# A Geological Guide to the Fossil Grove, Glasgow

by

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## About this Guide

This new booklet on the geology of the Fossil Grove is aimed everyone with an interest in geology, however slight - but it does contain more detail for students, professionals and academics alike and for whom some further reading is suggested.

A separate section on the geological framework of the Glasgow area is included, and for the beginner unfamilar with some technical terms, a short glossary is included.

This guide includes several localities in the quarry area - which is always open. The Fossil House itself is open on weekend afternoons from April-October.

The descriptions of the localities in the guide uses two font styles - *the text in italics contains the geological descriptions and interpretations at each locality*; whereas the regular font style is used for directions, history and other points of interest.

This booklet replaces two booklets (now out-of-print) produced by Glasgow City Council in 1972 and 1995. A new updated Guide to the Geology of Glasgow is being produced by the Geological Society of Glasgow - and this booklet on the Fossil Grove will form an integral part of it which will replace the out-of-print 'Geological Excursions around Glasgow and Girvan' published by the Society in 1992.

This guide has been produced by the Geological Society of Glasgow with generous support from the Fossil Grove Trust. Technical and editorial contributions from volunteers, friends and supporters are also gratefully acknowledged.

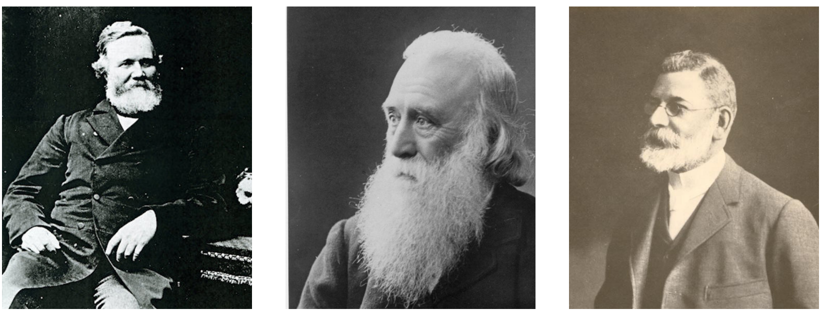

**Fig. A1.** Three Victorian 'gentlemen scientists' from the Geological Society of Glasgow who first described the fossil trees and recognised their importance. (L-R) David Corse Glen, John Young and Robert Kidston

## Introduction to the Fossil Grove

The Fossil Grove is Glasgow's oldest attraction. The spectacular fossil trees which can be seen at this site are relics of a distant past - very different from today. The city is fortunate to possess such an outstanding geological monument.

It is situated in Glasgow's Victoria Park, near the north entrance to the Clyde Tunnel. The building which protects the site is in the south-west corner of the park in a landscaped old quarry. Eleven fossil trees stumps, still in the position in which they grew, were uncovered by excavation work when the park was created nearly one-hundred and thirty years ago.

The grove of fossil trees has been carefully excavated with the trees preserved on site so that they can be viewed in association with each other and with the surrounding rock strata. The site has been recognised through its designation as a Site of Special Scientific Interest (SSSI) by Scottish Natural Heritage, who are collaborating in a new conservation effort with the Fossil Grove Trust and Historic Environment Scotland (Fig. I1)

As well as being a monument to a past geological age the Fossil Grove is a reminder of a vital aspect of Glasgow's development in the more recent past. It preserves the remains of the same forests which gave rise to the many coal seams present in the rocks underneath the city. These were once extensively worked in local pits and easy access to abundant reserves of fuel provided a major contribution to Glasgow's growth into a large and important city.


**Fig. I1.** The interior of the Fossil House. Laser-scan image courtesy of Historic Environment Scotland

## How to get to the Fossil Grove

*By Bus*

The Fossil Grove is very easy to get to by bus .There is a bus stop on Victoria Park Drive South for buses 1 (all variants) and X4. These express buses run along the Clydeside Expressway from the City Centre and their first stop is Westland Drive at Victoria Park Drive South - at the south-west corner of Victoria Park and very convenient for the Fossil Grove (see detailed map on Page 4). Buses 2 and 3 run along Dumbarton Road from the City Centre via the West End. The nearest stop for the Fossil Grove is near the petrol station on Dumbarton Road (Westland Drive at Dumbarton Road) then it is a short walk along Westland Drive to the corner of Victoria Park.

*By Train*

The nearest railway station is Jordanhill (just under a mile away). From the station follow the main road south towards the Clyde Tunnel and turn right into Victoria Park Drive North and enter the park through the main gates.

*By Bike*

National Cycle Route 7 runs alongside the Clyde from the City Centre and passes through Whiteinch.

*By Car*

There is no dedicated car park for the Fossil Grove or Victoria Park, however there are usually various on-road parking options around the park.

