

Building stones of Edinburgh: stratigraphy and origin of sandstones

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From: McMillan, A.A., Gillanders, R.J. and Fairhurst, J.A. 1999 [Building stones of Edinburgh](#). Edinburgh: Edinburgh Geological Society.

"Stratigraphy is the study of the stratified or sedimentary rocks: their nature, arrangement, and correlation from place to place"

D. T. Donovan, 1966

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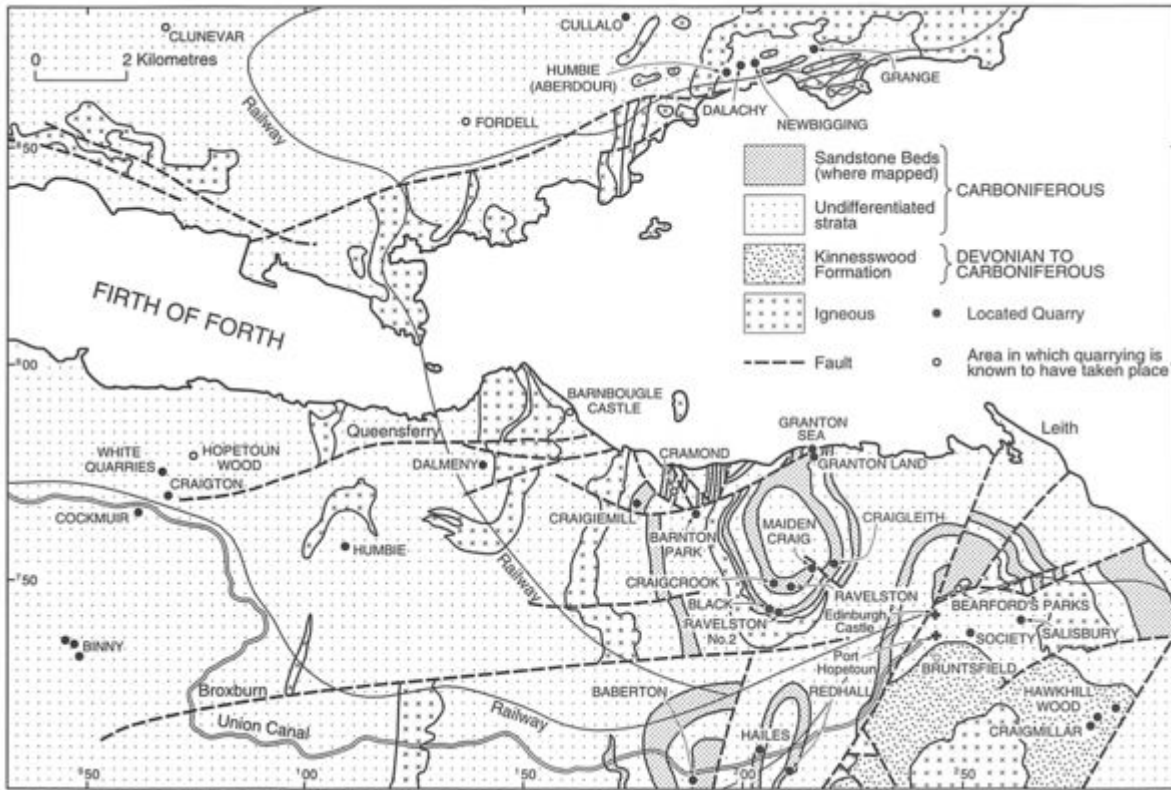
Stratigraphy and origin of sandstones used in Edinburgh

Sandstones used in Edinburgh's buildings have been quarried not only in the Lothians and Fife but also in many other parts of Scotland and northern England. The majority of quarries have long ceased operation. In some cases they have been infilled and re-developed so that little evidence remains today of their former extent. This chapter describes the locations and geological settings of both former and currently active building stone quarries and the stratigraphy of the sandstones worked. The information is summarised for selected quarries **[add hyperlink]**

Geological setting

Edinburgh lies within the Midland Valley of Scotland, an ancient rift valley or graben, bounded by two parallel faults, the Southern Upland Fault and the Highland Boundary Fault. The graben developed during the Devonian (410 to 360 million years ago) and Carboniferous (360 to 280 million years ago) periods and the resultant basin became a focus for sedimentation. To the south of the Midland Valley lie the mountains of the Southern Uplands formed by the folding, thrusting and uplift of greywackes and shales during the closure of a major ocean known as Iapetus. The mountain building episode is referred to as the Caledonian Orogeny. South of the Southern Uplands another series of major sedimentary basins including the Northumberland - Solway Basin formed during the Carboniferous period. North of the Midland Valley rise the mountains of the Grampian Highlands formed of ancient metamorphic and igneous rocks which have undergone several phases of folding and uplift.

In central Scotland the principal building sandstones were deposited as unconsolidated sands at intervals during the Devonian (the 'Old Red Sandstone') and Carboniferous periods. These and other sediments were laid down in a variety of depositional settings such as in rivers, deltas, seas and deserts. Detailed studies of the lithologies (composition and texture), sedimentary structures and fossils provide evidence for climatic changes as the surface of that part of the earth's crust which is now northern Britain moved northwards across equatorial latitudes.



Edinburgh and neighbourhood: geology and sandstone quarries.

