Permian, Triassic and Jurassic, Grampian Highlands

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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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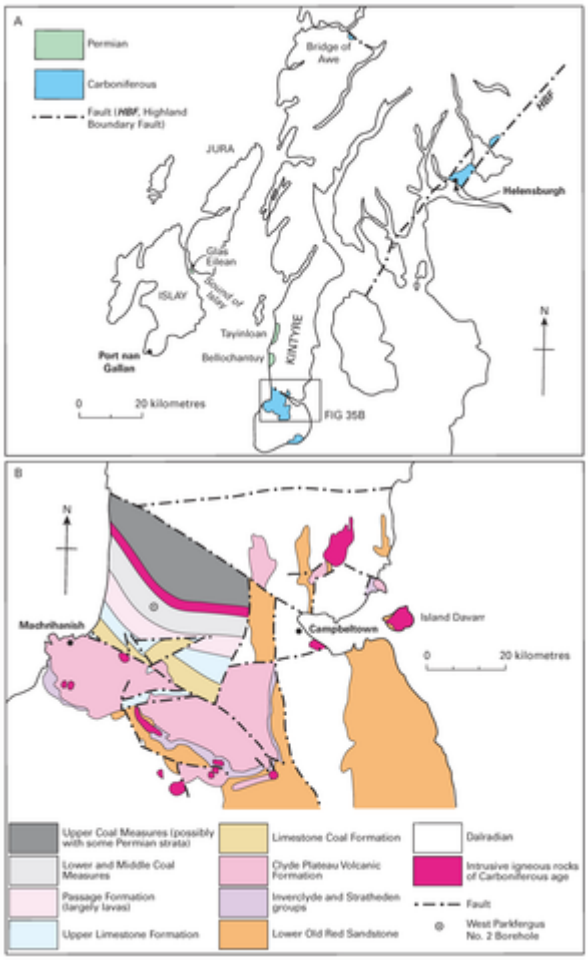
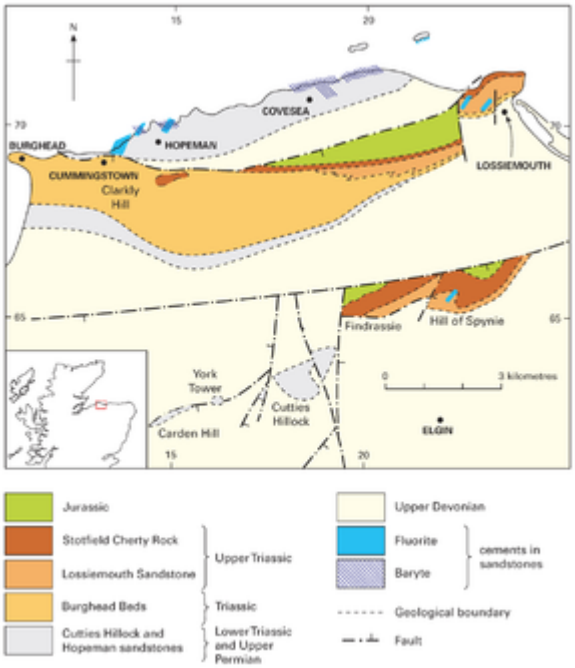


A Carboniferous and Permian rocks of the South-west Highlands. B Carboniferous rocks of southern Kintyre. P915443.



Permian and Triassic rocks of the Lossiemouth–Elgin area. P915445.

Islay and Kintyre

Offshore-shelf studies along the western seaboard of Scotland have shown that rocks of Permo-Triassic age occur in the Rathlin Basin, extending as far north as the southern end of Jura (McLean and Deegan, 1978; Evans et al., 1979), and in the Arran Basin, with possibly a 1400 m succession preserved onshore on the Isle of Arran (see Warrington et al., 1980 for summary of literature). Although the submarine outcrops are extensive, onshore exposures in the South-west Highlands are very limited.