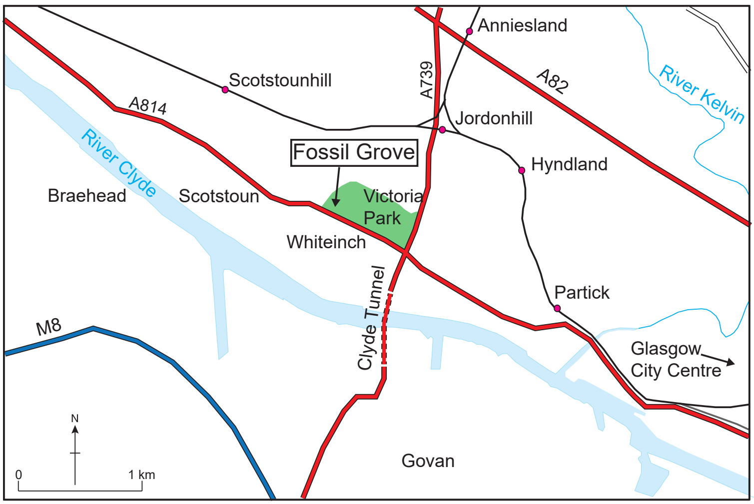


**Fig. I2.** Location of the Fossil Grove and Victoria Park.

## The History of the Fossil Grove

**Fig. I3.** Excavation of the fossil trees c. 1888.

In 1885 the Commissioners of the Burgh of Partick leased 46 acres of Scotstoun estate to form a public park. In late 1887 a path was being cut as part of the landscaping works through an old diused roadstone quarry when the first of the fossil tree stumps was uncovered (Fig. I3). By March the national newspapers were reporting on this important discovery. The Scotsman mentions “half-a-dozen tree-fossils” believed to belong to the family Lycopodii. The Partick Commissioners were told that the discovery “continued to excite great interest among scientific men, and was described as the most remarkable that had been made in the kingdom.” A contemporary report from a meeting in Kilmarnock suggested that “The forest now revealed is to Scotland what Pompeii is to Italy ...” In April 1888, a paper by Mr John Young and Mr D.C. Glen was read on the trees at a meeting of the Geological Society of Glasgow. A letter from Mr Robert Kidston of Stirling was also read out in which he reported that the trunks belong to the species *Lepidodendron veltheimianum* and the root system to *Stigmaria ficoides.* The meeting suggested that these fossils should be preserved in situ and that the area should be formed into a museum with a proper roof.

Subsequently a brick building with a glazed roof was erected in 1889 at a cost of about £400. A viewing gallery ran down the centre (Fig. I4). In the 1920s the roof timbers were replaced with metal roof trusses. During WWII, a bomb blast damaged the roof and one of the stumps. The glazed roof was eventually replaced with opaque panels in the 1970s.

**Fig. I4.** Interior of the Fossil House *c.* 1910 showing the roof timber work and the viewing gallery

The site is owned by Glasgow City Council and operated by their Land & Environmental Services Department. The Fossil Grove Trust are working with the Council to find new sources of funding to improve the overall visitor experience.


**Fig. FG1.** Geological map of the south-west corner of Victoria Park showing the location of the Fossil House and the localities described in the excursion.

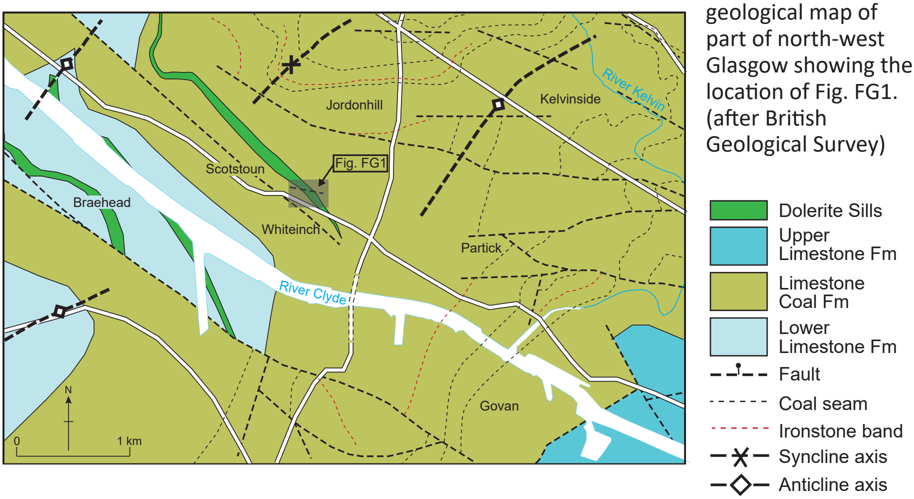


**Fig. FG2.** Simplified geological map of part of north-west Glasgow showing the location of Fig. FG1. (after British Geological Survey)

## Fossil Grove, Glasgow

Carboniferous tree stumps in their growth position in the world's oldest surving building[1] specifically designed for geoconservation. Igneous sills in the surrounding landscaped quarry area.

*Grade*: Easy.

*Terrain:* Tarmac and paving paths with some stone steps. Access to and within the Fossil House (locality 2) is level and wheel-chair friendly. Localities 1 and 3 also have level access.

*Duration*: 30 mins to 1 hour.

*Facilities:* Toilets within the building when open. Toilets near the main pond in the park are open from dawn-dusk all year.

*Access*: The park is open 24/7 but the Fossil House has restricted opening times. In 2017 these were Saturday and Sunday afternoons from April to the end of September. Check website. Admission is free.

*Dogs*: Welcome within the park

*Distance*: A circular walk around the quarry is about 400 m long - starting and finishing at the entrance notice board.

*Start*: At the entrance to the quarry [NS 5388 6724] by a notice board.

A geological map of the south-west corner of Victoria Park is shown in Fig. FG1. As well as the underlying bedrock geology, it shows the main features of the area including the paths through the park and quarry, the nearest bus stops (for the 1 and X4 buses), the location of the Fossil House, the small pond (in blue), the localities described in the text (circled numbers) and a suggested walking route between them (red dotted line).