At various times during the Devonian, river sands and gravels accumulated to form a thick succession of sandstones and conglomerates in the southern part of the Midland Valley. Lake sediments (principally flagstones) formed in Angus. During Middle Devonian times the Caithness flagstones formed in a large lake covering part of northern Scotland and the Northern Isles. In the Midland Valley and northern England during the tropical Carboniferous period, volcanic eruptions punctuated the deposition of thousands of metres of coal-bearing strata. Sequences of sandstone, mudstone, thin limestone, coal and ironstone were laid down in subsiding basins. Limestones and other marine fossil-bearing horizons mark periodic inundation of the land by shallow seas. The proportion and thickness of these component lithologies varied according to the conditions under which they were deposited.



General locations of building stone quarries in Scotland and northern England Lettered squares represent Ordnance Survey 100 km National Grid.

Other sandstones used in Edinburgh's buildings are of Permian to Triassic age (280 to 210 million years ago). For much of this time desert conditions prevailed in Britain which occupied a latitude similar to that of today's Sahara. Consequently, the sands that accumulated to form the 'New Red Sandstone' were deposited mainly as large windblown dunes. Evidence for this is shown by sedimentary structures including aeolian (wind-blown) dune cross-bedding and the high degree of sorting and sphericity of the sand grains. Red Permian sandstones, much used as building stone, occupy small basins in the Vale of Eden, Dumfries & Galloway and Ayrshire. In Moray, Permian and Triassic buff and white sandstones were also laid down in an aeolian environment but close to the margin of a sea, conditions which effected unusual stone characteristics including convolute bedding and patchy silicification.

As a result of folding and faulting of strata deep in the earth's crust and subsequent erosion over millions of years, different parts of the sequence of sedimentary rocks are exposed today at the surface. Recent sediments, including the unconsolidated sands, gravels, silts, clays and boulder clays (till) of the Quaternary ice sheets (deposited during the last few thousand years) often obscure the solid rocks. However the relative stratigraphic positions of different beds of sandstone can be determined by combining evidence from geological field mapping and records of boreholes, mine and quarry sections. Studies of fossiliferous strata such as shell-bearing mudstone and limestone enable the correlation or matching of sedimentary sequences.

The tables illustrate the principal formations from which sandstones have been worked. Formations are defined as sequences of strata that possess distinctive lithological characteristics. In central Scotland geological mapping by the British Geological Survey has enabled sandstones within these formations to be correlated between different quarries and outcrops. Typically sandstones from approximately the same stratigraphical horizon have been assigned local geographical names. Thus,

for example, within the West Lothian Oil-Shale Formation the Dunnet Sandstone of West Lothian may be correlated with the Grange Sandstone of West Fife. At a higher level within this formation, sandstones quarried at Binny, Humble and Dalmeny Quarries in West Lothian all belong to the same stratigraphical member named the Binny Sandstone .

System/Series	Group (Gp)	Formation (Fm)	Quarries	
TRIASSIC	un-named	Sandstones of Spynie	Spynie	
	Sherwood Sandstone Gp	St Bees Sandstone Fm	*Corsehill	
	un-named	Sandstones of Hopeman	*Lishach; Greenbrae	
PERMIAN	Appleby Gp	Mauchline Sandstone Fm	Balochmylie	
		Locharbriggs Sandstone Fm	*Locharbriggs	
		Thamesit Sandstone Fm	Gatlandsbridge, Closeburn	
		Cornockle Sandstone Fm	*Cornockle	
		Upper Coal Measures Fm	Use of stone not documented	
CARBONIFEROUS	Westphalian	Middle Coal Measures Fm	Auchinlea	
		Lower Coal Measures Fm	Braehead	
		Passage Fm	Longstonf, Blair; Sands	
	Namurian	Clackmannan Gp	Upper Limestone Fm	*Cowie Rock; Polmalis; Dunmore; *New Dunmore; Giffnock Sandstone; Braidbar; Bishopbriggs Sandstone; Huntershill; Plean (Blackcraig); Dullatur; Local quarrying: Joppa
			Limestone Coal Fm	Clunever; local quarry; Niddrie
			Lower Limestone Fm	Local quarrying
			West Lothian Oil-Shale Fm	Binny Sandstone; Binny; Hermand; Humble; Hopetoun White; Craigston; Cockmuir; Dalmeny Grange Sandstone; Grange; *Newbigging; Dalachy; Cullalo; Dunver Sandstone; Hopetoun Holes Sandstone; Hailes; Redhall; Ravelston Sandstone; Ravelston No. 2
	Viséan	Strathclyde Gp	Gullane Fm	Craigleith Sandstone; Craigleith; Maidenraig; Barnton Park; Ravelston; Granton; Bearford's Parks and other local quarries
			Arthur's Seat Volcanic Fm	Local quarrying
			Bailagan Fm	Camstone, Dumbiedykes, Society
DEVONIAN	Upper Calchness Flagstone Gp	Spittal Sub-Group (Middle Old Red Sandstone)	Craigmillar, Hawkhill Wood; and local quarries including those in the Meadows and Bruntsfield area (The Burgh Muir) and Grange	
		Arbuthnott Gp	Dundee Fm (Lower Old Red Sandstone)	*Spittal and many other currently operational quarries (see Chapter 8)
		Dundee Fm (Lower Old Red Sandstone)	Carrylie; Leoch	

The stratigraphy of Scottish sandstones used in Edinburgh's buildings.

