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## ELC\_4: Dunbar Shore, Dunbar

### Site information

#### Location and summary description:

3 to 4 km section of coastline, located to the west, north and east of the town of Dunbar. The site displays a variety of upper Devonian and lower Carboniferous geological strata, structures and intrusions, and coastal geomorphological features. There are also geological links to the social and economic history of the town and the built heritage.

#### National Grid reference:

Mid-point: [NT 68100 79300]

North-west end: [NT 66200 79400]

South-east end: [NT 69300 78500]

**Site type:** Natural section / exposure; Natural landform; Natural View

**Site ownership:** Crown

**Current use:** Open country

**Field surveyors:** Sarah Arkley, Katie Whitbread, Eileen Callaghan & Rachael Ellen

**Current geological designations:** 2 GCR sites (GCR ID: 182 and 2301), part of the Firth of Forth SSSI

**Date visited:** 26th March, 2014

**Other designations:** Firth of Forth SPA and Ramsar, Dunbar Conservation Area and John Muir Country Park, North Berwick – Dunbar AGLV

### Site map

(Figure 9) Dunbar Shore Location Map. The site comprises rock exposures along the shore platform and coastal landforms including shore platforms, raised beach, and areas of beach in the immediate vicinity of the main rock outcrops. The exact area of bedrock exposure (blue hatched areas) is likely to vary in time due to changes in the beach morphology. Geologically significant areas also included within the site boundary are important view or access points to the rock exposures. The adjacent geomorphological Tyne Estuary & Belhaven Bay Site ([ELC\\_28](#)) is shown for reference (transparent grey polygon).

### Site description

#### Background

The town of Dunbar is located on a headland jutting out into the North Sea, in an elevated position with high sea-cliffs and a rocky foreshore. The coastal landscape reflects the underlying geology; the hard igneous rocks which lie beneath the town were more resistant to erosion during the last ice age than the softer sedimentary rocks to the north and south. The siting of this strategically important east coast town must in part be due to the defensive qualities offered by the form of the coastline; the castle and battery were built on rocky promontories, almost surrounded by the sea, and defended the town and its occupants over centuries of invasions; the large solid harbours are cut into bedrock and protected fleets of

boats which brought trade, industry and prosperity to the town. Local industries exploited the natural geological resources; including clay to make bricks and tiles at Seafield, near Belhaven; igneous rocks were extracted from a quarry at Knockenhair, western Dunbar; red sandstone removed during the construction of the harbours may have been used as building stone in the harbour walls; and golf is thought to have been played on the raised beaches for almost 400 years.

The extent of the site is from Belhaven Bay to the Dunbar Golf Course, chosen as it includes extensive exposures of Devonian and Carboniferous sedimentary rocks, a selection of Carboniferous volcanic intrusions, a variety of structural features and a wide range of coastal and glacial Quaternary landforms.

### **Sedimentary rocks**

Devonian sedimentary rocks are well-exposed in the eastern part of the site, dominantly on the intertidal shore platform. The easterly dipping sequence contains bedded red and red-brown sandstones, with siltstones, silty mudstones and cornstones, and displays a range of sedimentary structures, including; channels, cross-bedding, reduction spots and ripples (ELC\_4\_P1). The sediments are thought to have been deposited in a partly fluvial (river) and partly lacustrine (lake) environment.

Thick bedded sandstone belonging to the Kinnesswood Formation is exposed in cliffs near the coastal path north of Dunbar (west of the leisure centre). The sandstone is strongly cross-bedded and there are accumulations of mudstone rip-up clasts at the base of some beds; these were deposited by large rivers. In the upper part of the sequence seen are developed nodular concretions, some of which clearly developed around plant roots (referred to as rhizocretions). These concretion beds are interpreted as fossil calcrete soils which developed in an arid or semi-arid climate (ELC\_4\_P2).

