic is found at Lossiemouth.[8] Much thicker Triassic deposits are found farther out into the North Sea in the Northern Viking Graben and Central North Sea (Fig.1.8), where the sequence is over 1000m (3300 ft) thick.

Upper Jurassic Kimmeridgian black bituminous organic shales and mudstones are widely distributed in the North Sea and are generally thought to be the source rock of the oil. Similar rocks occur onshore in Sutherland, between Brora and Helmsdale. Most of the oil and gas deposits have been found in fault-bounded basin structures called grabens (German *Grabe* = 'grave'). Reservoir rocks are sandstones of Jurassic to Tertiary age, or Zechstein (Upper Permian) carbonates.

Solid outcrops of Cretaceous rocks are absent from North-east Scotland, but fairly large ice-carried erratics brought inland from the North Sea floor are found near Fraserburgh. Upper Cretaceous rocks occur everywhere in

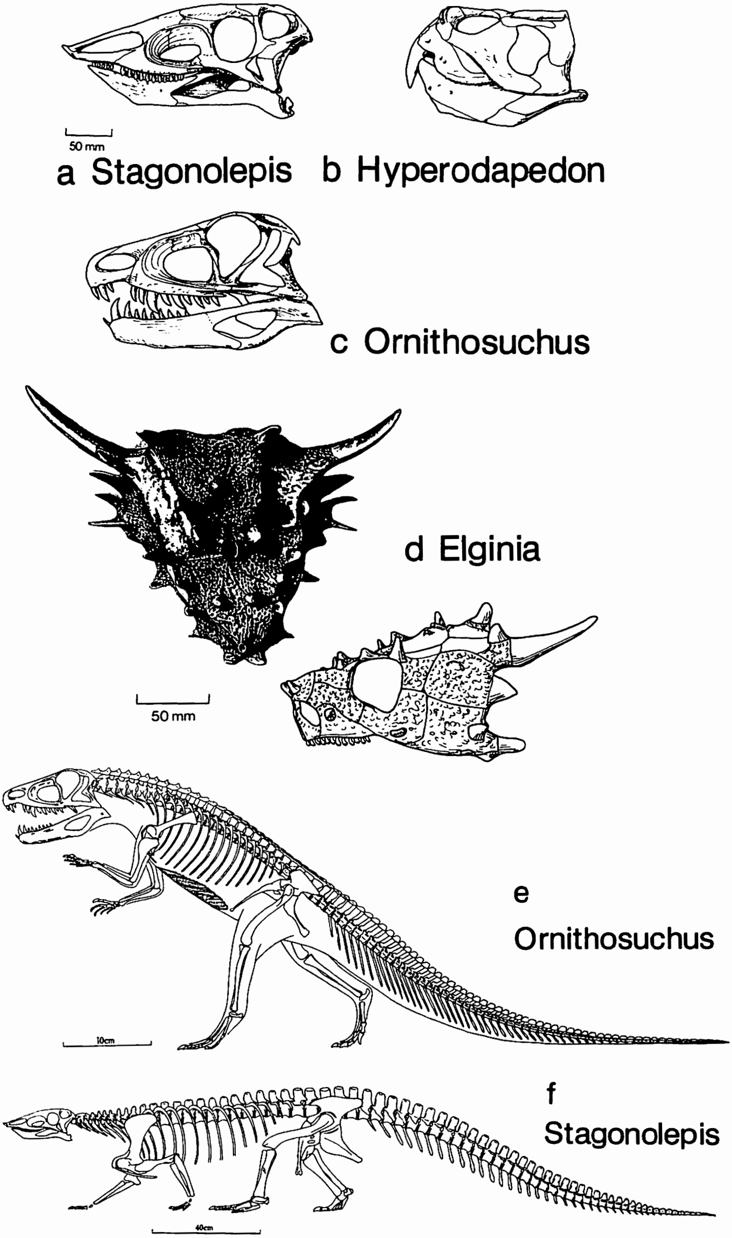

Fig.1.9 The Elgin reptiles. (a)–(d) reconstructed skulls, (e)–(f) reconstructed skeletons. After Benton 1977 and Benton & Walker 1985.