System/Series	Group (Gp)	Formation (Fm)	Quarries	
TRIASSIC	Sherwood Sandstone Gp	St Bees Sandstone Fm	*Bankend; *Birkhams; Shawk; Moat	
PERMIAN	Appleby Gp	Penrith Sandstone Fm	*Lazonby	
		Middle Coal Measures	*Heworthburn	
CARBONIFEROUS	Westphalian	Lower Coal Measures	*Woodlink	
		Namurian	Milstone Grit	Black Pasture; *Castlegate; *Dunhouse; *Stainton; Stanciffe; *Stanton Moor; *Stoke Hall; *Watsciffe; *Wellfield
			Middle Limestone Gp	Cocklaw; Gurnerton; Prudham; Purdovan; Densick
	Viséan	Lower Limestone Gp	*Woodburn; *Blaxter; Darney	
		Scrimston Gp	Cragg; Millnock; Pasturehill	
		Fell Sandstone Gp	Doddington; Granton Pike; Fairtoam	
		Cementstone Gp	Swinton; Whitsome Newton	

The stratigraphy of sandstones from England and the Scottish Borders used in Edinburgh's buildings.

It is important to note that characteristics such as colour and grain-size can vary considerably within a sandstone from quarry to quarry or even between beds in the same working. A distinction should also be made between the stratigraphical (geological) name of the sandstone and the trade name because the latter may have been applied to stone of different origin and from different stratigraphical positions. Wherever possible, this account defines both the stratigraphy and the quarry from which stone has been obtained.

Scottish Devonian sandstone (Old Red Sandstone)

During the Devonian Period the latitude of the Midland Valley is considered to have been sub-equatorial and the climate was semi-arid. Rivers which flowed principally during periods of torrential rainfall supplied large volumes of sediment to land-locked basins. Deposition of river (fluvial) and lake (lacustrine) sediments was preceded and periodically accompanied by outpourings of lavas from volcanoes, remnants of which form the Ochil Hills and Sidlaw Hills in the north and the Pentland Hills south-west of Edinburgh.

Sandstones of Angus

Within the Midland Valley, the Lower Devonian sedimentary succession is thickest in Strathmore, Angus where an estimated 7.5 km of strata are present. The Dundee Formation (of the Arbutnott Group), comprises a 1.5 km thick accumulation of mainly medium-and coarse-grained, cross-bedded, fluvial sandstones with interbedded, fine-grained lacustrine sandstones (flagstones). The latter were extensively worked for paving stones at Carmyllie quarries, near Arbroath, which supplied much stone for Edinburgh. Blue-grey freestone from Leoch Quarry, north-west of Dundee, has also been used in the city' Whilst in operation during the 19th century these and other quarries in Angus yielded an important assemblage of fossil fish and crustaceans' and plants.'

Caithness Flagstones

Strata of Middle Devonian age are absent in the Midland Valley but are extensively developed in Caithness and Orkney as flagstones (mainly laminated sandstones and silt-stones) which formed in a major lake. The flagstones are generally grey, demonstrating that a red hue is not ubiquitous to all strata of the 'Old Red Sandstone'. The total thickness of the flagstone succession in Caithness is 4 km and in Orkney over 2 km. The sequence is made up of well defined rhythmic units or cycles of sediment, usually 5 to 10m thick, reflecting fluctuations in the lake level. The cycles comprise, from top to base:



Spittal Quarry, Caithness. A modern working flagstone quarry showing the flat beds excavated for pavement.
P001607.

4. alternations of laminated siltstone and fine-grained sandstone

3. coarse, ripple-laminated siltstone often with very fine sand-filled syneresis cracks (formed under water in response to seasonal changes in salinity)

2. laminated siltstone and shale

1. grey or black carbonate- and bitumen-rich, laminated siltstone with fish remains ('fish beds')

On account of their strength and ease of splitting Caithness flagstones have been used extensively as paving and roofing throughout Britain and abroad. The best flagstones for pavement are typically grey, interlaminated, fine-grained sandstone and siltstone. Currently, flagstones of the Spittal Sub-Group of the Upper Caithness Flagstone Group" are worked at several quarries including those at Spittal . These have recently supplied paving stone for some of Edinburgh's major streetscaping projects.

Carboniferous sandstone of the Midland Valley of Scotland

Britain's northward drift meant that by Carboniferous times sedimentation took place in equatorial latitudes. The Midland Valley of Scotland and the sedimentary basins of the Scottish Borders and Northern England contain evidence for rivers, lakes, lagoons and seas. Periodic rises in global sea level resulted in widespread marine conditions from time to time. In eastern Scotland, former volcanic activity is preserved in remnants including Arthur's Seat, the Castle Rock and the lavas of the Garleton Hills, East Lothian." The sedimentary rocks are arranged as a series of cycles or rhythms of different lithologies. Principal rock types include coal, limestone, mudstone, siltstone, sandstone and fossil soil (seatearth). The proportion and thickness of these component lithologies varies according to the conditions under which they were deposited.

Inverclyde Group

The oldest Carboniferous strata in the Midland Valley are collectively referred to as the Inverclyde Group and comprise the Kinnesswood Formation and the Ballagan Formation' (formerly known as the Cementstone Group).



Rock specimen of Kinnesswood Formation sandstone from Craigmillar Quarry.

Kinnesswood Formation

In the Midland Valley, uplift, folding and faulting of strata occurred during the Middle Devonian. Renewed deposition of river sands occurred during latest Devonian and earliest Carboniferous times. In Midlothian, around the Pentland Hills the estimated thickness of these sedimentary rocks, referred to as the Kinnesswood Formation (formerly part of the Upper Old Red Sandstone), is 640m.