The Lower Carboniferous Sedimentary Rocks, exposed in the western part of the site (Belhaven Bay), belong to the upper part of the Ballagan Formation and are composed of thin cementstones (dolomitic limestones) and mudstones, interbedded with sandstone and siltstone (ELC\_4\_P3) & (ELC\_4\_P4). The sediments are thought to have been deposited in fluvial and shallow lagoonal environments and display sedimentary structures such as ripples and trace fossils (ELC\_4\_P5). The presence of surfaces with fossil mudcracks indicates a terrestrial environment. The strata appear gently folded and faulted where exposed on the intertidal shore platform near Belhaven Point, and has been intruded by a number of dykes of various compositions.

### **Volcanic rocks**

The early Carboniferous volcanic vents and intrusions which penetrated the sedimentary rocks, and for which the site is perhaps best known, are superbly exposed at various places along the intertidal shore platform and in cliff sections. The volcanic vents, starting at Belhaven Bay are named the Belhaven Point, Parade, Dove Rock, Castle Rocks, Old Harbour, Coastguard Station and Kirk Hill vents, which fed the early Carboniferous volcanoes. The vent material consists mainly of lithified volcanic ash (tuffs) (ELC\_4\_P8) & (ELC\_4\_P9), with some breccias, and basaltic intrusions. Bedded, poorly sorted pyroclastic rocks, including tuff and breccia, exposed in the cliffs to the west of the town show characteristics that are typical of volcanic eruptions that occur when magma comes into contact with large volumes of water (phreatomagmatic); these features include non-vesicular fragments, abrupt bed-by-bed changes in grain size and some fine examples of volcanic bomb sags. These bedded pyroclastic rocks were probably remnants of volcanic cones. A description of the early Carboniferous vents present along the site can be found in the Lothian Geology Excursion Guide (McAdam & Clarkson, 1986: pg119–132)

The strata are latterly traversed by a group of ENE–WSW trending quartz-dolerite dykes, best seen at Belhaven Bay (ELC\_4\_P6) and also form the offshore skerries north of Dunbar. Basaltic intrusions are additionally present within the site; the best example forms the foundations of The Battery and displays superb columnar jointing (ELC\_4\_P7).

### **Quaternary deposits and landforms**

Excellent Quaternary features and deposits are also present at the Dunbar site. Cross-sections through Quaternary raised beach deposits are exposed along the westward facing coast at Belhaven Bay, where gently dipping deposits of shingle, sand and shells are found overlying a rock platform cut into the Ballagan Formation (ELC\_4\_P10). Along the

coast various erosional landforms can be seen, including raised beaches, intertidal shore platforms, stacks, cliffs, caves, offshore skerries and an arch (ELC\_4\_P11). Two Geological Conservation Review sites (GCR ID 182 and 2301) are located along the Dunbar Shore coastline: one which describes four distinct shore platforms, of different ages, that have been particularly well-preserved in the vicinity of Dunbar (ranging in altitude from 25m above sea level to 11m below present sea level); and one which describes the excellent range of rocky coastal landforms, representative of erosional coastal features found along the east coast of Scotland. Both GCR sites are important in terms of Quaternary reconstruction, the interpretation of former sea-level changes and the erosional processes characteristic of rock-coast development in south-east Scotland.

### **Structural geology**

There are features throughout the entire site which show good examples of structural geology and its effect on fluid migration within rocks. Within the Devonian and Carboniferous strata, groundwater along local fractures has bleached the immediately surrounding rock, changing its colour from red to white (ELC\_4\_P12). Faults and fractures cross cut the sedimentary strata, forming natural linear gullies within the foreshore (ELC\_4\_P13). There are also local examples of deformation bands (fractures which have seen some displacement and quartz grain crushing) within the sedimentary strata. In other areas, dendritic growths of iron leaching out of fractures are seen in the Ballagan Formation. On a larger scale, there are faults displacing the sequences with local folds forming anticlines and synclines, particularly within the Ballagan Formation.