*The strata of shales and sandstones exposed here belong to the Limestone Coal Formation of the Clackmannan Group and were deposited during the Carboniferous Period about 325 million years ago. Here they dip gently NE but in the wider area they are gently deformed into open folds and cut by numerous faults (Fig. FG2). Coal seams and ironstones occur to the north and east. The quarry is formed in an igneous dolerite sill, which was intruded into the sediments about 290 million years ago (Early Permian) and which has a thin WNW-ESE trending outcrop pattern and is cut by a E-W trending fault.*

From the display panel and map at the entrance to the quarry area follow the path for 100 m to arrive at the lycopod sculpture in the centre of a grassy area.

1 About ten fossil tree stumps were uncovered near Sheffield fifteen years before the Fossil Grove and were protected with wooden sheds. The sheds have long-since disappeared but the four remaining stumps have been preserved and re-buried.

## Locality 1 [NS 5387 6729]

Lycopod statue and main quarry.

This sculpture of a lycopod tree is made in oak and was erected in 2014 as one of a number of sculptures in Glasgow's parks commemorating the 20th Commonwealth Games (Fig. FG3). It cunningly incorporates a realistic giant centipede.

**Fig. FG3.** Lycopod sculpture and centipede.

*The cliffs around the gardens mark the eastern end of the old quarry and are composed of dolerite - a medium-grained dark igneous rock - used widely for roadstone. It was intruded in a molten state in a horizontal layer parallel to the strata. This type of intrusion is called a sill and here it is about 5 metres thick - but neither the top or base are exposed at this locality.*

Walk 50 m west to the front entrance of the Fossil House and go inside (if it's open).

## Locality 2 [NS 5383 6731]

The Fossil House.

*The fossil stumps are seen from the eastern platform and are preserved as internal casts of hollow trees which grew to a height of 45 metres (taller than the trees outside) with a straight trunk and crown of branches (Fig. FG4). Inside, the trunks were not hard and woody but filled with a soft pith.*

*The stumps are numbered 1-11 on the map (Fig. FG5). Letters A-H and X mark the positions of fallen logs and branches. The trees are assigned to the genus* ***Lepidodendron****, one of a number of lycopods of Carboniferous age and related to today's small club mosses. These are often referred to as 'scale-trees' - so called because of the scale-like markings*

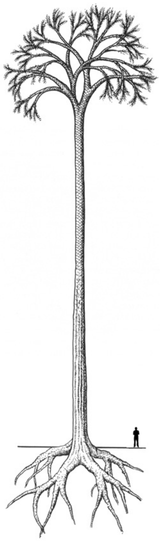

**Fig.FG4.** Reconstruction of a 'scale-tree' with its long straight trunk, a dense crown of branches and its bifurcating '*stigmaria*' root system. Each branch divides into two equal sized shoots unlike modern trees. (Note human for scale).

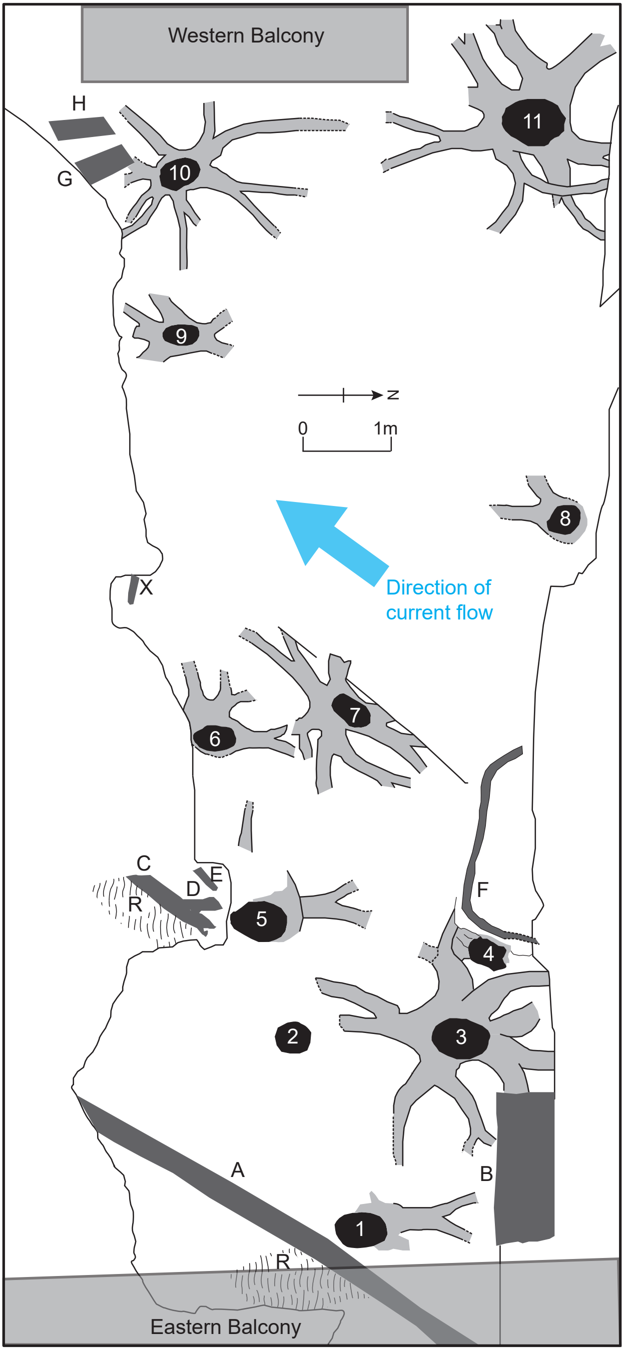


**Fig. FG5.** Map of the floor of the Fossil House (Locality 2) showing the locations of the stumps, tree fragments (A-H) and ripple marks (R). The small branch fragment at (X) has some leaf scars (see Fig. FG6). Following bomb damage Stump 9 has a concrete spacer inserted where a thin tongue of the dolerite sill cut through the stump.