A 120 m Permian succession is exposed on Glas Eilean and Black Rock, low-lying islands in the Sound of Islay, 5 km south of Port Askaig (P915443A; Pringle, 1944; Upton et al., 1987). The succession dips WSW and is bounded to the west by a fault. The basal 6 m consist of conglomerate, made up of rounded to subangular clasts of Dalradian Jura Quartzite up to 30 cm in size, set in a gritty ferruginous matrix. The conglomerate is succeeded by 1 m of reddish brown fine-grained sandstone. The overlying lava succession is broken by two thin beds of flaggy sandstone and a bed of sandy limestone 0.3 m thick. The individual lava flows are each less than 2 m thick, blocky and with easily eroded slaggy tops. The flows are amygdaloidal with calcite filling the original vesicles. They were deposited subaerially, interrupting a period of shallow-water sedimentation. The lavas are alkali olivine-basalts with phenocrysts, mainly of olivine, but with minor plagioclase and augite. A few of the lower flows have microphenocrysts of Al-Cr spinel. A K/Ar age determination on one of the freshest lavas yielded an age of 285 ± 5 Ma (early Permian), virtually identical to the age of the Mauchline lavas in Ayrshire. At Port nan Gallan, one mile east of the Mull of Oa at the southern tip of Islay, there is a small outcrop of breccia composed of blocks of quartzite, limestone and schist, set in a matrix of bright red sandstone with well-rounded grains. It forms part of a sea stack and was first described by Peach (1907). It was recognised as Permo-Triassic by Pringle (1952) and forms a breccia infill within a vertical fissure cut in the Islay Limestone. A more extensive Permo-Triassic red sandstone cover, now eroded away, has left the underlying Dalradian quartzites on the Mull of Oa red-stained.

Along the western coast of Kintyre, soft, current-bedded, red sandstones and conglomerates form three large outcrops between Bellochantuy and Tayinloan ((P915443)A). They are well displayed in reefs between tide marks, and the basal beds are exposed in road sections at Bellochantuy and in stream sections east of the road, such as in Allt a Ghaoidh. These sections of the basal beds include coarse breccias with pebbles of vein-quartz, mica-schist and quartzite. Some pebbles show wind facetting and quartz grains in the sandstones are well rounded and polished. The exposures in the road sections at Bellochantuy show a steep and irregular junction with the Dalradian, probably indicating that the depositional basin was bounded by high land to the east (Pringle, 1952).

Moray Firth

Permian and Triassic sandstones are exposed north and west of Elgin and on the coast between Burghead and Lossiemouth (P915445); they are largely of aeolian origin and are the only onshore occurrences of the extensive Permo-Triassic basin deposits developed off the Moray Firth and Aberdeenshire coasts (Frostick et al., 1988; Andrews et al., 1990). The outcrop pattern in the Elgin area is controlled by two ENE-trending faults throwing down to the south. The sandstones have yielded fossil reptile remains, which have been studied by many palaeontologists (see A D Walker, 1961; 1964 and references therein). Watson (1904) and Watson and Hickling (1914) have shown that two distinct faunas are present. The lower fauna, in the Hopeman and Cutties Hillock sandstones is probably of latest Permian age and the upper fauna, in the Lossiemouth Sandstone, is late Triassic (Benton and Walker, 1985).

The succession in the Elgin area is (Peacock et al., 1968):

Stotfield Cherty Rock	Upper Triassic
Sandstones of Lossiemouth, Spynie, and Findrassie	Upper Triassic
Burghead Beds	Triassic
Cutties Hillock and Hopeman sandstones	Lower Triassic and Upper Permian

Cutties Hillock and Hopeman Sandstones

The Cutties Hillock Sandstone forms the highest part of the Quarry Wood ridge and occurs in isolated outcrops at York Tower and Carden Hill (P915445). It is a fine- to coarse-grained, yellow to brownish sandstone, commonly laminated, and varies from soft to hard and siliceous. The basal sandstone beds contain pebbles, some of which are thought to be wind etched (Mackie, 1901a), but Williams (1973) has shown that the sandstones more likely represent sheet-flood deposits. The overlying sandstones exhibit large-scale cross-bedding, have well-rounded quartz grains and are interpreted as having formed from wind-deposited barchan dunes. Fossil reptiles found just above the basal beds have been identified as a pareiasaur, *Elginia,* and two dicynodonts, *Geikia* and *Gordonia;* they were compared by Watson and Hickling (1914) to forms occurring at the Permian–Triassic boundary in Russia and in the Karoo of South Africa. More recently, Walker (1973) recognised the presence of a procolophonid in support of such a correlation. However, Benton and Walker (1985) have suggested that certain vertebrate tracks indicate a latest Permian age.

In the northern outcrop at Hopeman and Covesea, the basal beds are not exposed. Williams (1973) recognised four phases of aeolian deposition separated by periods of flooding, which are locally preserved as playa deposits. The oldest phase is made up of well-developed linear seif and star-shaped dunes (Clemensen, 1987); the succeeding phases are formed by crescentic barchan dunes. The seif deposits, exposed on the coast, were laid down by winds from the SSE on the edges of a sand sea with mountains to the south. The succeeding phases of barchan dune were deposited by winds blowing mainly from the north-east (Shotton, 1956). The sandstones interpreted as sheet-flood deposits and exposed in the Quarry Wood area are probably equivalent in age to the seif deposits.