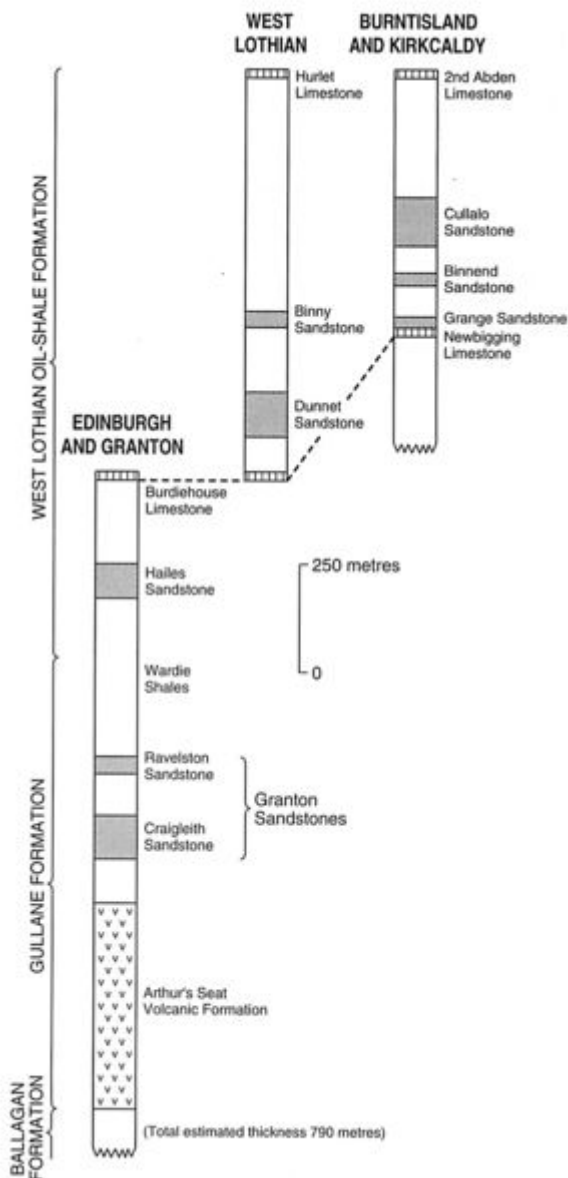
Sandstones from this sequence were extensively exploited for early building work in the city. Local quarrying from the 16th century onwards took place at Craigmillar and in the Meadows and Bruntsfield areas (the Burgh Muir) and Grange district.

Ballagan Formation

In the Edinburgh district the succeeding Ballagan Formation comprises sequences of interbedded sandstone, shale and cementstone (muddy limestone). The strata locally contain thin layers of gypsum and bands of nodular cornstone. This evidence indicates that the sediments were laid down in a coastal environment in which there were changes in water salinity, fluctuations in water table and periods of desiccation. Sandstones from the Ballagan Formation were formerly worked in the Camstone Quarries, east of Salisbury Crag on Arthur's Seat. They were also worked at Dumbiedykes, Society and many other quarries in the Old Town. Dolerite of Salisbury Crag was also worked, primarily for setts.

Strathclyde Group

The Strathclyde Group includes the Gullane Formation and the West Lothian Oil-Shale Formation (formerly the Lower and Upper Oil Shale Groups). The relative stratigraphical position of important building sandstones in these formations is shown in the diagram.



Generalized vertical sections in the Strathclyde Group of Lothian and Fife.

Arthur's Seat Volcanic Formation and Gullane Formation

Lying stratigraphically above the Ballagan Formation strata are the Arthur's Seat Volcanic Formation and Gullane Formation. The Arthur's Seat Formation comprises a series of basaltic lavas, agglomerates, tuffs and intrusive rocks which, being generally harder than the surrounding sedimentary rocks, are an important component in Edinburgh's distinctive landform. Notable hills composed of these volcanic rocks include Arthur's Seat, Calton Hill and the Castle Rock.

The Gullane Formation of the Lothians and Fife supplied the bulk of Edinburgh's top quality building sandstone. The formation consists of a cyclical deltaic sequence composed predominantly of fine- to coarse-grained sandstone interbedded with grey mud-stone and siltstone. Rivers flowing from the north-east extended across eastern Scotland, supplying large quantities of sediment into the subsiding basin. Within this deltaic sequence thick, workable, sandstones are found.

In Edinburgh two principal stratigraphic units, namely the Craigeith Sandstone and the Ravelston Sandstone, have been extensively worked for excellent stone. They are separated by about 90 m of other strata and are sometimes collectively known as the Granton Sandstones. In west Edinburgh

these sandstones form a circular outcrop known as the 'Granton Dome' or Granton Anticline. There were many early workings in the city centre but the principal supplies of the world famous Craigleith Sandstone were quarried in the Craigleith district at Granton. During quarrying operations at Craigleith and Granton many fossil trees were recovered.

West Lothian Oil-Shale Formation

The West Lothian Oil-Shale Formation is characterised by a cyclical sequence dominantly composed of pale coloured sandstones interbedded with grey mudstones and silt-stones. Within the upper part of the sequence the locally developed oil-shale seams (once economically-mined) are interpreted to have formed in freshwater lagoons in which abundant algae accumulated and putrified. These lagoons were populated by a remarkable fauna of crustaceans and fishes.

