Special Report of the

Reading Geological Society

Field Trip to Edinburgh

GEOLOGY OF THE MIDLAND VALLEY OF SCOTLAND

21st – 25th September 2021

Contents

Introduction

This Reading Geological Society Field Trip to Edinburgh, on 21st to 25th September 2021, was led by Angus Miller of Geowalks (Ref. 1) who organised the 5 day itinerary. He had previously, in February 2021, given us a Zoom lecture on the geology of Edinburgh, Fife and east Lothian. He now provided us, in advance, with a handout "Reading Geological Society visit to Central Scotland, September 2021" (Ref. 1) describing the Edinburgh, Holyrood Park, St. Andrews and Siccar Point sites to be visited and also provided references to three teachers' guides to Queensferry, Kinghorn and North Berwick that we could download. He also provided detailed leaflets to Holyrood Park, Dunbar, North Berwick and Siccar Point. Those articles contain a lot of detailed information which support, but is not necessarily included in, this report. A detailed list is given in the References section.

Angus also supplied the "Geowalks Booking & Medical Form" and "Geowalks Risk Assessment" to ensure that we understood and accepted the natural and Covid-19 related risks and Scottish regulations.

With the sites visited spread over such a wide area the References section also contains a list of 1:50,000 OS Landranger maps with grid references to 10 km squares containing the sites.

The party, consisting of Ailsa Davies, Sue Barr, Ricki Bull, Pam Goldstone, Carole Gregory, Hilary Jensen, Roger Lloyd, Peter Worsley and Roger York, had made their ways to Edinburgh on the Sunday and Monday to be ready for the start of the trip on Tuesday, 21st. (Unfortunately, Pip Taylor and David Ward had had to pull out at the last minute.)

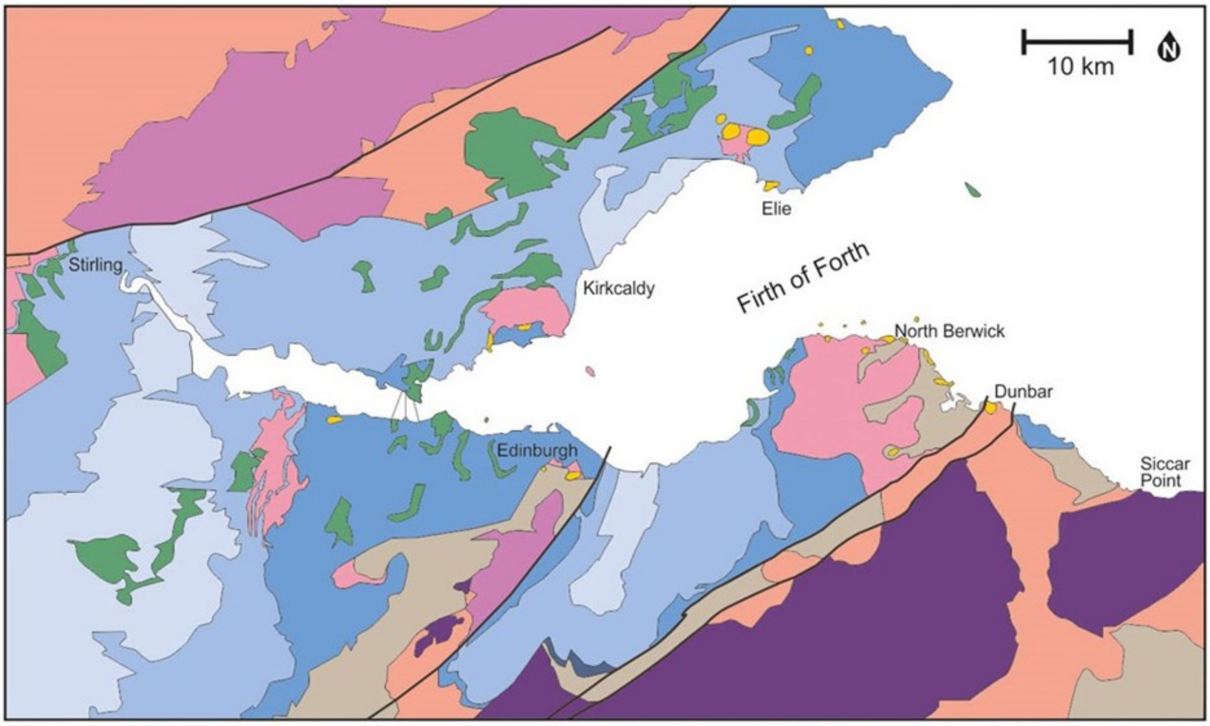
Five members of the party each agreed to note and write-up the events of one day. The photographs and the copyright are by the authors for the day unless otherwise stated. The maps are reproduced with permission from Edinburgh Geological Society.

The trip was organised by David Ward and Carole Gregory who arranged the leader, accommodation and coach travel to achieve a most successful week enjoyed by all.

Summary of the Geology

The Caledonian Orogeny was the result of the collision of the continents of Laurentia (North America, Greenland, Scotland) and Avalonia (Southern Britain) about 465-480 Ma and raised mountains in northern England and Scotland. Most of the area of this field trip is part of the Midland Valley terrane which rifted apart the Scottish Highlands from the Southern Uplands about 440 Ma. Those Caledonian mountains were the source of much of the sediment in the Midland Valley. The rifting was also the cause of much volcanism with vents, extrusive lava, ash and agglomerate and intrusive igneous rocks. The rifting eventually failed so the British Isles remained intact.

The earliest rocks seen were the Silurian and Devonian in the Southern Uplands but the bulk of the rocks were from the Early Carboniferous in the Midland Valley – sandstones to mudstones, limestones and, between them all, intrusive and extrusive volcanics.



Summary geological map of the Edinburgh area (from www.edinburghgeolsoc.org) (Ref. 2). The map shows the extent of the sites to be visited, from St. Andrews in the north to Queensferry in the west, Siccar Point in the south-east and the others in between.

Day Reports

<u>Tuesday September 21st 2021</u>

This day was to be spent on an illustrated geological walk in Edinburgh City Centre (including Castle Rock, Royal Mile, building stones and James Hutton Memorial Garden), and Holyrood Park (Arthur's Seat volcano, basalt lava flows, volcanic vent, Salisbury Crags intrusion).