**Fig. FG6.** Fragment of *Lepidodendron* from the Fossil Grove (at location 'X' on Fig. FG7) showing the distinctive pattern of diamond-shaped leaf scars. giving rise to the term 'scale trees'.

**Fig. FG7.** Stump 7 showing bifircating root systems

*left on the trunk and branches when leaves fell off (Fig. FG6). The root system, referred to as* ***Stigmaria****, have a characteristic bifurcating pattern; each of the main roots divides into two and then each also divides into two and so on (Fig. FG7). Ripple marks on some bedding surfaces (Fig. FG8 and marked 'R' on Fig. FG5) indicate a water current flow direction to the south-west. The sandstones are overlain by shales which would have been deposited as muds either in abandoned river channels or by overbank flows. Fig. FG9 illustrates the process of fossil formation. Decomposition of the soft inner tissues made the trunks hollow. Later inundation by a flood of fast flowing water depositing a thick bed of sand caused distortion of the hollow trunks and infilling with sand. With subsequent burial and lithification the trunks were preserved as internal moulds in sandstone in their life position. Stumps 3 and 7 are noticeably elliptical - like most of them - but they would have been round when alive. Although it is possible that the shape is due to later tectonic deformation, a more likely explanation is that it is caused by distortion by the fast-flowing river waters (Gastaldo 1986).*

*A cross-section through the Fossil House is shown in Fig. FG10 and shows the dip of the bedding and a possible configuration of the dolerite sill which was intruded some 35 million years later. One of these tongues cuts through stumps 8 and 9 and much of the floor of the excavated area is the top of one of these smaller dolerite sills which has cut through the root systems.*

**Fig. FG8.** Ripple marks and stump 6

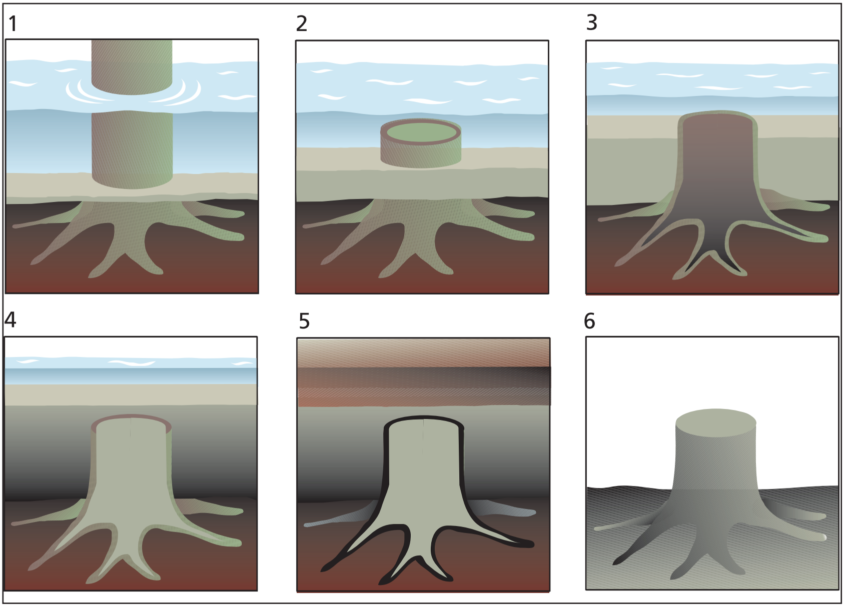


**Fig. FG9.** Stages in the process of fossilisation of the trees:

1. The living trees were killed when the area in which they were growing was flooded and the water deposited sand and mud around them.
2. The trunks projecting above the sediment broke off and were washed away.
3. The stumps decayed in the middle leaving only the outer bark.
4. More sediment was then washed into the now hollow stump and roots.
5. While deeply buried, the sand and mud were converted into solid rock and the bark to a very thin layer of coal.
6. After discovery, the rock outside the stumps and the coal layer were removed to leave the sandstone casts of the inside of the trees visible today.

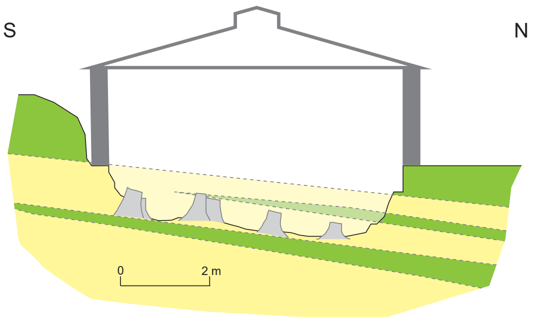


**Fig. FG10.** North-South cross-section through the Fossil House showing the tilt (dip) of the strata and a schematic configuration of the tongues of the intrusive dolerite sill

Exit the Fossil House, turn left along its northern wall to the opening of a narrow defile through the rocks on the right before the end of the building (Fig. FG11).

## Locality 3 [NS 5380 6734]

The Defile.