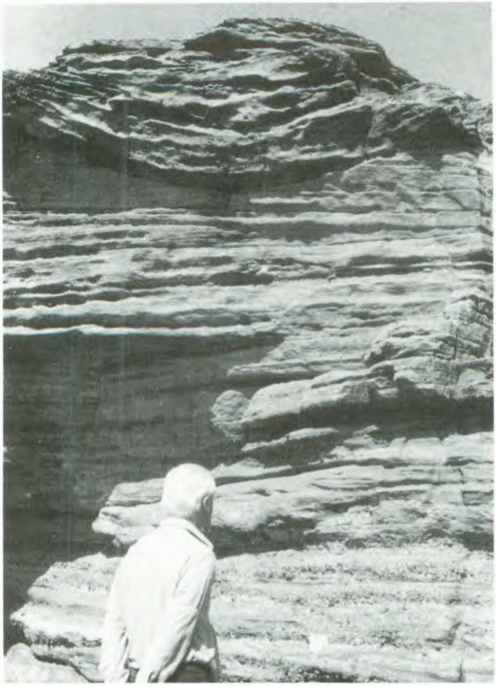

Fig.1.10 River channel in cross-bedded Burghead Beds, Burghead.

the North Sea (Fig.1.8), including 1400 m (4600 ft) of chalk in the Central Graben, gradually giving way to shales in the northern Viking Graben.[9]

During the Early Permian (about 275 m.y. ago), the Moray Firth was at about 15° north of the equator at a time of widespread desert conditions throughout Europe. The area around the Moray Firth was a low-lying basin containing sand dune fields and wadi deposits of intermittent torrential rivers, surrounded by the arid uplands of the Grampian mountains. In the Late Permian, the edge of the Zechstein Sea was close to the present shoreline of the Moray Firth. Great thicknesses of halite (salt from evaporating sea water) accumulated in parts of the basin.

In the Early Triassic the lowlands around the Moray Firth were being filled with evaporites and sands from the uplands, while the North Sea was occupied by shallow lakes. In Late Triassic to Early Jurassic times a shallow tropical sea transgressed into the Moray Firth area.[10] By the end of the Triassic, relief was greatly subdued and erosion and deposition had almost ceased. Rejuvenation in the Jurassic led to the deposition of deltaic and estuarine sediments in the Moray Firth. Major flooding by the sea took place in the Upper Jurassic and again in the Upper Cretaceous, the latter representing an important world-wide rise of sea level.[11]

Structure of the Moray Firth and Northern North Sea

The northern North Sea is dominated by graben structures, indicating stretching of the basin, with subsiding fault blocks rotating along curved faults, steep at the surface and shallowing at depth. Slip on these faults occurred in distinct episodes, during the Triassic, Late Jurassic and Early Cretaceous, with sedimentation continuing to fill the basins. The Inner Moray Firth basin contains over 3000 m (10,000 ft) of Jurassic and Lower Cretaceous sediments in the vicinity of the Great Glen Fault.[12]

LANDSCAPE DEVELOPMENT

Tertiary erosion

During Tertiary times, 65-2 million years ago, the North Sea was again a major sedimentary basin which received over 3000 m (10,000 ft) of sands, shales, mudstones and volcanic ash in the most rapidly subsiding part. In the early Tertiary, some 65-50 million years ago, the Hebridean volcanic

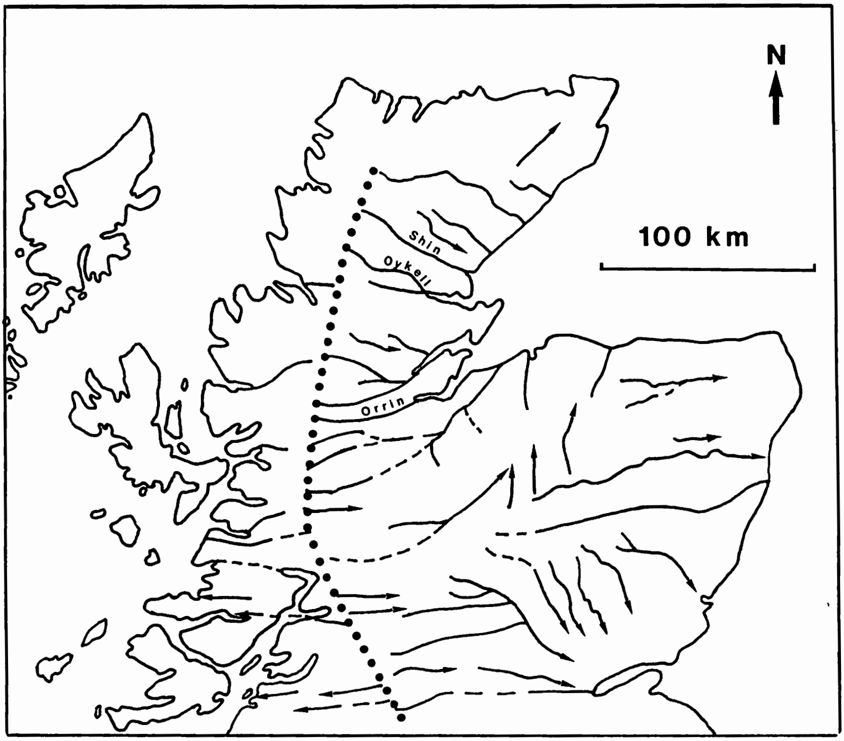

Fig.1.11 Original drainage pattern and watershed of northern Scotland, established in Tertiary times, 50 m.y. ago.