The group met with Angus Miller of Geowalks and the University of Edinburgh and he welcomed us to Edinburgh. We started our day in the Meadows to the south of Old Town and discussed the interaction of geology, landscape and people in Edinburgh. The east-west “grain” of the landscape is the result of ice movement from west to east from the southern Highlands along the Forth Valley and we will see many features of this over the next few days. The Meadows lies in a low-lying elongated east-west valley that was drained in the seventeenth century for a park alongside the housing development in Old Town to the north.

At the western end is a large sundial (Figure 1) known as the ‘Prince Albert Victor Sundial’ which was erected to commemorate the opening of the International Exhibition of Industry, Science and Art in 1886. There are several types of sandstone represented in the building stones used in its construction, and the names of the quarries in Scotland and the north of England and the masons’ marks are inscribed on some of them.

Figure 1: Prince Albert Victor Sundial

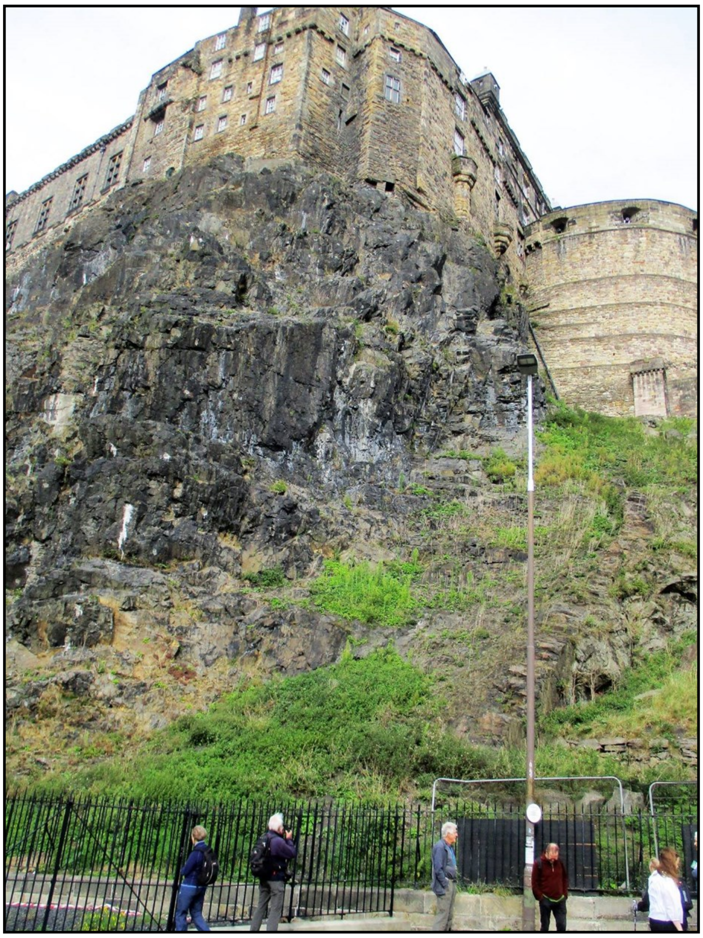
We walked north into the residential area formed of eighteenth and nineteenth century “Tenement” buildings that characterised this area of Edinburgh. These are four or five story terrace buildings, where a central staircase linked all the flats, and often where various social classes, tradesmen and professionals shared the same buildings. Here they were constructed from light coloured, cream or grey sandstones of Carboniferous age from local quarries to the north of the city. The building stones are mostly dressed, sometimes in situ. We walked along Lauriston Place and turned along Keir Street to the Vennel.

We were at the edge of the Old Town and walked northwards along the Vennel by one of the old town walls, the Flodden Wall. After the Battle of Flodden in 1513 an English invasion was expected and a new town wall was commissioned but not completed until 1560. The wall is about 6m high, and had been restored on multiple occasions; of the original four town walls, parts of the Kings walls, the Flodden wall and the Telfer wall remained.

From the Vennel is the iconic viewpoint of Edinburgh Castle, with the Flodden Wall on the right. (Figure 2) Castle Rock is a very prominent landmark in Edinburgh, crowned by Edinburgh Castle. The hill measures some 300 by 200 m and is about 40–50 m high. There has been a castle here since the twelfth century, but by seventeenth century it had become a military garrison and still is today. It is Scotland's most visited attraction and is now in the care of Historic Environment Scotland.

Figure 2: View of Edinburgh Castle from the Vennel

The solid strata of the Edinburgh area were formed during the Devonian and Carboniferous Periods. Devonian volcanic rocks lie to the south of the city, and the city centre is underlain by early Carboniferous sediments. It was a low-lying coastal area with sand and mud accumulating. Volcanic eruptions began with the formation of Castle Rock around 342 million years ago, closely followed by Arthur's Seat. These were small, short-lived basaltic volcanoes; what we see now has been heavily altered by fault movement, folding of the strata and erosion. (See map in Summary of Geology). Around 1000m of volcanic rock have been eroded from above Edinburgh Castle, the plug that we see now formed deep underground and almost nothing remains of the surface eruptions. There is no evidence of a conduit reaching the surface and no connection with this intrusion and any lava flow in the area as was once previously thought.



We crossed Grassmarket noting the microgranite paving and walked up Granny Green's Steps to Johnston Terrace at the junction of Lower Carboniferous sediments and the basaltic plug of Castle Rock. (Figure 3) Looking to the west are well jointed cliffs of the plug; looking east are the gently dipping sandstone and mudstone sedimentary rocks. The margin was clearly visible and showed some alteration. Glacial erosion in the Pleistocene changed Edinburgh's landscapes dramatically and the feature of Castle Rock is a classic crag-and-tail formation, with ice moving down the Central Valley from the west - the castle standing on the basalt "crag" and the Royal Mile has been built along the "tail" of Lower Carboniferous sandstones and mudstones.

Figure 3: Castle Rock: Edinburgh Castle on the dolerite plug

Walking eastwards along the Royal Mile we noted the building stones, the architecture and other features of the townscape, and passed St Giles Cathedral. The pavements were of great interest, recent improvements used Devonian sandstones from Caithness complete with occasional fossil fish. Turning south on St Mary's Street and the Pleasance we reached our next destination - tucked away is a garden dedicated to the memory of James Hutton, the founder of modern geology.

Figure 4: *"…no vestige of a beginning – no prospect of an end"* are the famous words of James Hutton, the founder of modern geology.

Plaques in the garden dedicated to his memory.