*The defile is cut through the dolerite of the main sill, which is well exposed in the rock faces. They are up to 5 m high and show the rock to be generally structureless (massive) with only widely spaced irregular joints and the bare surfaces allow the crystals to be seen. The paler, off-white to buff crystals are of feldspar and the rusty brown ones are pyroxene and olivine - now weathered to iron oxides and other minerals. Weathering of massive homogeneous rock such as this dolerite often results in "onion-skin" weathering where thin sheets of weathered rock peel off and the original rectangular blocks become rounded along their edges and corners. The dolerite contains some analcime (a sodium-aluminium silicate), therefore it is classified as an alkali dolerite - sometimes called a tecshenite. The analcime is often replaced by calcite. This sill is probably related to similar alkali dolerite sills of Ayrshire (Hall, et al. 1998; Monaghan & Browne 2010) and is probably about 290 million years old (Early Permian).*

**Fig. FG11.** Southern entrance to the defile (Locality 3)

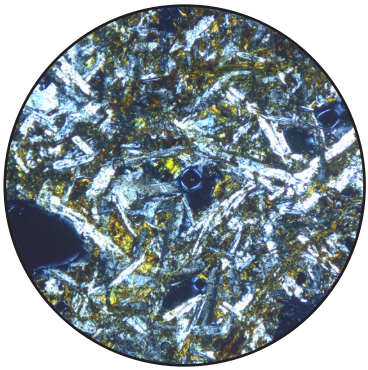

**Fig. FG12**. Microscopic view of the dolerite. Lath-shaped plagioclase with altered pyroxenes and holes which previously were filled with calcite replacing analcime.

At the end of the defile turn left at the 'T'-junction and go down the stone steps reach the pond. Cross over the pond on the stepping stones and look back at the low cliff on the northern


**Fig. FG13.** Cliff face at Locality 4 showing a sandstone bed about 0.5 m thick overlain by a cross-bedded sandstone bed. The dolerite sill forms the upper part of the cliff. The base of the sill can be followed as it dips down to the NE and a chilled margin can be observed.

side of the pond which is divided into two parts by the stone steps. Locality 4 comprises the low cliff on the left (west) of the steps and Locality 5 is the somewhat higher cliffs to their right (east).

## Locality 4 [NS 5377 6734]

North-west side of the pond

*A bed of sandstone, some 0.5 m thick, is exposed at the pond level and above it there are further thinner sandstone beds of about 0.5 m total thickness (Fig. FG13). The sandstones show traces of cross bedding - and it is likely that they were deposited as sand-bars in a large fast-flowing river system. The sill is exposed in the upper part of the cliff and its base can be followed along the cliff (and further west alongside the path that leads to the north-west exit gate) as it dips to NE at a low angle. The base of the sill has a thin (1-2 cm) chilled margin of very-fine crystals formed when the hot magma cooled rapidly on contact with the surrounding rocks during emplacement.*

Follow the path eastwards around the pond past the steps to the cliff overlooking the pond at its north-eastern end.


**Fig. FG14.** Cliff face at Locality 5 showing the thick dolerite sill, its contact with the sedimentary sequence beneath and the thin xenolithic 'rafts' (X) of sedimentary rocks caught up in the intrusion.

## Locality 5 [NS 5379 6732]

North-east side of the pond.

*The lower part of this cliff again exposes the base of the dolerite sill and the lower contact the underlying sedimentary rocks (Fig. FG14). Some thin 'rafts' of sedimentary strata (xenoliths) are incorporated within the dolerite at about 1.5 m and 2 m above the path. The sill has intruded along the bedding planes and in effect has 'jacked-up' the overlying strata.*

Return to the centre of the southern side of the pond and examine the rock faces on the opposite side of the pond from the two previous localities - the exposure is usually partially hidden by the vegetation (Fig. FG15).

## Locality 6 [NS 5379 6731]

South side of the pond

*Some 2 m of sandstones are exposed on the south side of the pond and show evidence of probable river channelling with some steeper dipping units*


**Fig. FG15.** Cliff face at Locality 6 showing a channel system developed in the sandstone sequence. The beds below the channel are cut off by the overlying channel sandstones which have a steeper dip. The thick rock unit at the base is a coarse-grained dolerite which is part of the sill complex.

*cutting across the underlying sub-horizontal layers. The base of the channel is clearly exposed and it appears to trend in a SW-NE direction parallel to the current flow. The thick rock unit at the base of the exposure is a coarse-grained dolerite which is part of the sill complex.*

*The base of the sill appears to be some 2m lower in the pond area compared to its position above these sandstones and at the Fossil House. This could be the result of fault with an approximate E-W orientation running along the south side of the pond and continuing along the northern side of the Fossil House (see Fig. FG1). The vegetation makes precise identification of its location difficult but it is likely to have a downthrow of about 2-3 m on its northern side. The fault cuts the sill, therefore it must be younger than it and is probably representative of the phase of extension that affected this area in the Permian.*

Return up the steps to the Fossil House.

# Geological Framework of the Glasgow Area

## Scotland on the Equator

The rocks around Glasgow are mainly sedimentary rocks deposited during the Carboniferous Period (approximately 360 to 300 million years ago). The Carboniferous was a time of great change in the Earth system. Rapid rises in oxygen and declines in carbon dioxide coincided with the proliferation of land plants. Scotland was part of a continent known as Laurussia (Fig. F1), which had gradually formed over the preceding 100 million years from several collisions of continents (the Caledonian Orogeny). A new Himalayan-scale mountain chain then formed as Laurussia collided with Gondwana in an event known as the Variscan Orogeny, which created the new supercontinent of Pangea. Although Scotland lay to the north of the collision zone in an area of shallow seas close to the equator, the orogeny caused sedimentary basins to develop on its northern flank which were accompanied by folding, faulting and significant volcanism.

