

Devonian, Grampian Highlands

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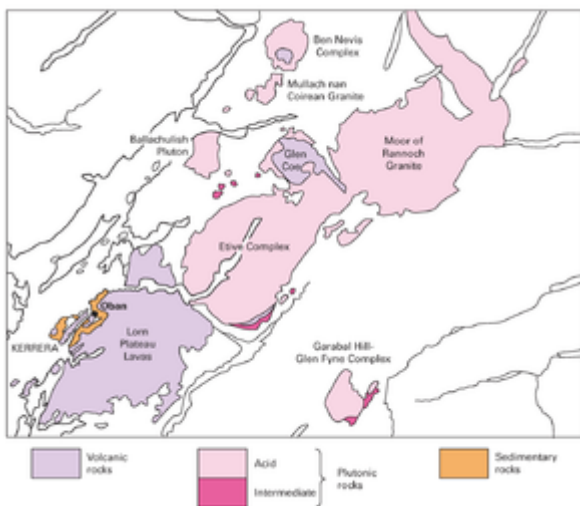
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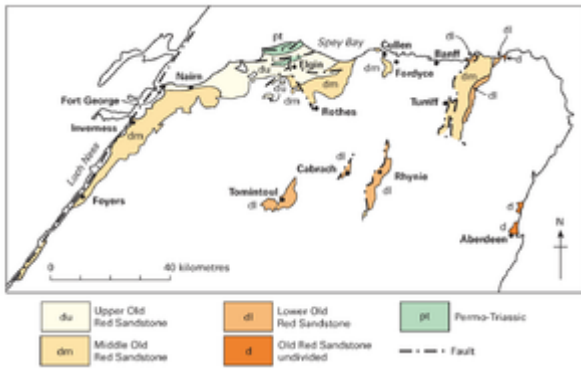
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Devonian

Devonian rocks are largely confined to the peripheral areas of the Grampian Highlands, although scattered downfaulted outliers in the interior point to a more extensive original cover. The Caledonian Orogeny was complete by early Devonian times and the Grampian Highlands were then part of a very large landmass lying astride the equator. Under semi-arid conditions, vast thicknesses of continental sediment were deposited to form the Old Red Sandstone megafacies in two distinct basinal areas, the Argyll Basin and the Orcadian Basin. The Old Red Sandstone succession which borders the Grampian Highlands on the southern side of the Highland Boundary Fault, was deposited in the separate Midland Valley Basin (Cameron and Stephenson, 1985).



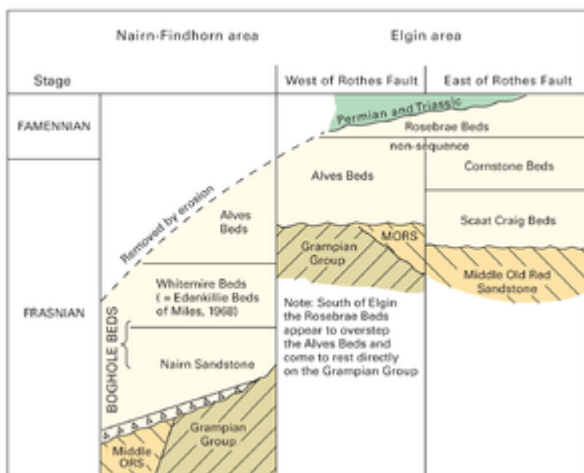
Sedimentary and volcanic rocks of the Lower Old Red Sandstone and their relationship to the Caledonian plutons (Argyll Suite) of the South-west Highlands. P915440.



Old Red Sandstone and Permo-Triassic rocks of the northern Grampian Highlands. P915441.



Lower Old Red Sandstone unconformable on Dalradian, Ailnack Gorge, Tomintoul, Banffshire. P220248.