The Hopeman Sandstone is up to 60 m thick in the Clarkly Borehole near Cummingstown, but thins eastwards, and is absent at Lossiemouth and Hill of Spynie. Contorted bedding in the Hopeman Sandstone is displayed in several exposures along the coast (Peacock, 1966). Williams (1973) has attributed the contortions to moistening or saturation of the sand during deposition of playa deposits, which were presumably subsequently removed by contemporaneous wind erosion. Glennie and Buller (1983), however, have suggested that the dune sands were moistened by a later Zechstein transgression, which caused partial homogenisation of the sand and created large-scale soft-sediment deformation structures. They also suggest that large pockets of air originally trapped within the dunes were later replaced by water, thus causing liquification of the original dune laminae and the disruption of structures.

The Hopeman Sandstone is in places cemented by fluorite, and patchy baryte mineralisation is well exposed in coastal sections north of Hopeman and Covesea (Mackie, 1901a).

Burghead Beds

The Burghead Beds are exposed around Burghead, where they reach a thickness of 60 m. They can be traced eastwards for some 6 km before passing laterally into the contemporaneous Lossiemouth Sandstone. They are unfossiliferous, and are interpreted as river-deposited, point-bar and floodplain deposits. The point-bar deposits were laid down in rivers of low sinuosity and high gradient and

consist of laminated sandy conglomerates overlain by trough cross-bedded sandstones interbedded with siltstones exhibiting both ripple marks and horizontal lamination. Good sections occur at the Burghead coastguard station and in a quarry at Clarkly Hill. The foresets in the cross-bedded sandstones show that the direction of current movement was from the WSW. Sandstones exposed farther east along the coast, and at Lossiemouth, were formed as flood-plain deposits.

Lossiemouth Sandstone

Aeolian sandstones of Upper Triassic age and partly equivalent in age to the Burghead Beds are exposed around Lossiemouth, and at Hill of Spynie and Findrassie. Their total thickness is less than 30 m. They are white, yellow and pink, fine- to coarse-grained sandstones that are siliceous at the top and calcareous towards the base. Joints within the sandstone commonly contain fluorite and baryte. Galena and fluorite are sporadic constituents of the sandstone matrix. The aeolian cross-bedding is generally obscured by silicification at the top of the sandstone, but is more pronounced in the lower cal-careous part.

The Lossiemouth Sandstone in all three localities has yielded reptile fossils, including *Brachyrhinodon taylori, Erpetosuchus granti, Hyperodapedon gordoni, Lep-topleuron lacertinum, Ornithosuchus longidens, Saltopus elginensis, Scleromochlus taylori* and *Stagonolepis robertsoni*, indicative of late Triassic age (Walker, 1961; 1964). Walker noted the complete articulation of the fossil remains, and concluded that they had been preserved in sediments laid down in their life environment. A more recent assessment of the Lossiemouth Sandstone fauna (Benton and Walker, 1985) has indicated the presence of a mixed assemblage of herbivores, carnivores and small omnivores.

The Lossiemouth Sandstone grades upwards into a coarse, silicified and calcareous sandstone named the *Sago Pudding Sandstone*, which reaches a thickness of 8 m and is characterised by large isolated quartz grains in a fine-grained matrix.

Stotfield Cherty Rock

At Lossiemouth and Hill of Spynie, the Lossiemouth Sandstone is overlain by a caliche horizon (Naylor et al., 1989), which consists of sandstone, veined and partly replaced by chert and limestone. The chert contains vugs filled with quartz, calcite and disseminated galena. The cherty rock was correlated by Judd (1873) with marly limestone and chert cropping out below the Lias at Golspie, thus establishing a connection with the sequence north of the Moray Firth.

Jurassic

The only known onshore rocks of undoubted Jurassic age in the Grampian Highlands region were proved in a Geological Survey borehole sunk in 1964 just south-west of Lossiemouth (Berridge and Ivimey-Cook, 1967). Approximately 70 m of the borehole section consists of basal calcareous mudstones and marls, overlain by a rhythmic sequence of sandstones, siltstones and fissile mudstones, succeeded by coarse-granular, kaolinitic sandstones. The overall lithofacies is similar to that of the Lias. Ammonites diagnostic of the *Echioceras raricostatum* Zone (uppermost Sinemurian) occurred about 28 m above the base of the hole together with bivalves. The underlying 17 m of mudstones, siltstones and sandstones contain *Euestheria* and are probably equivalent to the White Sandstone of Dunrobin, Sutherland (Neves and Selley, 1975). The environments of deposition varied from marine to non-marine and the oldest sediments (marl and cementstone) were probably deposited in a lagoonal environment of low salinity. This passed via an estuarine sequence (with *Euestheria)* into a fully marine environment (with ammonites) and then into a freshwater sequence

when the sandstones with kaolinite were formed. The ammonites from the borehole indicate a close correlation with those from the Lady's Walk Shale of the Dunrobin section, north of the Moray Firth.

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