## Sediments and Volcanoes

About three thousand metres of strata from this period are preserved in the Glasgow area (Fig. F2). There is a gradual upwards transition from unfossiliferous red sandstones of the Stratheden Group to mudstones and sandstones of the Inverclyde Group. They were mainly deposited in major easterly-flowing river systems in generally arid conditions at the very end of the Devonian period extending upwards into the early Carboniferous. A

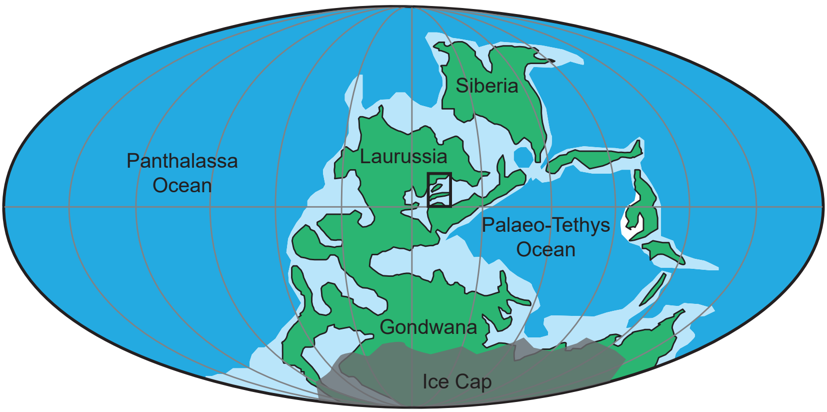


**Fig. F1.** A global palaeogeography for the Carboniferous. The boxed area highlights the location of the British Isles close to the equator (see Fig. F4). Gondwana and Laurussia are in the process of colliding, eventually resulting in the creation of the supercontinent Pangea. The southern part of Gondwana was covered in extensive ice sheets which had a major effect on the sea levels at this time.

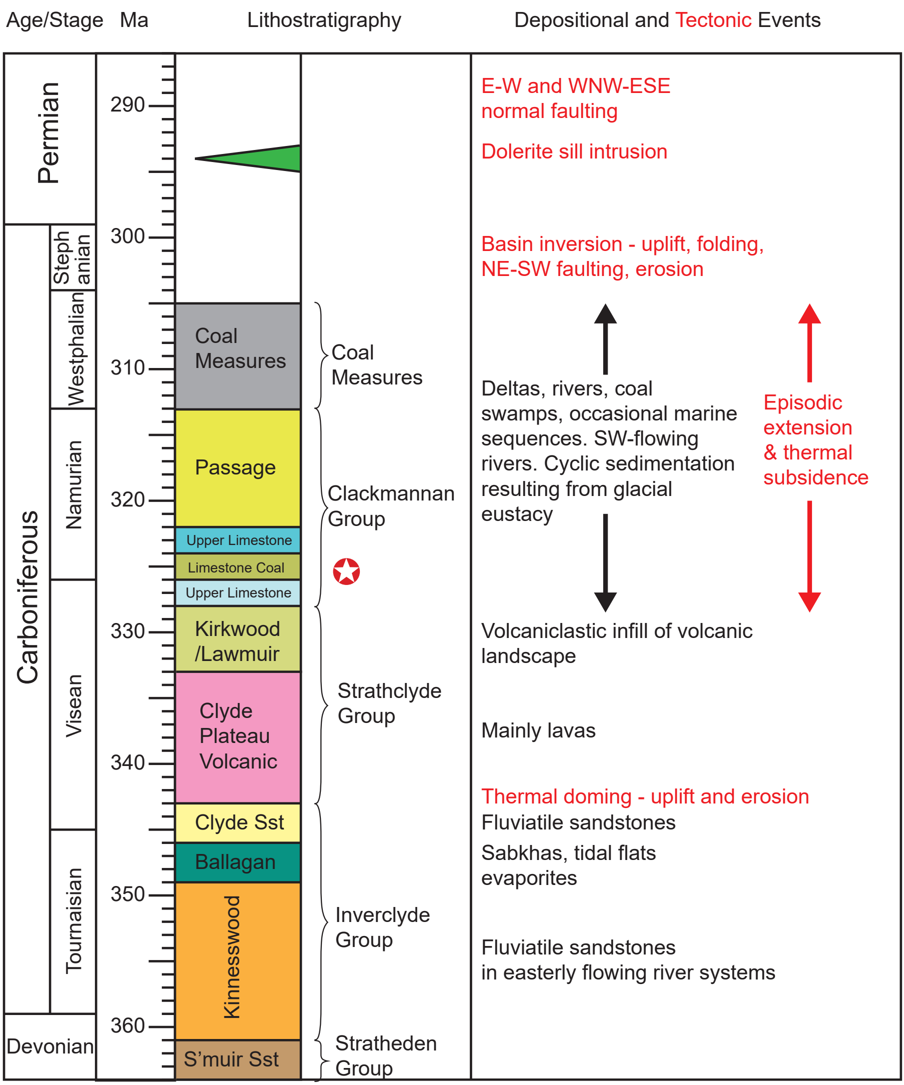


**Fig. F2.** Summary of stratigraphy of the rocks of the Glasgow area. Some 3000 m of rocks were deposited in five Groups ranging in age from the end of the Devonian through the Carboniferous and into the early Permian. Depositional and tectonic events are also shown. We = Westphalian, St = Stephanian, LL = Lower Limestone, LC = Limestone Coal, UL = Upper Limestone.

major volcanic episode then followed with the deposition of thick sequences of lavas and accompanying volcanic debris of the Strathclyde Group. The overlying Clackmannan Group comprises cyclic sequences of sandstones, siltstones, mudstones and thin limestones with some coals and ironstones which has been divided into four formations. Limestones, many of them fully marine, characterise the Upper and Lower Limestone Formations, whereas the intervening Limestone Coal Formation (despite its name) has no limestones. The overlying Passage Formation is dominated by sandstones and passes upwards into the Coal Measures – more cyclic alternations of mudstone, siltstone, sandstone and coal which is divided into three formations by 'marine bands' – thin beds of mudstone containing distinctive marine fossils which can be recognised at other localities and hence correlated.