Probable correlation of the lithostratigraphical divisions of the Upper Old Red Sandstone in the Nairn-Elgin area (based on Peacock et al., 1968). P915442

In northern Scotland, early Devonian extensional stresses gave rise to crustal fracturing which, in places, was accompanied by short-lived volcanic episodes. A series of half-graben developed in which a variety of alluvial, aeolian and fish-bearing lacustrine sediments accumulated. The largely extensional-tectonic non-marine sedimentary regime was maintained throughout the Devonian, but differential movements and intervals of heavy precipitation periodically led to interbasinal lacustrine conditions.

Traditionally, the Scottish Devonian succession has been subdivided into Lower, Middle and Upper Old Red Sandstone which, until recently, were regarded as separate units corresponding to the three Devonian subsystems. Fossil evidence, mainly based upon palynomorph (spore) assemblages, now demonstrates that the unit boundaries are diachronous and do not coincide with breaks in sequence at the Lower-Middle and Middle-Upper Devonian boundaries.

The largest area of preserved Devonian rocks occurs in Moray and Buchan, along the southern border of the former major Orcadian Basin. Three main subdivisions of the rocks, representing distinct environmental suites, are recognisable and they will be referred to as Lower, Middle and Upper Old Red Sandstone in this account. Correlations based upon fossil-fish assemblages are important in the lacustrine facies present, especially in the Middle Old Red Sandstone, where the Achanarras Assemblage is prominent. Most of the Orcadian Basin succession is represented in this region by Middle Old Red Sandstone sedimentary rocks. The Lower group is less extensively developed and is in places overstepped by later sequences. Due to erosion, relatively little of the Upper Old Red Sandstone is presently preserved on land.

Rocks of the Argyll Basin occur in the south-western part of the Grampian Highlands. The succession is dominated by a thick pile of andesitic lavas that overlie sedimentary rocks assigned to the Lower Old Red Sandstone. No rocks of the Middle and Upper Old Red Sandstone are preserved in the onshore exposures of the Argyll Basin succession.

Lower Old Red Sandstone

The Lower Old Red Sandstone sedimentary rocks accumulated in small isolated fault-bounded basins and comprise conglomeratic fans, breccia screes and rockfalls of very locally derived rocks that pass basinwards into fluvial fine-grained sandstones and playa-lake carbonate-bearing mudstones.

In Argyll, the Lower Old Red Sandstone sedimentary rocks underlie volcanic rocks and are exposed on Kerrera, around Oban and in Glen Coe (P915440). They lens out eastwards beneath the Lorn Plateau lavas which form a 300 km² spread between Oban and Loch Awe; volcanic rocks are also preserved within Glen Coe and on top of Ben Nevis.

The Lower Old Red Sandstone rocks on Kerrera rest on an irregular Dalradian rock surface. They comprise a basal unit of breccia and conglomerate, which is succeeded by sandstones, shaly mudstones and up to 300 m of siltstones and thin limestones with, locally, intercalated lavas. The oldest flaggy shaly mudstones contain a varied fauna of cephalaspid and anaspid fish including *Cephalaspis lornensis* (Waterston in Craig, 1965), as well as the millipede *Kampecaris obanensis* and plant remains (Lee and Bailey, 1925). Such a fauna is considered to be Prídolí (uppermost Silurian) in age, similar to that of the Stonehaven Group in the Midland Valley succession, south of the Highland Boundary Fault. The basal beds at Oban are somewhat younger. Sections of sandstone with overlying thick grey shaly-mudstone-bearing conglomerates are well exposed. Andesite boulders within these conglomerates indicate there was volcanic activity in the Grampian region prior to sedimentation. At several localities, the mudstones have yielded fossil assemblages that include the eurypterid *Pterygotus anglicus* as well as *Kampecaris forfarensis*, *K. obanensis*, *C.*

lornensis, *Mesocanthus mitchelli*, *Theolodus sp.*, ostracods and plants. In Glen Coe, the oldest beds are breccias and conglomerates with green and blackish shaly mudstones; near the foot of Buchaille Etive Mòr, plant remains, including *Pachythea fasciculata*, occur within the blackish mudstones.