Angus gave us a short history saying that Hutton (1726 – 1797) had studied chemistry and medicine at the universities of Edinburgh, Paris and Leiden then in mid-1750 returned to Edinburgh and resumed chemical experiments with close friend, James Davie. Their work on production of sal ammoniac from soot led to their partnership in a profitable chemical works, manufacturing the crystalline salt which was used for dyeing, metalworking and as smelling salts. This provided him with an income for the rest of his life to immerse himself initially in agriculture and farming, and then into geological studies. From the early 1750s to 1770 he lived on his inherited Berwickshire farm of Slighhouses then moved into Edinburgh to a house he had built on St Johns Hill overlooking Salisbury Crags. He made many field excursions and from his studies of the landscape and coastlines he developed his "Theory of the Earth" that geological features could not be static but underwent continuing transformation over indefinitely long periods of time. From this he argued, contrary to conventional religious tenets of his day, that the Earth could not be young. He was one of the earliest proponents of what later became known as uniformitarianism which explains features of the Earth's crust as the outcome of continuing natural processes over the long geologic time scale.

Also in the garden there was a Reading University connection. A wooden seat served as a memorial to Norman Butcher who was a lecturer in geology in the 1960s. (I remember his lectures in geological mapping!) He was instrumental in creating the Hutton Garden.

From here, the next stop was at the entrance of Holyrood Park, passing the Dynamic Earth Exhibition centre, which was sadly closed. After a walk around the outside of the impressive Holyrood House we entered the park via St Margaret's Well.

Angus painted a picture of the area some 342 +/- 1MA being a low coastline and shallow seas with deposition of sandstones and mudstones when the volcanic activity commenced from Arthur's Seat Volcano. This was small in scale, mostly phreatic explosions, with basaltic lavas and ash. The Salisbury Crags dolerite sill was intruded about 8M years after the Arthur's Seat volcano ceased erupting. Subsequent tectonics gave the gentle regional dip to the east.

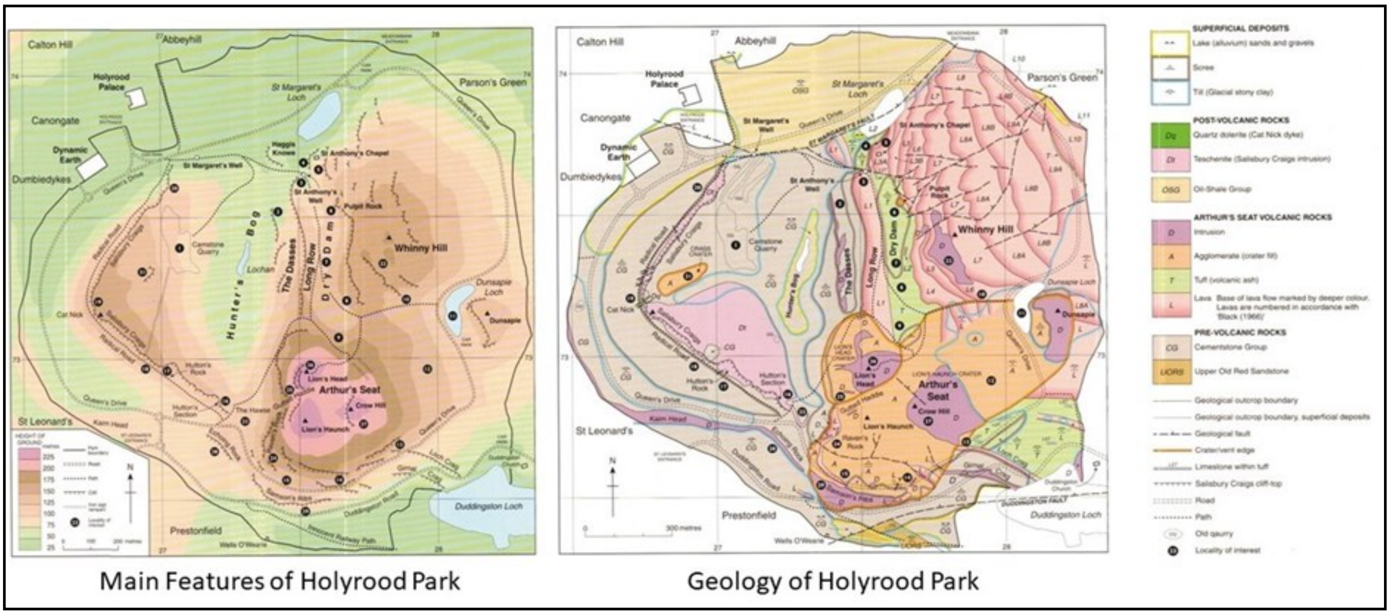


Figure 5: This shows two maps of Holyrood Park to give an idea of the features and the geology of the park. The maps are reproduced from and may be seen in a readable size in the leaflet "Discovering Edinburgh's Volcano" (Ref. 3) or in :- https://www.edinburghgeolsoc.org/publications/geological-excursion-guides/ .

Our first stop in the park was at Camstone Quarry on the north eastern facing slopes of Salisbury Crags overlooking Hunter's Bog. Exposures of Lower Carboniferous sandstones and mudstones were examined showing ripple marks and mudcracks. (Figure 6). We also saw numerous burrows and concretions and other sedimentary features, further evidence of the shallow marine environment. Sandstone was extracted from here between 1529 and 1536 to build Holyrood Palace. The quarries were last used at the end of the nineteenth century.

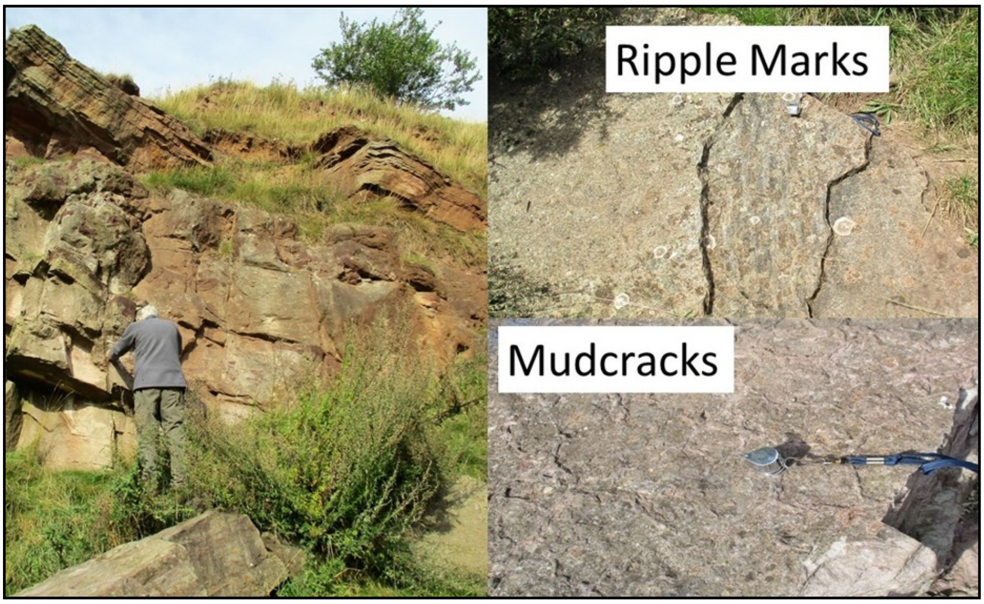


Figure 6:

Camstone Quarry

From here we had an excellent view across the park to Arthur's Seat. (Figure 7) In the foreground is the low-lying are of Hunter's Bog and the shallow scree and vegetation slopes of the Dasses. Many lavas have been identified, the oldest being Long Row lava, and overlain by Dry Dam ash and then by a series of Whinny Hill lavas. Lion's Head and Lion's Haunch are composed of agglomerate which is the debris that filled the crater when the volcanic activity ceased. Glaciation has moulded the landscape giving rise to the current morphology.

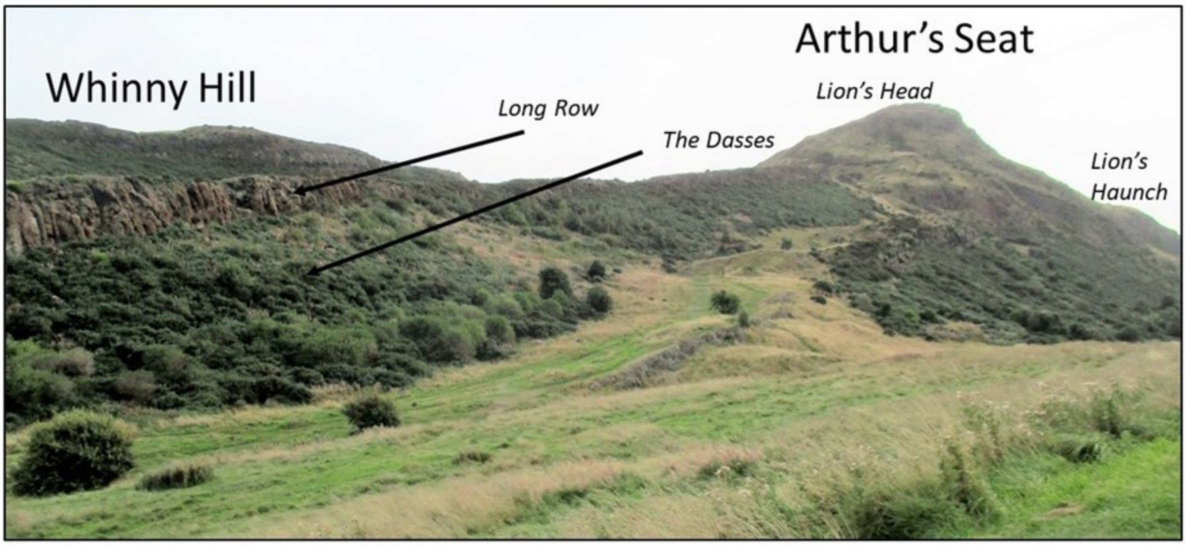


Figure 7: Arthur's Seat

The basalt crags in the Dasses were the next stop and there was some discussion about whether the markings were due to ice erosion but the received wisdom is that they are flow lines as a result of basalt intrusion. (Figure 8)

Figure 8: Flow lines in the basalt crags in the Dasses

James Hutton's section was of great interest to many but the Radical Road leading along the bottom of Salisbury Crags was blocked due to "high risk of rockfall". However, we managed to get a view of the iconic section. The contact between the dolerite sill that forms the crags and the sedimentary strata was noted by Hutton and used as evidence in his Theory of the Earth. (Figure 9)

Figure 9: James Hutton's section

We continued on our Geowalk and passed round the base of Arthur's Seat onto Queens Drive and discussed the good view over to the Pentland Hills to the south. We examined the outcrops along the road examining the crater agglomerate; it is composed of clasts of basalt in an iron-stained matrix. We also noted striations on bedrock beside the road and the effect that glaciation had on this landscape, stripping away the softer rocks. (Figure 10)

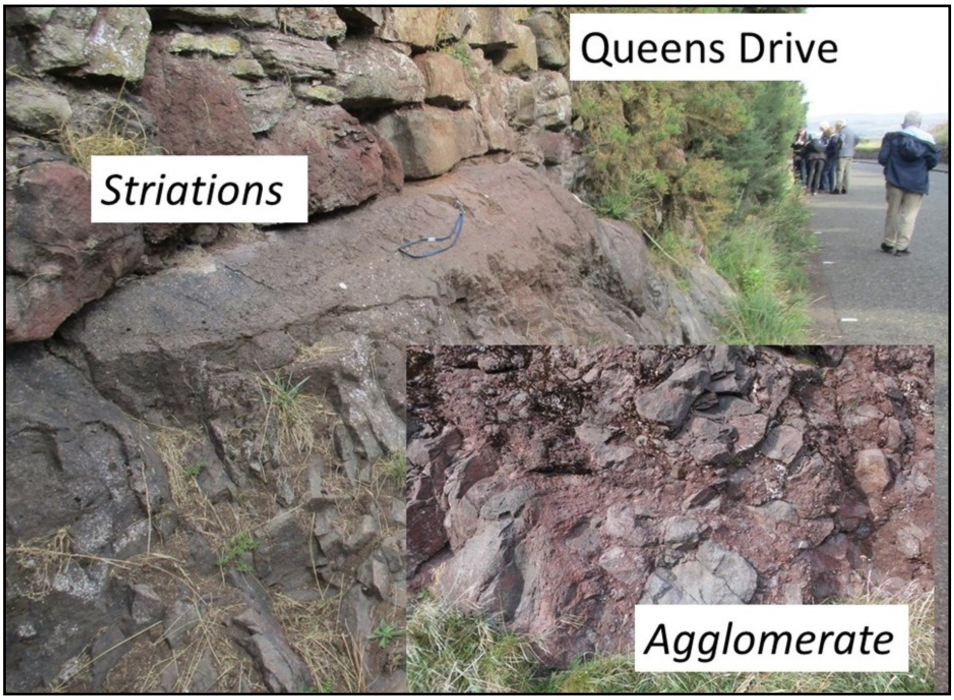


Figure 10: Queen's Drive - ancient volcanics and recent glaciation.