Sandstones within this formation from local sources and from West Lothian and Fife have been used widely in Edinburgh. On the south-west outskirts of Edinburgh, the Hailes Sandstone was worked at Hailes and Redhall. It was also quarried at Craigmill near Cramond Brig and briefly at Baberton, but here a quarry, newly opened in the 1890s, had to be abandoned because the stone was so full of fossils as to be useless.

Above the Burdiehouse Limestone, a non-marine limestone up to 15 m thick, containing fossil plants, fish and ostracods, the upper part of the West Lothian Oil-Shale Formation, is characterised by the occurrence of nine or ten oil-shale seams. The latter were formerly mined extensively in West Lothian. Two thick sandstones are present in this part of the sequence and were worked for building stone, particularly in West Lothian and in Fife. The Dunnet Sandstone of West Lothian, comprising mainly grey or brownish sandstones attains a thickness of 219 m in the Deans and Livingston districts.

FIGURE 3.5 Craigleith Quarry, Edinburgh. This dramatic photograph shows the quarry at a time when the stone was becoming too expensive to work. The quarry is partially infilled with spoil. Thick massive beds of sandstone are exposed in the face beneath the pump engine house. In the background is a steeply inclined roadway. Photograph by Thomas Begbie (c.1850). Reproduced by permission of the City Art Centre, Edinburgh.

FIGURE 3.6 Craigleith Quarry, Edinburgh Taken at about the same time as the Thomas Begbie photograph, this photograph, looking east, places the quarry in its setting on the western fringe of the city. Contrast the thickly bedded massive sandstone at the base of the quarry with thin overlying strata. Stewarts Melville College, built 1849-55 mainly of Binny Sandstone from West Lothian, is seen beyond the quarry with Edinburgh Castle and Arthur's Seat in the background. Photograph by W.D.Clark (c.1858). Reproduced by courtesy of Edinburgh City Libraries.

Quarrying in the Dunnet Sandstone dates back to 1697 at Hopetoun Quarry which provided stone for the building of Hopetoun House.

The Fife correlative of the Dunnet Sandstone is known as the Grange Sandstone. It has been worked principally near Burntisland at Grange, Newbigging and Dalachy quarries. These quarries yielded large quantities of fine-dressed freestone blocks which were supplied to Edinburgh, Glasgow and Dundee as well as many parts of Fife. There is uncertainty as to whether the fine-grained, yellowish sandstone worked at the many Cullaloe quarries is correlated with the Grange Sandstone or is, higher in the sequence.

Higher in the West Lothian Oil-Shale Formation is the Binny Sandstone which lies between the

Dunnet Sandstone and the Brayburn Oil-Shale and was formerly quarried at ten localities in West Lothian and Midlothian. The most notable workings include those at Binny near Uphall; Hermand near West Calder; Humbie near Winchburgh; Hopetoun White, Craigton and Cockntuir quarries near Philpstoun; and Dalmeny.

FIGURE 3.7 Hailes Quarry: Extract of the Ordnance Survey 25 inch County Map Edinburghshire 111.13 and 111.14 (1914 edition). Note scale is reduced. Reproduced by permission of the Trustees of the National Library of Scotland.



Hailes Quarry, Slateford, Edinburgh. General view of the quarry looking north, with the tramway bridge (not shown on the Ordnance Survey 25 inch County map, 1914 edition) and steam pumping engine in middle distance.

Corstorphine Hill and Donaldson's Hospital are in the background. At this end of the quarry, the blue stone was more of a 'liver rock' in which lamination was not discernable. BGS Photograph B932, P000183 (c.1913).

Clackmannan Group Lower Limestone Formation

Strata of the Lower Limestone Formation exhibit generally a marine lithology with rhythmic sequences of thin coals overlain by limestone, mudstone with marine shells, followed by sandstone. In the Lothians, sandstones have been worked for local building purposes" but have generally proved too soft to be considered for use as construction stone in Edinburgh.

In Fife, sandstone overlying the Charlestown Main Limestone of the Lower Limestone Formation was worked at Millstonemeadow Quarry, near Otterston Loch east of Fordell Castle. The stone was said to have iron concretions which stained black on exposure.



Huntershill Quarry, Bishopbriggs The Bishopbriggs Sandstone was quarried and mined in Huntershill Quarry, Bishopbriggs. The sandstone is developed as two units, the lower part 18m thick and the upper part 14m. Mining by the stoop and room (pillar and stall) commenced in the 1850s as the overburden of poor quality strata and till increased in thickness. The galleries were some 15 m high. The quarrying process was started by 'miners' who drove horizontal mines near the top of the post (bed). Quarrymen then wrought downwards from the mines, a few feet of solid sandstone being left to support the roof. Mining continued until about 1907 when a serious roof fall killed 5 men. BGS Photograph C2417 P000050(c.1908).

Limestone Coal and Upper Limestone Formations

Sandstones of the succeeding Limestone Coal Formation and the Upper Limestone Formation of the Clackmannan Group have been used in the main only locally for building stone. They were also used for furnace hearths, glass manufacture and for moulding purposes in the Lothians. Local sources of stone from these formations were worked at Niddrie and Joppa respectively. The Limestone Coal Formation consists mainly of deltaic sequences of siltstones, mudstones and valuable coals with frequent channel sandstones. Sandstone of this formation brought to Edinburgh from Fife includes that from Clunevar, west of Dunfermline. Coarse-grained, cross-bedded sandstones at the base of the Limestone Coal Formation were worked at several quarries near Fordell Castle.