Deposition was controlled by crustal extension and fault movements in conjunction with thermal subsidence. Sea-level also rose and fell as the Gondwana ice-caps expanded and retracted in a cyclic manner. Towards the end of the Carboniferous there was a significant period of tectonic activity related to the Variscan Orogeny. Many of the faults were reactivated (inverted) and NE-SW trending folds developed resulting in uplift and erosion of the strata. In the early part of the Permian igneous sills were intruded in several phases in central Scotland; the dolerite intrusions exposed in the Glasgow area are probably about 294 million years old and part of a major episode of igneous activity centred on Ayrshire and Renfrewshire. Some faulting, mainly E-W trending, followed this igneous activity.

## The Midland Valley 'Graben'

The Glasgow area was part of a series of fault-bounded depositional basins sandwiched between the Highland High to the north and the Southern Uplands High to the south (Fig F3). These highs were bounded by major faults (such as the Highland Boundary Fault and the Southern Uplands Fault) and strike-slip movements on these were probably responsible for the creation of the Midland Valley graben. Major braided river systems flowing towards the south-west brought in sediment mainly from the north-east and filled the developing depocentres.

## Swamps, lakes, rivers and floods

The complex array of the sediment types and depositional environments prevalent during the Namurian and Westphalian is summarised on Fig. F4. The sediments were brought into the coastal plain by a complex array of rivers with numerous braided and meandering channels which deposited sands in the channels and finer overbank deposits of siltstone and mudstone at times of flood which formed natural levees. These channels were surrounded

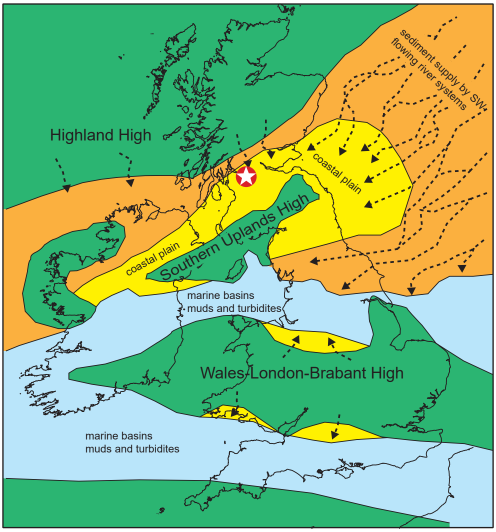


**Fig. F3.** Palaeogeography of the Upper Carboniferous of the British Isles. Glasgow (marked by a star symbol) was situated on a coastal plain in the Midland Valley graben.

by shallow fresh or brackish lakes (often stagnant with iron enrichment) which sometimes were inundated by the sea (forming marine bands) or sometimes became filled-up with sediment allowing land plants to colonise them in the humid equatorial conditions. These swamps became the sites of thick peat deposits which eventually became coal seams. Occasionally the levees were breached causing floods of sand to be spread either into the lakes as lacustrine deltas or onto the marshy areas as crevasse splay lobes. This is the mechanism believed to be responsible for the formation of the Fossil Grove. Many types of sediment could thus be deposited at the same time (diachronous) resulting in difficulty in tracing (correlating) individual beds of rock over long distances

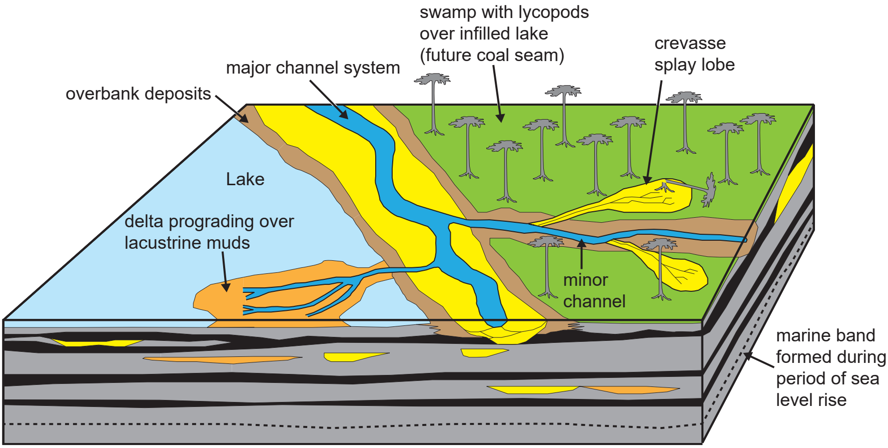


**Fig. F4.** Schematic model of the depositional systems prevalent during the Namurian and Westphalian of the Glasgow area. A minor channel has been breached during a flood and has deposited a sand-bed over the swamp, knocking down trees in the process. This is how the Fossil Grove formed.

## Carboniferous Fossils

Fig. F5. *Arthropleura* - a giant 2 m long early arthropod. Note human hand for scale.