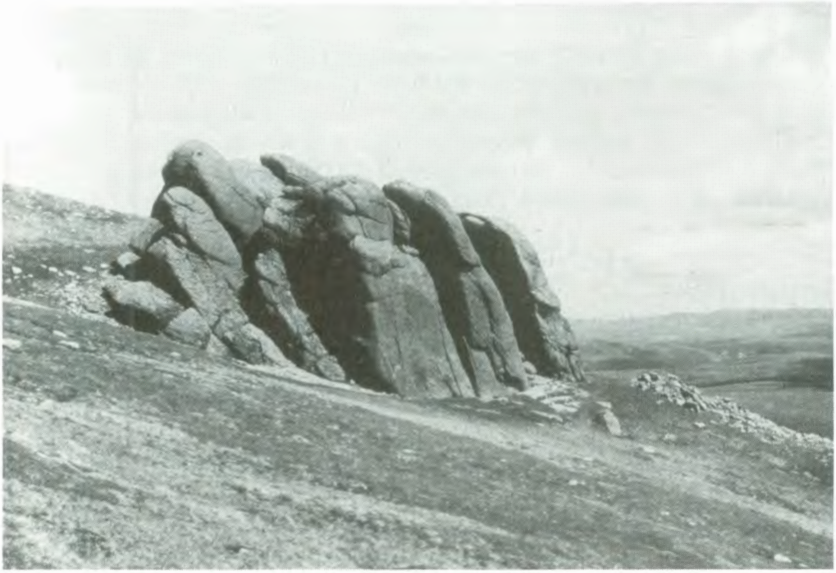

Fig.1.12 Granite tors on Ben Avon.

province was being formed, with the intrusion of central complexes in Skye, Rum, Ardnamurchan, Mull and Arran. The west coast was uplifted by over 1500 m (4900 ft) and an easterly-dipping slope was established over northern Scotland. It was at this time that the main river pattern became established and great volumes of rock were stripped off the Highlands by east-flowing streams and deposited in the North Sea basin (Fig.1.11). During the Tertiary, the climate was warm and humid, with weathering effects penetrating deep beneath the land surface. Granite tors are a remnant of this weathering (Fig.1.12).

Quaternary Glaciation

Climatic conditions in northern Europe deteriorated rapidly at the end of the Tertiary, plunging Scotland into a glacial epoch about two million years ago, at the start of the Pleistocene. The great ice age was characterised by numerous fluctuations from glacial to mild climatic episodes, with the last ice disappearing around 12,000 years ago. Sugden notes that North Sea glacial sediments indicate the presence of an ice sheet 700,000 years ago, but that evidence of earlier glaciers has now been destroyed.[13] The ice age consisted of the cyclic build-up and wastage of glaciers every 100,000 years, separated by warmer interglacials lasting 10,000 years. The centre of the ice sheet was near Rannoch Moor and it was 1800 m (nearly 6,000 ft) high over the Cairngorms. Ice moved down Tertiary river valleys, such as the Spey, taking ice into the Moray Firth. The blue-grey drift, though, indicates onshore movement of ice from the Moray Firth area. The ice sheet melted comparatively rapidly, with most of Scotland completely free of ice only 5,000 years after the glacial maximum. Consequently, vast volumes of meltwater carried great loads of sediment which had been trapped in the ice and contributed to erosional and depositional features that helped shape the landscape. Scratch marks (or glacial striae) are caused by pebbles embedded in the ice sheet causing grinding, polishing and scratching. Examples can be found in Quarry Wood, Elgin.

The Cairngorms and the Mounth were areas of extensive upland glacial erosion, as witnessed by corries, U-shaped valleys, smooth, rounded granite tops and glacial troughs, e.g. Loch Avon (Fig.1.4). Glacial deposits in the highland areas are represented by moraines and in lowland areas by water-laid deposits such as river terraces, lake deposits and sands and gravels of eskers and kames deposited from streams flowing beneath and around the edges of the ice sheet. Tills predominate around the east, deposited by ice moving SE from the Moray Firth.