At the southern end of Kintyre ([P915443](#)), there is a thick succession of Lower Old Red Sandstone rocks which Friend and Macdonald (1968) have subdivided into the following formations:

		Thickness m
Bastard Sandstone Formation	Purple sandstone with red siltstones; beds generally finely laminated and flat-bedded with some cross-bedding	100
New Orleans Conglomerate Formation	Generally coarse conglomerate with many large lava boulders; near the top interbedded with reddish purple sandstone and siltstone with some calcareous concretions; local pumice lapilli	890
Glenramsgill Formation, Quartzite Conglomerate Member	Conglomerate with mainly quartzite clasts up to 1 m in diameter overlain by 200 m of purple sandstone and siltstone	300
Glenramsgill Formation, Basal Breccia Member	Poorly bedded breccia of Dalradian clasts; passing upwards into red sandstones and siltstones replete with fine-grained Dalradian detritus; lava fragments common near the top	150

In terms of the Midland Valley Old Red Sandstone succession, the Bastard Sandstone Formation is possibly the lateral equivalent of part of the Garvock Group and the lower formations parts of the Arbutnott Group. Friend and Macdonald (1968) have suggested that the sediments were mainly derived from the north-west, in the area of Islay and Jura, and the volcanic fragments were transported from a Devonian lava field in northern Kintyre similar to that of the Lorn Plateau. On the southern coast of Kintyre, three vents cut through the junction of the Glenramsgill and New Orleans formations. Lava was intruded in only one of these vents, which largely comprise columns of gas-transported conglomerate and sandstone clasts. The Lower Old Red

Sandstone succession on Sanda Island, separated by faulting from that on the mainland of Kintyre, shows differences in detail, although the lithologies are generally similar.

Sedimentary and volcanic rocks of Devonian age occur on both sides of the Highland Boundary Fault in the Crieff and Blairgowrie areas; they form part of the Arbutnott Group of the Midland Valley Old Red Sandstone succession described in the Regional Guide for the Midland Valley of Scotland (Cameron and Stephenson, 1985).

In the North-east Highlands, relatively small outliers at Tomintoul, Cabrach, Rhynie, Aberdeen and Turriff ([P915441](#)) are considered to be remnants of a more extensive development of the Lower Old Red Sandstone. Most represent irregular infillings of half-graben on the southern periphery of the Orcadian Basin. The Tomintoul Outlier is the sedimentary fill of an irregular NE-trending depression on the Dalradian basement. In the south-west, the outlier consists of a basal breccia overlain by a considerable, but unknown, thickness of coarse angular- and rounded-clast conglomerate. The sequence is well exposed in Ailnack Gorge ([P220248](#)), where the clasts are mainly of metasedimentary lithologies and up to 1 m in diameter. To the north-east, this conglomerate is overlain by red, immature medium-grained sandstones. The Cabrach Outlier is fault-bounded on its north-western side. Here a basal conglomerate is overlain by grey and red, friable, or red micaceous

sandstone intercalated with coarse conglomerate layers; an outcrop of altered amygdaloidal andesite in the northern part of the outlier may represent a lava flow.

The Rhynie Outlier forms a 21 km-long NNE-trending outcrop some 12 km east of the Cabrach Outlier. It contains andesitic lavas and is fault-bounded on the western side. The rocks of this outlier may be the oldest in the Orcadian province; the sequence is (Gould, 1997):

		Thickness m
Dryden Flags Formation	Greenish grey flaggy siltstone with some mudstone and rare micaceous sandstone. Includes the Rhynie Chert Member near the base	260-800
Quarry Hill Sandstone Formation	Pale pink to grey massive sandstone with thin siltstone interbeds	0-400
Tillybrachty Sandstone Formation	Soft, whitish to deep purple sandstone with conglomerate lenses. Andesitic lava with minor tuff occur in the northern part of the outcrop	100-1400
Carlinden Shale Formation	Red and grey shaly mudstones with paler silty layers and calcareous sandstone beds	0-50
Corbie's Tongue Conglomerate Formation	Compact conglomerate or breccia with some pebbly sandstone interbeds	0-20