No fossil animal remains have been found at Fossil Grove itself. However, finds from elsewhere in rocks of the same age show that many creatures lived in and around the coal age forests. Freshwater mussels and fish inhabited the pools and lagoons. Amphibians also lived in these waters and on land. Spiders, scorpions and many different insects thrived in the tropical conditions. There were no bird predators and oxygen levels were high, so insects and other related animals grew very large. These included huge dragonflies with 70 cm wingspans and *Arthropleura* - a 2 m long millipede-like animal which is the largest invertebrate of all time (Fig. F5).


**Fig. F6.** An ammonoid (goniatite). Fossils of these ancestors of the ammonites can be found in the marine bands throughout the Carboniferous and are extremely useful in stratigraphic analyses

Ammonoids (also known as goniatites) are marine molluscs found in the 'marine bands' (Fig. F6) and are ancestors of the more familiar ammonites. They evolved quite rapidly and the different species have been used successfully to trace individual marine bands in Scotland and further afield.

Internationally important fossils have also been found in rocks of this age in Scotland. The 'Bearsden Shark' (Fig. F7) is unique and still no-one is quite sure what function the strange appendage on its head was for. One of the earliest known reptiles in the world (*Westlothiana lizziae*, Fig. F8) was found in rocks of this age near Bathgate and is possibly the earliest ancestor of the dinosaurs.

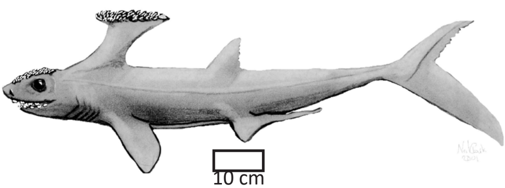


**Fig. F7.** A reconstruction of the 'Bearsden Shark' *(Akmonistion zangerli)* from the Limestone Coal Formation in Bearsden. The fossil is now in the Hunterian.


**Fig. F8.** A reconstruction of *Westlothiana lizziae* - possibly the earliest known ancestor of the dinosaurs.

# Glossary

## A

Anticline: a fold that is convex up and has its oldest beds at its core.

## B

Braided river: a river system comprising a network of small channels separated by small and often temporary islands called braid bars. Braided rivers occur when the sediment load is large.

## C

Carboniferous: a geologic period and system that extends from the end of the Devonian Period, about 359 million years ago, to the beginning of the Permian Period, about 299 million years ago.

Correlation: the process used to understand relationships between strata at different localities.

Cross-bedding: a sedimentary structure, particularly common in sandstones, produced by deposition on what were originally inclined surfaces, such as the faces of dunes, bars and megaripples, and which now lies at an angle to the bedding planes.

## D

Delta: a sediment accumulation that forms when a river deposits its sediment load on entering a sea, ocean, lake or reservoir.

Diachronous: term applied to a a sedimentary rock formation in which apparently similar material varies in age from place to place

Dolerite: a mafic, crystalline, sub-volcanic rock equivalent to volcanic basalt or plutonic gabbro.

## E

Evaporite: a sedimentary rock that results from concentration and crystallization by evaporation from an aqueous solution.

## F

Fault: a planar fracture or discontinuity in a volume of rock, across which there has been significant displacement as a result of earth movement.

Feldspar: a group of rock-forming silicate minerals that make up about 60% of the Earth’s crust. There are two main types, Plagioclase containing calcium and sodium and Orthoclase containing potassium.

## I

Inversion: the relative uplift of a sedimentary basin or similar structure as a result of crustal shortening. An extensional fault is considered to be inverted if it is reactivated in the opposite direction to its original movement.

## J

Joint: a break (fracture) of natural origin in the continuity of either a layer or body of rock that lacks any visible or measurable movement across it. Although they can occur singly, they most frequently occur as joint sets and systems.

## M

Ma: abbreviation used widely by geologists for million years ago or million years.

Magma: a mixture of molten or semi-molten rock, volatiles and solids that is found beneath the surface of the Earth.

Mudstone: a fine-grained sedimentary rock whose original constituents were clays or muds.

## N

Normal fault: a fault which drops rock on one side of the fault down relative to the other side. It dips in the direction of the downthrown side and indicates extension.

## O

Orogeny: the forces and events leading to a large structural deformation of the Earth's lithosphere (crust and uppermost mantle) due to the movement of tectonic plates. The process of mountain building is called orogenesis.

## P

Palaeomagnetism: the study of the record of the Earth's magnetic field in rocks. Certain minerals lock-in a record of the direction and intensity of the magnetic field when they form. This can provide information on the past location of tectonic plates.

Plagioclase: a series of silicate minerals in the feldspar family. The series ranges from albite to anorthite where sodium and calcium atoms respectively substitute for each other in the crystal lattice.

Pyroxene: an important rock-forming silicate mineral found in many igneous and metamorphic rocks.

## R

Radiometric dating: a technique used to date materials such as rocks or carbon, usually based on a comparison between the observed abundance of a naturally occurring radioactive isotope and its decay products, using known decay rates.

## S

Sill: a tabular sheet of rock that has intruded between older layers of sedimentary rock, or even along the direction of foliation in metamorphic rock.

Syncline: a concave-up fold with younger layers closer to the centre of the structure.

## V

Variscan Orogeny: an extensive and long-lasting mountain building era which occurred from the Devonian to the Early Permian, c. 400-270 million years ago. It was caused by the collision of the continents of Laurussia and Gondwana.

## Fossil Grove

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