A significant group of building stones used in Edinburgh (and Glasgow) is found in strata of the Upper Limestone Formation in west-central Scotland. In the Glasgow and Stirling areas, thick sandstones occur between two marine limestones, the Index and Calm limestones. The sandstones are interpreted to have formed as deltaic channel sands. The Bishopbriggs (or Kenmure) Sandstone was quarried and mined at Bishopbriggs in Huntershill Quarry and at Dullatur Quarry, Kilsyth. At Plean (Blackcraig) Quarry, Kilsyth, the stone was known locally as the Plean White Freestone.

At a higher horizon, between the Huntershill Cement Limestone and Lyoncross Coal, a resistant sandstone occurs both in the Glasgow (where it forms part of the Barrhead Grit) and Stirling areas known as the Cadger's Loan Sandstone (or Rock). It was worked at Cadger's Loan Quarry which was

sometimes referred to as 'Plean'. However the stone was inferior to that won at Plean (Blackcraig) Quarry and was mainly used for rubble work. The Giffnock Sandstone which lies between the Lyoncross and Orchard limestones" and was formerly worked at quarries at Giffnock supplied much stone to Glasgow. Some stone from Giffnock was used in Edinburgh.

Between the Orchard and Cahny limestones, extensive quarrying took place in the Stirling district in the 'Cowie Rock' and stone for Edinburgh was wrought at Dunmore and Polmaise quarries.' Nearby the original Dunmore Quarry, a new working was opened in 1985 by Scottish Natural Stones Ltd.

Passage Formation

The succeeding Passage Formation marks a period of increasing deposition of coarse-grained fluvial sediments with periodic marine incursions. Locally, unusually thick coals developed in small isolated rapidly-subsiding basins, for example at Westfield in Fife. Thick sandstones were worked for building stones from an early date at Longannet, Blair and Sands quarries to the north of the Forth near Kincardine. The Old Statistical Account (1794) notes that 'the quarry of Longannet path been in great reputation, time immemorial. It is a durable stone perfectly white, of a small greek [grain] and takes on a fine smooth polish. The demand for it has been greater than the quarriers have ever been able to supply'.

Coal Measures

Many extensive and workable coals are developed in the Lower and Middle Coal Measures. Deposition of fluvial channel sands and silts resulted in the formation of a number of thick sandstones. Lower Coal Measures sandstones were quarried on an extensive scale in West Lothian, near Fauldhouse and in Midlothian, south of Inveresk and at Bonnyrigg. Sandstone used in Edinburgh was worked at Braehead, West Lothian.

In Middle Coal Measures strata, quarries at Auchinlea, Motherwell provided much building stone for Glasgow and some for Edinburgh." The stone lies stratigraphically below a thin development of the Airdrie Blackband Ironstone, a resource extensively worked in the Airdrie district from about 1830 until 1875.

Upper Coal Measures sediments were laid down in rivers and deltas. The main rock types are red, white and grey sandstones, siltstones and mudstones. Reddening of the sandstones is believed to have occurred as a result of the movement of oxidizing iron-rich solutions through the strata during Permian times when desert conditions developed. Former quarries in west-central Scotland such as those at Bothwell Park, Uddingston supplied much greyish red and red building stone but there are no documented uses in Edinburgh's buildings.

Permian and Triassic Sandstone (New Red Sandstone) of Dumfries & Galloway and Ayrshire

Sandstones of the 'New Red Sandstone' of Permian age, unlike their counterparts in the Carboniferous, developed in desert environments. In south-west Scotland, there is little direct fossil evidence of the age of these rocks which occupy several distinct basins separated from each other by older (Lower Palaeozoic) rocks." Red aeolian sandstones of the Appleby Group used in Edinburgh have been quarried over centuries near Dumfries at Locharbriggs, Corncockle, Closeburn and Gatelawbridge and in Ayrshire at Mauchline (Ballochmyle Quarries). Red fluvial sandstone of the Sherwood Sandstone Group is quarried at Corsehill, Annan. About 90 years ago Boyle reviewed the characteristics and uses of the many red sandstone quarries. A recent detailed stratigraphy of the

sandstones was published by Brookfield.'

Appleby Group

Locharbriggs Sandstone Formation

On the north side of the Dumfries Basin at Locharbriggs up to 25 m of the Locharbriggs Sandstone Formation is exposed in quarries currently worked by Baird & Stevenson (Quarrymasters) Ltd. Geophysical evidence suggests the strata may attain a total thickness of up to 1 km. The sandstone shows aeolian dune-bedding arranged as wedge-shaped and planar tabular foresets, between 0.5 and 2.0 m thick, dipping between 10 and 30° to the south-west. Trackways of reptiles have been found preserved on bedding planes.

Thornhill Sandstone Formation

In the Thornhill Basin, red aeolian, dune-bedded sandstones of the Thornhill Sandstone Formation, estimated to be over 200 m thick, have been worked over many centuries at the Closeburn and Gatelawbridge quarries near Thornhill. Both sources have supplied Edinburgh with building stone.

Corncockle Sandstone Formation

In the Lochmaben Basin at the intermittently operational Corncockle Quarry, red sandstones of the Corncockle Sandstone Formation were formerly noted for the abundance of reptilian footprints found in them. Sedimentary structures include large scale aeolian cross-bedding and tabular foresets which dip up to 40° to the south-west. The vertical face of the quarry exposes up to 30m of strata. As at Locharbriggs, the uniform dip of the cross-lamination indicates that the prevailing winds transported and deposited the sands from the east-north-east.