Archer (1978) has shown that early sheet-flood conglomerates were succeeded by braided-stream deposits directed northwards and later by flood-plain sediments, the latter containing the Rhynie Chert sequence (Mackie, 1914). This chert incorporates remains of Devonian plants that grew on a peat bed close to a volcanic centre. Silica-rich volcanic waters rapidly flooded the local vegetation and prevented the microbial breakdown of plant tissues, thereby perfectly preserving their microscopic structures. Such remains include the psilophytes *Rhynia*, *Horneophyton* and *Asteroxylon* (Kidston and Lang, 1921) as well as fungi and myxophcean blue-green algae. In addition to the spectacular botanical remains, other fossils in the chert include the crustacean *Lepidocaris rhyniensis*, the arachnid *Paleocharinus rhyniensis* and the collembolids *Rhyniella praecursor* and *Rhyniognatha hirsti*. Trace-fossil burrows of annelids and possible lungfish (Archer, 1978) also occur along with spores of probable Siegenian age (Richardson, 1967). The Rhynie Chert is enriched in gold (0.18 ppm) and arsenic (79 ppm) (Rice and Trewin, 1988). In a fault zone of silicified brecciated chert and tuffaceous sandstone, values rise to 1.72 ppm and 89 ppm respectively and silicified boxworks are developed after pyrite. The whole cherty sequence is interpreted as a fully preserved precious-metal-bearing, hot-spring system.

The Turriff Outlier is the largest in the North-east Highlands. Here the Lower Old Red Sandstone is known as the Crovie Group (Read, 1923) and has been considered to be of Siegenian-Emsian age (Westoll, 1977). It rests unconformably upon the Dalradian Macduff Slate Formation and is unconformably overlain by Middle Old Red Sandstone.

Good sections of the Lower Old Red Sandstone can be examined at Crovie, New Aberdour (Sweet, 1985) and Gardenstown. Basal alluvial-fan sediments are overlain by a coarsening-upward sequence of deposits representing environmental changes from low-sinuosity ephemeral streams via floodplain meandering rivers to high-velocity braided rivers on an alluvial fan. Palaeocurrent data suggest a north-westerly dispersion. The unconformable junction with the Middle Old Red Sandstone is well exposed at Pennan. Scattered throughout the North-east Highlands are relatively small undated outliers of red cobble to sandy deposits assigned to the Devonian. Outliers such as those at Aberdeen, near Towie, south-west of Keith and beneath the viaduct at Dufftown, may be remnants of the Lower Old Red Sandstone. At Buckie, a hornblende-andesite exposed in Gollachy Burn occurs

also as clasts in the overlying Middle Old Red Sandstone conglomerate and may therefore belong to the Lower Old Red Sandstone. It is similar to an andesite cutting metamorphic rocks 5 km south-west of Cullen, in Banffshire, which may be of the same age.

Middle Old Red Sandstone

Rocks of the Middle Old Red Sandstone represent sediments laid down in numerous interconnected half-graben basins into which far-travelled clasts were deposited. This period of deposition was characterised by the development of ephemeral playa lakes with peripheral sandy wind-affected alluvial systems alternating with periods of extensive lake deepening when carbonate-mudstone sedimentation prevailed. Such lacustrine sediments are usually marked by particular fossil-fish assemblages, among which the oldest Achanarras Assemblage is the most widely recognised. In many places, the extension of the Orcadian Basin at this time is reflected by overstepping of the Lower Old Red Sandstone on to a variety of pre-Devonian rocks. Continuing movements on some of the half-graben faults resulted in conspicuous unconformities between the Lower and Middle Old Red Sandstone but, away from the fault zones, sedimentation was continuous without any break in sequence (Rogers, 1987). Palynological evidence indicates that the Middle Old Red Sandstone spans the Lower-Middle Devonian boundary, ranging in age from late Emsian to late Givetian, with the Achanarras Assemblage probably lying within the early Eifelian (Marshall *in* Rogers, 1987). There are no Middle Old Red Sandstone rocks in the Grampian Highlands south of Foyers. The main outcrops lie along the Great Glen between Foyers and Nairn, between Buckie and the Rothes Fault, and in the Turriff Outlier (P915441).