In the Moray Firth, glacial drift up to 70 m (230 ft) occurs in five elongate E-W basins, parallel to the coast between Lossiemouth and Fraserburgh. The inland drift consists of till (boulders set in a matrix of sand or clay) and meltwater sands, especially in the wide Spey valley. Along the Moray coast there is the blue-grey drift, containing rock derived from the sea bed. The drift contains glacial tills, meltwater and lake deposits. Ice-margin features, such as ridges and mounds known as eskers and kames, are quite common east of Elgin. Terrace features are found in the Spey, Findhorn and Avon (Fig.1.13). The lower Spey may have been dammed by ice, so that a lake formed which was rapidly filled by fine sediments. Once the ice began to melt and retreat, the water level in the lake dropped and the river cut a series of terraces into the lake deposits.[14]

River system

The drainage of Moray is adequately covered by Sinclair Ross in *The Moray Book*.[15] In general we may say that the river system is controlled by the underlying geological structure and that most of the rivers occupy wide valleys relative to their streams.

This is an indication that the river system is very old, dating back to the Tertiary erosion event (Fig.1.11). Some general principles may be illustrated by reference to the Spey, Moray's largest river. The Spey rises in the southwest and its initial course is controlled by the NE-striking Ericht-Laidon fault which runs parallel to and is associated with the Great Glen Fault. Most of the tributaries of the Spey drain the extensive mountain country to the south of the river, consisting of granites intruded

Fig.1.13 Terrace features in the River Avon at Tomintoul.

into Moine rocks. Thus, large volumes of granite, gneiss and schist are transported, especially during sudden snowmelts or floods. Sediment has accumulated over a long time interval in the broad strath areas and wide rock basins; these alternate with narrow sections where rock gorges and rock bars have caused restrictions. In its wide floodplain, the middle Spey flows along a gentle gradient and the area is characterised by broad alluvial plains, marsh and open lochs. Downstream of the middle stretch, the Spey flows down a moderately steep bedrock channel in a NNE direction through the Pass of Sourden, near Rothes. On emerging on to the coastal plain, the river retains a moderate gradient. It cuts down 10 m (30 ft) into glacial outwash deposits and forms the most extensive braided river system in Britain. The Spey carries great quantities of coarse sediment into the river mouth and contributes to the growth of coastal spits in Spey Bay and to the accumulation of deltaic deposits just offshore.

Formation of the coast

The evolution of the coastline of Moray is controlled by the underlying geology and owes much to the interplay of glaciation, deglaciation and changes in sea level. The outer coast of the Moray Firth, extending eastwards from the Spey is dominated by rocky headlands and cliffs alternating with small bays and coves reflecting the changes in rock types of the

Dalradian succession. The schists and flags are almost vertical and strike at right angles to the coast. Variations in hardness and resistance to erosion are reflected in a series of promontories and bays or coves. Beaches are sheltered and thus quite stable.

During the ice age, the enormous weight of the ice sheet depressed the land surface. Once the ice began to melt, the weight was removed relatively rapidly and the land began to rise in a rebound fashion. Periodic uplift caused a relative fall in sea level, with the level of each pulse of uplift being reflected in a sequence of raised shorelines. In the early post-glacial period, sea level rose worldwide as a result of the melting of the Arctic ice sheets. Around 6,500 years ago, this rise was at a maximum and caused flooding around the Moray Firth. Coastal peat and woodlands were drowned and a narrow post-glacial coastal plain formed.[16] Sea level has remained essentially constant for the last 3,000 years.[17]

Evidence for these former sea levels can be seen in raised beaches backed by cliffs along much of the outer Moray Firth coast. Caves, arches and stacks now sit well back from the previous waterline. The middle coastline[17] stretches from Ardersier to the Spey and is dominated by sand and shingle forelands and raised beaches. The outline of the coast here is fairly smooth and there is considerable sediment drift westwards parallel to the shore. Rivers such as the Spey and Findhorn are and have been important in helping to shape the coastline. Both rivers contribute substantial amounts of sediment and their channels have migrated westwards. There are long sections of coast with rapidly extending spits, bars and dunes.[18] The Culbin area is well known for its dune system, built on the shingle bars and ridges of an old storm beach, and now protected by afforestation.

The Loch of Spynie was once an arm of the sea, resulting from flooding of the coastal area in post-glacial times. Ships were once able to navigate the Lossie as far as Spynie. The loch seems to have been cut off from the sea during the period 1380-1450 AD by sediment deposition by the Lossie. The loch grew in area behind its dam; a canal was dug in 1810 but final draining did not occur until 1880.