Mauchline Sandstone Formation

In Ayrshire, the Mauchline Basin contains over 450 m of large scale cross-bedded, well-sorted, bright red, fine-grained, aeolian sandstones of the Mauchline Sandstone. Building stone was worked in several quarries including Mauchline (Ballochmyle quarries), Barskimming and Failford. The stone was much used in Glasgow. Craig lists stone from Ballochmyle Quarry as having been used in Edinburgh.

Sherwood Sandstone Group

St Bees Sandstone Formation

Early Triassic rocks outcrop in the Annan and Gretna district and form part of the sequence of strata extending southwards into the Carlisle Basin and Vale of Eden. Around Annan they are represented by unfossiliferous water-lain sandstones of the St Bees Sandstone Formation. Stone from this sequence was worked at several quarries including Annanlea, Cove at Kirkpatrick-Fleming (currently operated by Block Stone Ltd) and Corsehill, near Annan. The last-named, recently reopened during 1981 and currently operated by the Onyx Contractors, has supplied much stone to Edinburgh.

Permian and Triassic sandstone ('New Red Sandstone') of

Moray

Strata of the 'New Red Sandstone' in the Elgin district have long been quarried at Cuttishillock, Clashach, Greenbrae and Spynie. They have yielded much good stone in a variety of colours including white, red and brown. The quarries were famous for yielding fossil reptilian fauna, specimens of which may be seen in the Elgin Museum and National Museum of Scotland. Upper Permian sandstones of Cuttishillock (Quarry Wood), notable for yielding bones of the *Gordonia* fauna collected during the 19th century, range from 30 to 46 m thick and are of variable hardness. Sand grains are typically millet seed-shaped and this together with large scale cross-bedding points to an aeolian origin for the deposits. In 1976, quarries were working this sandstone at Cuttishillock. However, it is not documented whether stone from this source has in the past been supplied to Edinburgh.

On the Moray coast, the Sandstones of Hopeman (considered to be equivalent in age to those of Cuttishillock) have been used in recent years from Greenbrae and Clashach quarries. Clashach is currently supplying stone to the Stirling Stone Group for several major buildings in Edinburgh..

Upper Triassic siliceous sandstones have been worked at Spynie, Elgin. The first specimen of *Leptopleuron* (*Telerpeton*), a small lizard-like reptile was discovered at Spynie in 1851. This discovery raised the question of the true age of the reptile-bearing Elgin sandstones, which hitherto had been regarded as belonging to the Devonian Period.

Carboniferous sandstone from the Scottish Borders and England

Many quarries working Carboniferous sandstones in the Scottish Borders and England have supplied top quality building stone for Edinburgh during the last 100 years. Usage increased as locally available supplies became scarce and as transport, particularly the railway network, developed. In recent years the requirement for matching material for repair and for cladding has encouraged a steady trade in stone from England, especially that of Carboniferous age. Durable stone is found at many horizons, most notably in the Lower Carboniferous (Visean) and Millstone Grit (Namurian) sequences of Northumberland, County Durham and Derbyshire. Coal Measures (Westphalian) sandstones from Yorkshire and Tyne and Wear have also been utilised in the city.

Lower Carboniferous

Strata of Lower Carboniferous age are found over a wide area of the Scottish Borders and Northern England. As in the Midland Valley of Scotland, Carboniferous sandstones of the Northumberland - Solway Basin were deposited principally in major river systems which fed deltas in a subsiding sedimentary basin. Typically, the sandstones suitable for building stones are quartz arenites. Marine and deltaic sedimentation was initially confined to a series of troughs or basins, the principal ones being the Northumberland Trough, the Stainmore Trough and the Craven Basin. Each was partially bounded by faults, some of which were active during sedimentation. The intervening ground consisted of blocks or massifs named the Cumbrian-Alston Ridge and the Askrigg Block. These were submerged by the sea only in the late Dinantian, and thereafter, with relatively slow subsidence, remained areas of thin Carboniferous sequences. Cyclical sedimentation took place in response to changes of sea level and variation in rates of subsidence and sediment input. Sequences of sedimentary rocks, known as 'Yoredale Cycles', comprise, where complete, a marine limestone, followed by calciferous fossiliferous shale, ferruginous shale with marine fossils, silty shale, sandstone, silt-earth and coal. Each cycle is generally 15 to 30 m thick and represents the

transition from marine to terrigenous conditions. In the Northumberland Basin the cycles tend to be thinner with a larger terrigenous element representing closer proximity to land.

Cementstone Group

Rocks, roughly equivalent in age and of similar origin to those in the Midland Valley Ballagan Formation are found in the Cementstone Group of the Scottish Borders. In the Tweed Valley, the strata consist of micaceous mudstone and shale, cementstone and thin sandstone. The lithologies and restricted fauna suggest an estuarine environment in which brackish shallow-water lagoons developed. Thick cross-bedded sandstones are present in the upper part of the group and these have been worked near Greenlaw at Swinton and Whitsome Newton. Both quarries have supplied Edinburgh with stone.

Fell Sandstone Group

The geologically oldest English sandstones used in Edinburgh are found in the Fell Sandstone Group of Northumberland. The Group roughly correlates with the middle and upper parts of the Border Group of the Scottish Borders but cannot be precisely correlated because of a lack of diagnostic marine fauna." The sandstones, which were deposited as sheet sands in braided rivers, have provided a valuable source of good building stone. In Edinburgh fine representatives can be seen from a number of former quarries, notably Doddington which worked massive, cross-bedded, pink stone. Sandstone for Edinburgh was also worked at Glanton Pike.