As we left the park, we had a great view of Lion's Head and Lion's Haunch behind us. (Figure 11)

Figure 11: Lion's Head and Lion's Haunch

Reported by Hilary Jensen

Wednesday September 22nd 2021

The aim of the day was to look at a Carboniferous coastal succession, some lava flows and intrusions working on both the south and north shores of the Firth of Forth - Queensferry and Kinghorn. It also included two crossings over the Forth Bridge by train.

Morning - South Shore – Queensferry (OS map 65 NT 137784 to 148792)

The itinerary and the geology are described in detail in Ref. 5: "The South Queensferry Shore A Teacher's Guide". The Lower Carboniferous rocks of this area were formed around 350 million years ago and dip to the west. The succession of the Lower Carboniferous Strathclyde Group is as follows:

West Lothian Oil-Shale Formation	Dunnet Sandstone
	White Trap, sandstones, & lagoonal cementstones & hornfels sedimentary rocks
	Pumpherston Shell-bed
	Oil-shale and Queensferry Cements
Gullane Formation	Faulted sandstones and mudstones
	Indurated mudstones
	Alkali-dolerite sill
	Quartz-dolerite sill

We started the day with a train journey from Edinburgh to Dalmeny station for South Queensferry on the shores of the Firth of Forth where we spent the morning. Here, three bridges cross the firth; the iconic Forth Bridge (also known as the Forth Rail Bridge), the Forth Road Bridge and the Queensferry Crossing. These bridges were built at this point not only because the firth is fairly narrow but a dolerite ridge provides solid foundations. The rail crossing was being planned when the Tay Bridge disaster took place resulting in the design of the Forth Bridge being over engineered by the same architect. The Aberdonian granite piers are filled with other rocks including some limestone which causes a white stream of calcite to seep from the joints of the piers.

Figure 1: The three Forth bridges

From the station we walked down a long flight of steps through the woods to the shore under the Forth Bridge. Our first stop was to look at the Dunnet sandstone a few hundred metres east of the bridge; some was river lain and some deltaic. The sequence was initially yellow sandstone deposition followed by swampy conditions. We observed ripples, cross bedding and plant remains. *Calamites* were abundant here but there are no stumps remaining. *Stigmaria* and Lepidodendron were, however, found.

Figure 2: Impression of *Lepidodendron* in the Dunnet Sandstone (RY)

Walking eastwards we then stopped to look at the cliff and a sequence of sandstone and mudstone with a white bed. This is not part of the sedimentary sequence but an altered basalt sill. Minerals in the sill had reacted with the organic sediments and were replaced by Calcium Carbonate ($CaCO_2$), iron and clay minerals to produce the 'White Trap'.

Figure 3: The White Trap *in situ*

Further along the cliff we came across the oil shale beds. There are some 20 bands which were mined both at the surface and underground to extract the oil for lighting. Parrot coal was also mined here; this is very poor coal - it only just burned cracking loudly like a parrot! It was used to obtain gas.

The oil shale industry came to end when North Sea oil came on-stream.

At the point at the end of this bay stromatolites are exposed; these formed in the early Carboniferous.

Walking on we entered the Dalmeny Estate at the Long Craig Gate stopping to look at the highly folded sandstone layers of the pier before walking through the estate to investigate the dolerite sill south west of Hound Point. This is quartz-dolerite intruded during the Upper Carboniferous with alkali feldspar, pyroxene and olivine. We saw some 'titan' augite crystals in a feldspar matrix. Towards the end of this intrusive period the veins became more silica rich.

At this point we returned back to South Queensferry, climbing back up the hill to catch a train to Kinghorn travelling over the majestic Forth Bridge.

Afternoon - North Shore – Kinghorn (OS map 66 NT 275873 to 279882)

After admiring the view across the Forth to Edinburgh, the Bass Rock and Berwick Law, we walked eastward along the coast and down to the shore to work our way northwards up the succession. This was described in Ref. 6: "Teacher's Guide: Higher & Intermediate 2 Kinghorn, Fife". The coastal path is a on a raised beach which can also be seen on the southern side of the Forth. The rocks here are at the top of the Strathclyde Group.

Our first stop was a basalt lava flow, with a soil horizon within and topped by tuff.

This flow is the same age as Arthur's Seat visited yesterday, Carboniferous about 300 million years ago so part of the Hercynian Orogeny. All the volcanic activity in this area is linked to the Midland Valley Rift which is bounded by the Highland Boundary Fault to the north and the Southern Upland Fault to the south. The rifting was slow, relative to the East Africa Rift for example, the rifting here lasting from the Devonian through to the late Carboniferous.

The sequence we looked at was as follows:

Limestone
Mudstone
Seat-earth
Tuff
Basalt lava flow
Soil horizon
Basaltic lava flow

Figure 4: Ailsa pointing at he soil horizon (HJ)

Looking at part of the lower part of the basalt flow there was some discussion about the rounded formations as to whether it was onion skin weathering or pillow lavas. It was generally accepted that they are pillows formed under water.

The soil horizon is a formed from volcanic ash that had been subject to a substantial period of tropical weathering.

Stretched vesicles were seen on the top of the basalt flow filled with minerals, amygdales; calcite, barite and chlorite. The basalt is also columnar jointed in places so must have cooled slowly.

The ash is a green tuff. This was been laid down in reducing conditions under water.

Walking further east we stopped to look west, this area used to be a coal field now the land has been re-generated. At our next stop we encountered the dolomitised limestone on the beach. Due to the dip of the rocks (approximately 20 degrees to the east it was determined that these rocks lay above the tuff looked at previously.

Figure 5:

The dolerite sill showing the dip

Burrows, brachiopods and corals were found, with bivalves in the mudstone below

Figure 6: Figure 6: Coral *Syphonodendron* in the limestone.

Wednesday’s visit to Fife ended as we boarded the train back across the Forth Bridge.

Reported by Ailsa Davies

Thursday September 23rd 2021

Today we had the luxury of a mini coach to take us on the two-hour journey to St Andrews, stopping off in Elie to view the diatreme at Elie Ness.