### **Access and additional information**

Access and views of the coastline at Dunbar is very good, greatly aided by the presence of coastal footpaths, particularly the John Muir Way. At the western end of the site, the John Muir Way meanders along the high cliff tops providing excellent views of the geology and coastal erosion features on the shore below, and of views further afield towards the Bass Rock and the islands lying within the Firth of Forth. At the eastern end the path winds its way along the raised beach and provides easy access to the foreshore.

Along the sea front, and particularly around the Victoria and Cromwell harbours, there are a significant number of information boards describing and illustrating the local history and wildlife of the area. However, there is little mention of the local geology or landscape, despite it being an important factor in the siting and building of Dunbar Castle, the Battery and the two harbours; and in how the local area has been shaped during the Ice Age. The information described in these few pages should show that there is great scope for introducing geology to those that visit the Dunbar area, particularly with the town's association to John Muir, who campaigned for the preservation of natural environments through his work as an environmentalist, geologist and botanist.

## **Stratigraphy and rock types**

**Age:** Devono-Carboniferous

**Formation:** Upper Old Red Sandstone and Kinnesswood Formation

**Rock type:** Sandstones, siltstones and mudstones

**Age:** Lower Carboniferous

**Formation:** Ballagan Formation

**Rock type:** Sandstone, siltstone and dolomitic limestone (cementstone)

**Age:** Lower Carboniferous

**Formation:** Southern Scotland Dinantian Plugs and Vents Suite

**Rock type:** Tuff and breccia

**Age:** Upper Carboniferous

**Formation:** Central Scotland Late Carboniferous Tholeiitic Dyke Swarm

**Rock type:** Quartz-microgabbro (quartz-dolerite)

**Age:** Carboniferous to Early Permian

**Formation:** Midland Valley Carboniferous to Early Permian Alkaline Basic Dyke Suite

**Rock type:** Microgabbro (dolerite)

**Age:** Quaternary

**Formation:** Raised marine deposits of Flandrian Age

**Rock type:** Sand and gravel with shells

## **Assessment of site: access and safety**

**Road access and parking** Good access from Belhaven Bay car park and there are various places to park with access to the coast from Dunbar town centre. The John Muir Way footpath follows the coastline around Dunbar and allows excellent access to and/or views of most of the site.

**Safety of access** Well-trodden footpaths generally provide good, safe access for visitors to look at outcrops and landforms along most of the site, but care should be taken if leaving the main paths. Access to the shore platform is restricted north of Dunbar where there are high vertical cliffs. All visitors should be aware of the tide times when planning a visit, as many of the exposures are only visible at low tide, and due to the high cliffs an unwary visitor could be cut off from their planned exit route.

**Safety of exposure** Although the majority of the cliffs appear stable, care should always be taken when beneath cliffs of any height and visitors should not stand beneath any overhanging areas. The rocky intertidal areas have an uneven surface, and are in places boulder-strewn and often slippery with algal growth. Stout footwear is recommended. The site may feel very exposed under certain weather conditions, and the weather forecast should be checked before visits.

**Access** Access is along the foreshore/beach and there are numerous footpaths leading down to the site from the town and car park.

**Current condition** Rock exposures are generally clean and free of vegetation or litter, due to washing from tides, but the intertidal zones can be covered in seaweed or barnacles obscuring small-scale geological features.

**Current conflicting activities** Two golf courses are located adjacent to the site and may restrict access to parts of the site, but paths are generally present along their shore edge or access can be gained by walking along the foreshore.

**Restricting conditions** Tide: many of the geological exposures are located in the intertidal range and therefore covered at high tide.

**Nature of exposure** Vertical cliff sections, intertidal & beach exposures and coastal landforms.

## **Assessment of site: culture, heritage & economic value**

**Historic, archaeological & literary associations** Dunbar Castle (dating from around the 13th century), The Battery (built in 1781), Dunbar's Harbours (Cromwell and Victoria) and McArthur's Store may all have used local stone in their

construction. Dunbar is the birthplace of John Muir (naturalist and early advocate of the preservation of the natural environment) and the Town House Museum in Dunbar (displays a variety of local history).