Soils

Arguably the most important soil in the district is that of the Laich of Moray. The Moray Firth lowlands contain yellow and pale red Old Red Sandstone and some light yellow New Red Sandstone (Permo-Triassic) with a drift cover of reddish brown sandy loam. Dominant soils are podzols derived from acid parents — schist, quartzite and granite — with a coarse texture and free drainage. Fluvioglacial, raised beach and alluvial soils are very rich in sands, which are liable to wind erosion.

Fig.1.14 Reconstructed crushing mill and old spoil heaps at the Lecht iron and manganese mine.

ECONOMIC GEOLOGY

Middle Dalradian rocks around the Lecht area contain strata-bound deposits of iron and manganese.[19] Iron ore was first mined in 1730 and transported to Nethybridge for smelting, using charcoal derived from the Speyside forests. The venture was unprofitable and the mine closed in 1737, but re-opened in 1841, this time for its manganese. At one time, 65 workers were employed and there were fairly extensive workings including adits, an 85-foot deep shaft and 60-foot deep pits.[20] The crushing mill has been reconstructed (Fig.1.14). The ore was crushed then hand-picked and taken to Portgordon before being shipped to Newcastle for use in bleaches. Cheaper Russian imports caused a price collapse and the mine closed in 1846. Reconnaissance work by the Geological Survey led to the conclusion that the area has around a quarter of a million tonnes of 7% manganese oxide.[21] The Middle Dalradian has the potential for base metal exploration in the future.

Some other potentially useful minerals have been reported.[22] These include fluorite in the Hopeman Sandstone and baryte which cements some of the sandstone at Covesea and is found along joint surfaces at Lossiemouth. The Stotfield Cherty Rock has galena, hematite, fluorite, baryte, calcite and quartz mineralization associated with it. Galena (lead sulphide) was once worked at Stotfield around 1880, but attempts proved unsuccessful.

Building stones in the district include the New Red Sandstone and Old Red Sandstone. The Hopeman Sandstone (NRS) was particularly prized for its colour and toughness. Locally, Moine and Dalradian schist have been used for building materials, for roadstone, paving and, formerly, roofing slates. Glacial sands and gravels are another important source of construction materials.

Limestone occurs in the Dalradian, and quarries once worked at Tomintoul, Keith and Dufftown. Impure limey 'cornstones' occur in the Lower ORS near Elgin, and these were once exploited as local sources of agricultural lime, together with Triassic cherty limestone at Inverugie. Large blocks of Jurassic rock, carried in by the ice, were exploited to destruction.

Period	Age (m.y.)	Major geological events
Recent	0.01	Uplift; raised beaches; modern rivers; coastal landforms
Quaternary	1–2	Ice Age: erosion in uplands, sands, gravels and drift deposited in valleys
Tertiary	60–65	Deep erosion; rivers established; deposition in North Sea
Cretaceous	144	Warm tropical sea in area of North Sea; subdued relief on land
Jurassic	213	Shallow tropical sea, fine sediments laid down in North Sea grabens; oil and gas source rocks
Triassic	248	New Red Sandstone desert deposits, rivers, salt evaporites; reptiles
Permian	286	
Carboniferous	360	No sediments: area above sea level
Devonian	408	Old Red Sandstone deposition in lakes and fans on slopes of young, high Caledonian mountains; fish in lakes. Great Glen Fault. Granites
Silurian	438	Folding, metamorphism, Grampian Orogeny;
Ordovician	505	intrusion of gabbro, thrusting, uplift
Cambrian	590	(Top of Dalradian could be Cambrian in age)
Vendian	670	Dalradian sedimentation in fault-bounded basins, rapid subsidence, crustal stretching
Riphean		Grampian Division Moine deposited
(Precambrian)	1000	Central Highland Division Moine deposited; then deformed in Grenville Orogeny

Fig.1.15 Geological History of Moray

There are fairly extensive deposits of brick clay of marine origin in the Spynie basin, also at Cullen and Craigellachie. Peat is found in higher areas of the district, but it is no longer an important fuel, although it does still have its use in the whisky distilling industry.

The North Sea oil and gas deposits are an asset of considerable importance and are likely to last beyond the end of the century. Deposits are found in association with graben-type structures in the Jurassic Kimmeridge Clay. Oil occurs in traps beneath shales of Jurassic to Tertiary age, while gas is usually restricted to the Lower Tertiary. Reservoir rocks are usually Jurassic sandstones, like the Hopeman Sandstone. Fig.1.15 summarises the geological development of Moray.

Notes

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