Elie Ness (OS map 59 NT 49570 99393)

A short walk from the main street took us to the harbour and then across the headland to our objective. The diatreme is one of many in this area and is mainly composed of tuffs with small intrusions of basalt dykes and evidence of country rocks within the matrix. It experienced a long history of eruptions and infill from Late Carboniferous to Early Permian times.

This diatreme is known for the existence of the 'Elie Rubies' or more accurately pyrope garnets, which are found in this location. Unfortunately none were found, although we all had a good look.

Figure 1: Angus inspecting the diatreme (and looking for "rubies")

We were only able to examine the rocks briefly, owing to both tide and time and spent most of our time there looking for 'rubies', but a research paper 'Eruptive history of an alkali basaltic diatreme from Elie Ness, Fife, Scotland' can be found on https://www.researchgate.net (Ref. 7). (Also see Ref. 8.)

St Andrews (OS map 59 NO 51244 16910 – Castle)

We began our visit at **St Andrews Castle** and the **University of St Andrews Wardlaw Muse-**

Figure 2: St. Andrew's Castle

The castle sits on a headland of Carboniferous sandstone overlooking the North Sea. It has a long history and had been destroyed and rebuilt during the wars of Scottish Independence during the 14th century and again later. By the middle of the 17th century it had become beyond repair and the stone of its walls used for repair of various other buildings, all that remains is now maintained by Historic Environment Scotland.

The museum is relatively tiny, but inside there was a small section with information about the local geology and also much to our surprise a cabinet containing flint hand axes and scrapers collected in Happisburgh, Norfolk.

Figure 3: Flint implements in the museum

Maiden Rock Syncline and Sea stack (OS map 59 NT 526159)

We then began our walk south along the sea front and the coast path, stopping on occasion to view the folded strata on the beach. The rocks here are of Carboniferous sandstone which have been subject to a later period of folding forming the Maiden Rock Syncline. The western limb of the fold was steepened so much that it overturned and now dips towards the east.

An old sea stack – the Maiden Rock, which was formed when the sea was 4 metres higher than now, consists of vertically dipping sandstone. It stands on the remnant of a postglacial raised beach and survives as the rocks around it (bedding planes and fault planes) were preferentially eroded by the sea.

Figure 4: Overturned bedding

Figure 5: Maiden Rock

Further south of Maiden Rock we had hoped to view an area of the cliffs where we would be able to see evidence of fluvial sedimentary deposits with a marine band, demonstrating the incursion of the sea at times. Here we had also hoped to see evidence of terrestrial life. An Eurypterid trace fossil had been discovered here, but unfortunately the access to the beach was so overgrown that it could not be found.

Figure 6: Eurypterid trace fossil (by permission of Lara Reid)

Kinkell Ness and the Rock and Spindle (OS map 59 NT 539156)

Our final stop for the day was to visit the evidence of volcanism at this site. It involved a long walk up and down a rather treacherous path, made slippery by the only rain we experienced during our time in Edinburgh.

The Kinkell Ness Vent intruded into Lower Carboniferous sandstones.

The stages in the history of the vent were described by S.R. Kirk in 1925.

> The initial volcanic outburst consisted mainly of gas discharge which produced the vent or pipe. This was followed by repeated pyroclastic activity, the formation of the bedded tuff cone and subsequent collapse of the bedded tuff into the vent.
>
> Emplacement of vent intrusions consisting of basalt generally packed with xenoliths, but locally relatively free of these.
>
> Emplacement of basalt dykes which may extend outside the vent.

There are three sea stacks in this area, we were headed for the stack at the northern end of the vent known as The Rock and Spindle vent, so called because of its resemblance to the equipment that was used for spinning wool and flax in the past.

The tall part of the stack is the Rock. It consists mainly of agglomerate, rich in large xenoliths of fragmented basalt, with a dyke on the north-western side of the stack. The Spindle, on the south-eastern side of the stack, is the circular section, with radial columnar joints, of a cylindrical intrusion of basalt.

Surrounding the stack are the remains of the sandstones, tuffs and agglomerates from the past history of the vent. There was little time to examine these exposures as a rapid return to the coach was necessary.

Figure 7: The Rock and Spindle

Reported by Carole Gregory

Friday September 24th 2021

This day started with a short train ride out of Edinburgh to Dunbar where we saw a good succession of volcanic rocks on the coast, and interesting off-shore islands, followed, after lunch, by a bus ride to North Berwick where we saw more volcanic and some wind faceted rocks, before a fish-and-chip supper and a train ride back to Edinburgh.

Morning - Dunbar (OS map 67 NT 6878)

On Friday morning's trip we were joined by Angus' dog, who livened up our day in a positive way - incredibly well-behaved, even on the train from Edinburgh and enjoying romps on the beach while we studied various formations in Dunbar and, later in the afternoon, in North Berwick.

Figure 1: Angus' dog by top of basalt column near the Battery in Dunbar harbour

Figure 2: Pebbles on East Beach Dunbar

We began our Dunbar (Ref. 9) explorations at East Beach (NT 681790). After the loss of sand in the storms about 5 yrs ago, a consultant advised putting in banks of boulders to change the erosion patterns. Thus far this seems to be working and it is hoped that it will also help to mitigate some effects of climate change.

Bedrock here is upper Devonian Old Red Sandstone (ORS) which outcrops along the coast for a couple of miles, giving sheltered bays. Here the sandstone dips to the east.

Inland is older Great Conglomerate (GC). From early in the Devonian with the exposure of sedimentary conglomerate formation, storm waters and rivers transported GC south (and to here), originally as quartzite pebbles, rounded and fractured. Some of these pebbles are found on the beach.

Close to the top of the East Beach, ORS outcropped below and above rock from volcanic eruptions. While the ORS created sheltered bays, volcanic rock formed headlands and islands. It is the volcanic rock which defines and borders the harbour, both intrusions and agglomerates.

Figure 3: Angus standing on ORS and volcanic rock junction – ORS and the edge of a volcanic vent which was active about 345 Ma.

There are no lava flows here but volcanic agglomerate between the sloping surface and the curved wall that flows around the harbour . Volcanic material moving past approximately 345 Ma, when what is now surface was deep underground, formed striations on the ORS; the original surface levels could have been thousands of metres above this

Dunbar Harbour is within an ancient volcano, the vent stretching from the ORS and volcanic rock junction at East Beach through to the Castle. At the harbour are both rocks forms by explosive eruptions and also those formed when magma cooled inside the volcano; among these can be found examples of columnar basalt.