In the Langholm district of the Scottish Borders, sandstone of the Border Group (equivalent of the Fell Sandstone of Northumberland), was formerly quarried at Fairloans, near Hawick.

Scremerston Coal Group

The Scremerston Coal Group of north Northumberland roughly correlates with the Upper Border Group of North Cumbria where typical sequences comprise limestone -shale - sandstone — seatearth - coal, Sandstones used in Edinburgh have been worked at Cragg near Bellingham, Milknock and Pasturehill quarries.

Lower and Middle Limestone Groups

These groups represent the uppermost part of the Lower Carboniferous (Visean) up to the base of the Great Limestone which is the correlative of the Hosie Limestones in the Midland Valley of Scotland. Lithologically, the groups show repeated rhythmic Yoredale cycles: limestone succeeded in turn by calcareous shale, silty shale, sandstone, seat-earth and coal. Many of the sandstones are thick, well-sorted and fine-grained and make good building stones. Edinburgh has been supplied with sandstones from the Lower Limestone Group worked at Woodburn. Stone from Blaxter and Darneys quarries has been used at various times during the 20th century. Sandstones of the Middle Limestone Group have been worked at Cocklaw, Gunnerton, Prudham and Purdovanlix and also at Denwick. Gunnerton Quarry exposes a 15 to 20 m thick coarse-grained, cross-bedded sandstone known as the Camphill Sandstone. Medium- to coarse-grained sandstones worked at Cocklaw and Prudham are situated near the top of the Group, below the horizon of the Great Limestone.

Millstone Grit

Cyclic sedimentation was maintained throughout Namurian times with the deposition of the Millstone Grit. The latter comprises sequences of thin limestones, marine and non-marine shales, sandstones and thin coals. Thick coarse-grained, cross-bedded channel sandstones are also present. Overall, the series represents a transition from the marine-estuarine conditions of the Lower

Carboniferous to deltaic and fluvial conditions of the Coal Measures.

Many quarries have exploited the Millstone Grit sandstones and those which have supplied Edinburgh include Black Pasture, Catcastle, Dunhouse, Stainton, Stancliffe, Stanton Moor, Stoke Hall, Wattscliffe and Wellfield. All are currently producing stone and many examples of their quarry products may be seen in the city. Black Pasture quarry exposes some 15m of sandstone with shelly lenticular patches, lying above the Great Limestone. At Dunhouse and Stainton, the sandstones lie between the Upper Fell Top and Grindstone Limestones and consist of up to 12 m of pale grey, fine-grained, massive or thick-bedded sandstone. The rock contains 95% free silica, with mica, feldspar and carbonaceous fragments." At Stancliffe, the local Ashover Grit comprises 30 to 120 m of buff to light grey, massive, fine to medium-grained sandstone with subordinate bands of siltstone and mudstone. It is said to be excellent for building and decorative purposes. Many quarries including Wellfield worked the Rough Rock at Crossland Hill, west of Huddersfield and, in recent years, a light brown, very durable, fine-grained sandstone under the trade name of 'Crossland Hill HardYork Stone' has been used in Edinburgh. A fine-grained sandstone from Stoke Hall Quarry, Eyam, Derbyshire has also been used in Edinburgh recently.

Coal Measures

Lower and Middle Coal Measures crop out over wide areas in Northumberland, Durham, West Cumbria, Lancashire and West Yorkshire. Deltaic and fluvial conditions prevailed in an extensive subsiding gulf. Although cycles of strata are seldom complete, the usual sequence is a marine shale, overlain by non-marine shale, sandstone, seat-earth and coal. Individual cyclothems range from 1 to 30m in thickness. The total thickness of Coal Measures strata varies from 100 to 1200m." Sandstone for Edinburgh has been wrought in Middle Coal Measures strata at Heworthburn, Springwell and Woodkirk. The last named is described as a fine-grained, fawn-brown sandstone."

Permian and Triassic sandstone ('New Red Sandstone') of England

During late Carboniferous and early Permian times the land was uplifted and erosion produced thick accumulations of wind-blown and fluvial sandstones and siltstones." Red sandstones of Permian and Triassic age crop out west of the Pennines around Carlisle in the Vale of Eden and along a coastal strip south of Whitehaven. In the Vale of Eden, the Appleby Group of Permian age comprises Brockram (a conglomerate of angular and rounded Carboniferous pebbles in a matrix of red sandstone) overlain by the Penrith Sandstone Formation. The latter (correlated with the desert aeolian red sandstones of the Dumfries & Galloway) is represented by up to 460 m of medium- to coarse-grained, generally poorly cemented aeolian sandstones. Cementation with silica is however non-uniform and locally the sandstones are well silicified. They are generally red-brown and dune bedding suggests that they were transported and deposited by winds blowing mainly from the east-south-east. The formation is worked at Lazonby, Penrith and this source has supplied Edinburgh with stone from time to time.

Higher in the sequence the Cumbrian Coast Group comprises dull red, evaporitic mudstones, thin sandstones and siltstones containing ripple marks and desiccation cracks. The overlying St Bees Sandstone Formation (Sherwood Sandstone Group) of early Triassic age comprises bright red water-lain, non-marine sandstone with beds of dull red mudstone. In Cumbria, sandstones in this formation are worked intermittently at Bankend Quarry, Bigrigg, Birkham's Quarry, Whitehaven and also at Shawk Quarry, Thursby. Red sandstones from Moat Quarry, north of Longtown, formerly supplied stone for Edinburgh.

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