The sequence along the south-eastern side of the Great Glen rests upon a rolling surface of metamorphic and granitic rocks and the basal breccio-conglomerate forms a discontinuous spread incorporating a number of lenticular fans and possible canyon-fills. It is 75 m thick near Daviot and about 150 m thick near Cawdor, but over certain pre-Devonian knolls it is absent. The succession in the south-west, around Inverfarigaig, consists of thick lenticular granite-scrree breccias, arkosic gritty sandstones, Moine-clast breccias and conglomerates, intercalated with and overlain by fine-grained sandstone, siltstone and rare shaly mudstone (Stephenson, 1972; Mykura, 1982). These sediments were involved in contemporaneous landslips and localised thrusting and to the north-east pass laterally into thick granite-clast-rich breccio-conglomerates derived from the south-west. North-east of Inverfarigaig, towards Inverness and Nairn, the conglomerates pass by intercalation into a succession of sandstones, flaggy siltstones and shaly mudstones commonly containing fish-bearing nodular limestone. In the area between Inverness and Nairn, the following succession has been established (Horne and Hinxman, 1914; Horne, 1923; Fletcher et al., 1995):

		Thickness m
Hillhead Sandstone Formation	Sandstones, flags and fish-bearing shaly mudstones	900
Inshes Flagstone Formation	Grey and purple flaggy micaceous sandstones, some dark calcareous flags and laminated shaly mudstones with limestone nodules	300
Leanach Sandstone Formation	Red sandstones, some flaggy with interbedded shaly mudstones	500

Nairnside Sandstone Formation	Grey and brown graded flaggy sandstones, siltstones and fish-bearing calcareous mudstones with limestone nodules; includes the Easter Town Siltstone and Clava Mudstone members	120
Daviot Conglomerate Formation	Bouldery to pebbly breccio-conglomerates with thin sandstones and a limestone bed	0-150

Exposures of the lacustrine mudstones and siltstones of the Nairnside Sandstone Formation occur in the River Nairn at Easter Altglugie, in two sections at Clava, in the southern tributary of the River Nairn at Easter Town, at Knockloan 5 km south of Nairn and at several localities near Lethan Bar and Easter Clune. The fauna is typical of the Achanarras Assemblage and includes *Cheirolepis* sp., *Coccosteus cuspidatus*, *Dipterus valenciennesis*, *Mesacanthus* sp. and *Osteolepis* sp. The lowest fish-bed appears to be that in Easter Town Burn and *Asmussia* [*Estheria*] sp. is abundant beneath the fish-bearing Clava Mudstone. The best exposure of the Leanach Sandstone was at the Leanach Quarry on the southern flank of Culloden Moor. The fauna recorded by Taylor (in *Horne, 1923, p. 69*) includes 'Coccosteus decipiens', *Glyptolepis* sp., *Homosteus* sp. and *Pterichthyodes milleri*. From the evidence seen in the building stones hewn from this quarry, for the construction of the Clava Railway Viaduct, the Leanach sequence includes aeolian sandstones. Dark calcareous and slightly bituminous flags with limestone concretions within the Inshes Flagstone Formation exposed near Raigmore (Inverness) have yielded 'Coccosteus' and *Osteolepis* species as well as plant remains. A higher fauna, comparable with that of the topmost 'Middle Old Red Sandstone' formations in north-eastern Caithness and Orkney, occurs in Hillhead Quarry, 12 km east of Inverness, where *Homosteus milleri* and *Millerosteus minor* have been identified in the Hillhead Sandstone.