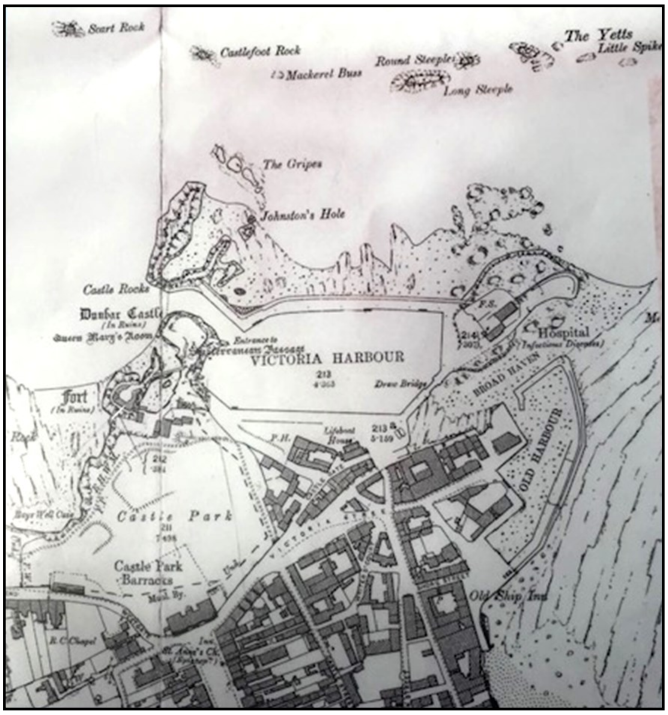


Figure 4: Map of castle area and islands

The castle, built to protect Victoria harbour (NT 678794) is on the end of the basaltic vent (red basalt, the local variant, as the olivine was dissolved). Some of this basalt is columnar, the interior less defined than the edge. Although the Castle headland is composed of a solid basalt intrusion, it is surrounded by fractured and altered sedimentary rocks. Parts of this area had been quarried for walls and buildings in the 18th century as a new harbour was created.

From the Castle could be seen the Black Islands offshore which are dolerite E/W dyke intrusions similar to the quartz dolerite seen in Queensferry and were formed with evidence of magma pulses through fractures in the sandstones.

Figure 5: Islands off Dunbar

Continuing west, a dark sea stack of igneous rock, called Doo Rock, can be found in Old Bathing Pool Bay. It is surrounded by softer sedimentary rocks.

Further west along the beach a succession of red sandstone layers demonstrate how iron dissolves and is re-precipitated to form red concretions. Between these layers are quartz sands in some of which red ironstone tubes can be seen.

It is hypothesised that tubes mark the positions of roots of land plants that were growing in the sand and would mark some of the earliest evidence of life on land in Scotland. Trough Cross-bedding from the deposits in braided channels can be seen in the sandstone that lies on the low headland at the end of the bay.

Figure 6: Doo rock

Figure 7: Possible roots in the red iron-stained beds (RY)

Going further west to the next bay, although it is all red rock, the stack and the westernmost cliff are both higher and more massive than that on the eastern side of the bay. This bay is bounded by a fault on the left – the western cliff and stack are made of volcanic rock with basalt and other fragments laid down in layers. The beach is strewn with debris that probably erupted from several small localised volcanoes in many, individual, small-scale eruptions. All faults bounded beyond this point are tectonic and run inland.

The next section of the coast is a wave-cut platform and is still being eroded as high tide reaches the base of the cliffs. There are several dykes formed when magma seeped upwards along the cracks. We learned that the term dykes used worldwide came from the description of the Scottish dykes since they often form walls when surrounded by softer rocks.

After a break for lunch many of us had time to visit the John Muir's Birthplace, a museum dedicated to the naturalist, explorer, and conservationist who was born and spent his childhood in Dunbar. He is perhaps better known as the founder of the Sierra Club in the United States and was also a major influence behind the formation of the Yosemite Park, declared by the then president, Franklin Roosevelt.

Afternoon - North Berwick – (OS maps 66, 67 NT 5585)

From Dunbar we caught the bus to North Berwick (Refs. 10 and 11), to the Northeast of Dunbar and approximately halfway back to Edinburgh. Looking to the east, Berwick Law, the remains of an extinct volcano, rises very steeply beyond the town. In earlier times, red phonolite was extracted from Berwick Law to build many of the buildings of North Berwick.

We were helped by a strong wind to arrive at the West Beach near the Seabird Centre (NT 554857). Lava flows created an intrusion here. Windblown materials and ashfall occurred close to the vent and the result is a fine-grained basalt which cooled quickly.

At North Berwick, arising about 200m above the vent, very explosive phreatic eruptions occurred that were silica enriched. However, it is worth noting that not all lava flows in this area are from the same source.

On the foreshore near the paddling pool we were able to see tuff that formed when the volcanic ash fell and settled into layers that slowly turned into rock. These layers lie below the lava flow and show how active the volcano was before the eruptions. This red tuff is usually layered and has white reduction spots each having a black spot in the middle which may have caused the reduction spots.

Figure 8: Tuff with white spots

Further east down the beach we came to the Yellow Craig rock which was named because of the yellow lichen which colonises it. This formation is a dyke. The chilled margins of the dyke have finer grains and some phenocrysts and feldspars, with some holes which are mostly thought to be where crystals have fallen out. It is slightly vesicular.

As we looked back toward the shore the existence of bands of red and green (green where the iron had not oxidised) tuff with a thin limestone layer between was visible, all dipping towards the land.

Figure 9: Yellow Craig Rock - basalt dyke (RY)

Further east from Yellow Craig we came to a layer of veined green tuff that was lined with white, probably calcite, veins and where Peter pointed out a ventifact surface (where wind-driven sand or ice crystals have in this case, polished out a surface). Also within this formation are basalt bombs that were brought up by the eruption and incorporated into the ash.

Figure 10: Basalt block showing columnar jointing and wind cut facets (RY)

Some of us continued with Angus to the foot of Partan Craig. From a distance it has a broad, upwards concave shape with the right-hand side steeper and as we got closer the size of the clasts that we found became larger. This material is vent agglomerate - pyroclastic coarse accumulation of blocks of volcanic material that contains at least 75% bombs, rounded clasts in a matrix of lava or ash. The clasts are fragments, tuff, and particles that may be derived from existing material that has been caught up in the eruption and which, in this case, has fallen into the volcanic vent. Here also the wall of the vent may have partially collapsed. This area is the edge of a vent that extends about 500m further to the east and was the source of some of the volcanic material that is to be found in North Berwick.