Farther east, the Middle Old Red Sandstone sequence to the south-west of Buckie consists of a basal conglomerate overlain by a varied stack of thin conglomerates, sandstones and shaly mudstones containing a typical Achanarras Assemblage of *Cheiracanthus* sp., *Dipterus* sp., *Osteolepis* sp. and *Pterichthyodes* sp. (Peacock et al., 1969). A higher fish bed at Dipple, near Fochabers Bridge, has yielded *Dickosteus thrieplandi*, a species typical of strata that overlie beds of Achanarras age elsewhere. In the north-east, the Middle Old Red Sandstone of the Turriff Outlier is represented by the 'Findon Group' (Read, 1923). This group comprises a basal slate-clast breccia up to 60 m thick overlain by the Findon Fish Bed and a sequence of breccias and conglomerates. The fish bed also contains abundant plant remains and occurs as a 2 m-thick section of grey and red shaly mudstone with limestone nodules in the Den of Findon containing a typical Achanarras Assemblage fauna (Read, 1923). In addition to the main outcrops, numerous patches of coarse-grained pebbly and cobbly red beds are scattered about the Moray Firth coast and its hinterland. All appear to be remnants of a former Middle Old Red Sandstone cover now preserved in hollows and depressions in the pre-Devonian basement. Notable sections occur on the coast in Sandend Bay and Cullen Bay, and inland in the Burn of Deskford.

Upper Old Red Sandstone

The Upper Old Red Sandstone in the main part of the Orcadian Basin is characterised by coarser-grained fluvial sediments than the underlying sequence and by the development of sabkha deposits, indicative of marginal marine conditions. The only Upper Old Red Sandstone in the Grampian Highlands lies on the southern side of the Moray Firth, between Fort George in the west and Spey Bay in the east, where they are peripheral to the basal succession ([P915441](#)).

Although the relationship with the Middle Old Red Sandstone is generally unconformable, in the southern part of the Orcadian Basin, there is evidence to indicate that the junction largely represents a facies change without any break in sequence. In the Nairn-Elgin district, the basal beds

appear to be of late Givetian age and the sedimentary sequence spans the Middle-Upper Devonian boundary. To date, no early Famennian sedimentary rocks have been recognised and there is the possibility of a sequence-break between late Frasnian and late Famennian-?Tournaisian beds around Elgin (Rogers, 1987). Because of lack of exposure, the nature of the boundary on the southern side of the Moray Firth is not resolved, although it is clear that the Upper Old Red Sandstone is diachronous from west to east and that the oldest beds are restricted to the western region (P915442). The overall shallow-water and rare dry-bed conditions are reflected by relatively rapid lateral facies changes and by some overstepping of units along the margins of fault-bounded sub-basins. The Upper Old Red Sandstone is made up essentially of sandstone and the recognised subdivisions are based mainly upon six distinctive fossil-fish assemblages (Traquair, 1896; 1897; 1905; Westoll, 1951; Tarlo, 1961; Miles, 1968) that have correlatives in Baltic, Belgium, Spitzbergen and Greenland successions.

The oldest unit is the Nairn Sandstone Formation, which comprises an irregular basal reddish conglomerate overlain by red, grey and yellow calcareous cross-bedded and flaggy sandstones containing thin beds of conglomerate and soft or shaly limestone-bearing mudstone. Good exposures occur on the beach north-west of Nairn, in Muckle Burn, at Glenshiel and in the Findhorn area. In the Findhorn area, the sandstone is faulted against Pre-cambrian gneisses (Black and Mackenzie, 1957) and some mudstone beds have been desiccated to clay galls. High in this section, a 3 m-thick calcrete bed named the Cothall Limestone (Parnell, 1983) is succeeded by 2.6 m of red and violet marl containing fossiliferous limestone concretions veined with calcite, cherty dolomite and pyrite; there are also patches of mamillate chalcedony. The fish fauna of the Nairn Sandstone comprises two main faunules. The lower is characterised by *Asterolepis maxima*, *Psammolepis tessellata* and *P. undulata*, whilst the upper one, known as the Boghole faunule, is distinguished by *A. alta* and *Eusthenopteron traquairi*; species common to both faunules include *Coccosteus magnus*, *Polyplocodus leptognathus* and *Holoptychius decoratus*. The first appearance of *Bothriolepis* has been taken to mark the base of another unit that bears the name *Whitemire Beds* (P915442). The *Whitemire* fauna is first encountered about 7 m above the *Boghole* faunule (Westoll, 1951) and is transitional in type between the *Boghole* and the overlying *Alves* faunas. The diagnostic species is *Bothriolepis taylori* and the assemblage includes *C. ex. gr. magnus* and *H. nobilissimus*, which are common in the older faunule, and *Psammosteus taylori*, *Cosmacanthus*, *Conchodus* and *H. giganteus* present in the *Alves* faunule.

In the Nairn-Findhorn area, a younger fauna occurs in a sequence of grey to reddish siliceous pebbly sandstones named the *Alves* Beds, which, in the Elgin area, rests unconformably on metamorphic rocks near Burgie (P915442). The diagnostic species are *B. alvesiensis* and *B. gigantea*, with *H. nobilissimus* extending upwards into these beds. East of the *Rothes* Fault, the *Alves* succession is represented by two lithological units. The lower *Scaat Craig* Beds, comprising red and yellow sandstone and fine conglomerate, contain taxa such as *Cosmacanthus malcolmsoni*, *Conchodus ostreiformis* and coccosteomorph arthrodires, which are closely linked to the *Whitemire* fauna below. The *Alves* fauna, however, is distinguished by *P. cf. falcatus*, *Traquairosteus pustulatus* and *B. paradoxa*. The influence of an active *Rothes* Fault on *Alves* sedimentation is possibly reflected by the deposition east of the fault of a more carbonate-rich succession of pale grey and reddish brown marly sandstones, which overlies the *Scaat Craig* Beds. This sequence is characterised by sandy cherty calcrete beds representing palaeosols and is named the *Cornstone* Beds.

The highest strata in the Upper Old Red Sandstone are preserved in the Elgin area and form the *Rosebrae* Beds (P915442). They are well exposed in Quarry Wood, west of Elgin, and comprise brownish grey, yellow and reddish sandstone with only scarce pebbles. The fish fauna includes *Phyllolepis cf. woodwardi*, *B. cristata*, *B. laverocklochensis*, *Phaneropleuron cf. andersoni*, *Rhychodipterus elginensis* and *Glyptopomus elginensis*. Associated taxa include *B. alvesiensis*,

Conchodus, *Eusthenopteron* and *H. nobilissimus*, all present in the underlying units. Palynological evidence (Marshall in Rogers, 1987) suggests that the Rosebrae Beds are late Famennian in age at their base and that the highest strata may transgress the Devonian–Carboniferous boundary; a non-sequence may separate the Alves and Cornstone beds from the Rosebrae Beds.

The bulk of the Upper Old Red Sandstone sediments are coarse grained and were laid down as small alluvial fans and by braided rivers marginal to alluvial plains and shallow lakes. An overall northerly flow is indicated by palaeocurrent structures (Westoll, 1977). The finer-grained sediments represent distal floodplain deposits, ponded lags in abandoned channels or lacustrine carbonate muds. Wet periods are indicated by fish-bearing limestones and dry periods by beds of wind-etched pebbles and palaeosol profiles.

Studies of heavy-mineral suites in the Elgin sequence (Mackie, 1897–1923) have shown contrasts between the Middle and Upper Old Red Sandstone sequences. Grains in the former are larger and more angular, having much garnet associated with subordinate iron oxide, rutile, monazite and, more locally, staurolite and epidote. In the Upper Old Red Sandstone, small rounded zircons predominate, with tourmaline, rutile, anatase and monazite also abundant.

Upper Devonian rocks overlying Dalradian and Cambro-Ordovician rocks along the Highland Border between Balmaha, east of Loch Lomond, and Kilcreggan, west of Helensburgh, are part of the Stratheden Group of the Midland Valley succession. They are described in the Regional Guide for the Midland Valley of Scotland (Cameron and Stephenson, 1985, p. 31).

The Upper Devonian rocks of Kintyre are described along with the Carboniferous rocks of that area in [Carboniferous, Grampian Highlands](#).

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