Islands: Fidra (NT 512869), Lamb (NT 535866), Craigleith (NT 552870), Bass Rock (NT 602874),

From the coast several islands of igneous rock can be seen, which, together with Berwick Law, formed underground. The fact that we see them today indicates that a considerable amount of erosion has taken place.

Bass Rock is made of phonolite, a less common rock than basalt, and is an ancient plug. Phonolite is silica rich and rings like a bell when struck. It is of a composition between mafic and felsic and has been called clinkstone in the past.

Of the other islands: Craigleith is a laccolith; Fidra and Lamb are the remains of a sill.

As a final aside, non-geological – Uri Geller owns the island of Lamb which he evidently believes is a hiding place for ancient Egyptian treasures. I leave you with that thought.

Reported by Ricki Bull

Saturday September 25th 2021

Cockburnspath (OS map 67 NT 775711)

Saturday was our visit to Hutton's Unconformity at Siccar Point. We travelled by minibus to Cockburnspath where we prepared for a day's walking along the coast path – the Southern Uplands Way. Angus briefed us on our position and the geological history of the Midland Valley of Scotland. We were situated to the south, on the Southern Uplands terrane – the result of the Caledonian orogeny. The fault which separates the Southern Uplands and Midland Valley terranes is rarely visible in outcrop.

From Cockburnspath we negotiated several paths over or under the East Coast Mainline railway and the A1 main road to reach the coast path above Cove beach.

Cove Beach (OS map 67 NT 780719)

The cliffs are of Carboniferous sandstone with glacial till on top. Some beds are brittle limestone and these may be seen on the foreshore, broken into rectangular blocks. The apparent bedding in sandstone closer to the cliffs and at an acute angle to the limestone beds, is, in fact, the effect of cross-bedding.

These beds are the Ballagan Formation which consists of sandstone, siltstone and dolomitic limestone, deposited approximately 345 to 359 million years ago in the Carboniferous Period. The sediments are fluvial in origin, ranging from coarse- to fine-grained and form beds and lenses of deposits reflecting the channels, floodplains and levees of a river or estuary.

Figure 1: Cove Beach showing the cliffs, the limestone and the cross-bedding

Cove Harbour (OS map 67 NT 785717)

Further along the path we came to Cove Harbour. The northern harbour wall is accessible by road but the southern part can only be reached by boat or through a pedestrian tunnel from the road through the cliff. Again, the Carboniferous sandstone and limestone bedding can be seen on the foreshore.

Beyond the harbour two stacks are visible. The nearer (western) is red sandstone and has an arch worn by the sea, the eastern stack is not so eroded as its base is normally clear of the sea. To the west of this eastern stack there is a fault.

In the next cove the actual dip of the beds can be seen more clearly to be about 30º to the north-west.

Pease Bay (OS map 67 NT 792711)

At Pease bay we left the coast path to visit the beach for lunch and take advantage of the facilities of the holiday park. At the north end of the park there was a small headland of cross-bedded red sandstone in very thin beds (~10 cm). The dip was about 20º to the north. One group of very thin beds were almost laminar.

One thin (~20 cm) bed has cross-bedding in alternating directions. I wondered if this is tidal?

In other beds there are faint suggestions of tubular structures. Could these be burrows?

These rocks belong to the Stratheden Group and Inverclyde Group (undifferentiated). The interbedded sandstone and argillaceous rocks formed approximately 347 to 383 Ma in the Carboniferous and Devonian Periods and are fluvial in origin. They are detrital, generally coarse-grained and form beds and fans of deposits where rivers flow from upland valleys onto lowland plains.

Figure 2: Long ripple marks in the red sandstone. And burrows?

As we climbed out of Pease Bay, Peter Worsley observed that part of the holiday village was on a raised beach of Devensian age. Raised beaches are common because of the isostatic uplift and depression caused by the melting or addition of glacial ice. The valley behind Pease Bay containing the river, railway and the A1 road, is steep-sided and flat-bottomed and is thought to be a glacial melt-water channel.

Siccar Point (OS map 67 NT 812711)

We continued the walk from Pease Bay up the road and stepped path to the cliff top passing a notice board describing Hutton's hopes then reaching the board above the Point which described the proof of his theory (Refs. 12 and 13) The path down to the exposure was rather steep and no-one attempted it but the view from the top was excellent. From the cliff top we could clearly see the base of the cliff with the vertical strata of the Silurian greywacke (433 to 444 Ma) and, lying on top of that and in the cliff to the east side, the near horizontal Devonian red sandstone (370 Ma). (See also Refs 1, 12 and 13.)

This Silurian greywacke is part of the Gala Group - sedimentary rock formed in deep seas from coarse- to fine-grained slurries of debris from the continental shelf flowing into a deep-sea environment resulting in distinctively graded bedding - turbidites. The field wall beside the path that we passed on the way to the site was mainly greywacke.

Figure 3: Hutton's Unconformity at Siccar Point

Figure 4: Hutton's Unconformity at Siccar Point. The cliff to the east of the lower exposure shows the ORS bedding.

Extra

One major spectacle, on the last part of the walk to Siccar Point, was a display by a pod of dolphins which was spotted by our leader. The pod travelled parallel with the coast, in the same direction as us, occasionally leaping sometimes two at a time clear of the water. The whole party was transfixed. Were they showing off?

Figure 5: Dolphins leaping off Siccar Point

We then walked across the fields to the nearby road where the coach was waiting for us to take us back to Edinburgh.

Last Evening

Supper that last evening was a party held at the flat where some of the party were staying. We bought in pizzas and desserts and, as a contribution from te absent David Ward, some beer and wine. Next day we travelled home.

Reported by Roger York

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1:50,000 OS Landranger maps with grid references to 10 km squares containing the sites to be visited.

Edinburgh	66	NT	25x73x
Holyrood Park	66	NT	27x73x
Queensferry	65	NT	14x78x
Kinghorn	66	NT	26x86x
Elie	59	NT	495993
St. Andrews	59	NO	51x15x
Dunbar	67	NT	67x79x
North Berwick	66	NT	55x85x
Cove Harbour	67	NT	790716
Siccar Point	67	NT	812710

The Group at the memorial garden site of Hutton's house: Hilary, Carole, Ailsa, Roger L, Sue, Ricki, Roger Y, Pam, Peter (HJ)

The Group at Siccar Point: Ricki, Sue, Carole, Ailsa, Angus, Roger Y, Pam Roger L, Hilary, Peter (HJ)