**Aesthetic landscape** Coastal landscape

**History of earth sciences** John Muir's birthplace

**Economic geology** Information from the John Muir Birthplace Fact Sheet, Number 3.12- Dunbar Geology: "A lot of the stone was exploited in Muir's time. The Castle Rock was quarried for walls and buildings as a new harbour was created. Marls and mudstones to the west were burnt for cement and deposits of clay at Belhaven were worked for brick and tile manufacture. To the east many tons of fossiliferous limestones and shales were burnt every year for lime (used as mortar and field dressing)."

### Assessment of site: geoscientific merit

Rarity	Quality	Literature/collections	Primary interest
<b>Lithostratigraphy</b>	Regional	Good	x
<b>Sedimentology</b>	Regional	Excellent	x
<b>Igneous/mineral/metamorphic geology</b>	Regional	Excellent	x
<b>Structural geology</b>	Local	Good	
<b>Palaeontology</b>			May and Hansom, 2003; Gordon and Sutherland, 1993
<b>Geomorphology</b>	Regional	Excellent	x

### Site geoscientific value

The shore section at Dunbar has excellent exposures of both volcanic (particularly phreatomagmatic deposits) and sedimentological (particularly paleosols) features, indicative of Carboniferous volcanic and terrestrial (including fluvial) environments. There are also excellent exposures of raised beaches and their relationship with the underlying rocks.

Dunbar Shore provides excellent, regionally significant examples of Carboniferous volcanic rocks, fossil calcrete paleosols and of their lithostratigraphical relationships. It also provides excellent examples of Quaternary landforms with regional significance.

### Assessment of site: current site usage

**Community** The attractive town, local history, scenic coastline and easy access means both locals and visitors from further afield are regularly passing through the site. The two golf courses located on raised beaches adjacent to the site additionally draws people to the area.

**Education** The site displays a wide variety of features suitable for educational visits. Most of the site has good safe accessibility and would be suitable for larger groups. The site has potential for geosciences research, and teaching potential for Higher/Further and School level education. Use of the site for teaching purposes may be enhanced by leaflets or online information. Members of the general public would benefit from on-site interpretation such as sign boards or a Geo-trail.

### Assessment of site: fragility and potential use of the site

**Fragility** Weathering/erosion; development of coastal defences may affect the geodiversity

**Potential use** Research, Higher/Further Education, School Education, On-site interpretation, On-site geotrail, Multidisciplinary

## Geodiversity summary

An outstanding site containing a wide variety of good quality geological and geomorphological features. This site exposes a long, semi-continuous section through typical upper Devonian to lower Carboniferous sedimentary strata. The strata display a variety of characteristic sedimentary structures which allow an interpretation of the environment at the time of deposition, with an excellent assortment of early Carboniferous volcanic intrusions (particularly vents and dykes) and of pyroclastic rocks, and a selection of structural geological features (particularly faults and fractures) which have cut through the strata. The site additionally displays classic examples of landforms typically found along rocky coastlines, some of which have been nationally recognised. It is an attractive coastal site with easy access and has numerous links to the built heritage and social/economic history of the local area, with ample opportunity to enhance existing visitor information with some geology.

## Site photos

(ELC\_4\_P1) Ripples formed on the upper surface of a red sandstone bed within the Devonian sequence, visible on the intertidal shore platform east of Dunbar. The ripples appear asymmetrical, suggesting they were formed within a uni-directional flow, such as a river. Preservation of the ripples gives us an indication of the flow direction at the time of deposition, in this example, the ripples suggest a flow towards the south. Photo looking west. © BGS, NERC.

(ELC\_4\_P2) Excellent examples of palaeosols (fossilised soils) within the Kinnesswood Formation are revealed in an easily accessible cliff section above high water mark and immediately off the coastal path north of Dunbar. Red-brown 'roots' can be seen penetrating down through white sandstones from a sharp horizon. This horizon likely indicates a break in the deposition of sediments, long enough for plants to colonise and soils to start forming. The dark red horizon beneath the palaeosol may represent an iron-pan and indicate the level of the water table within the sediments at the time of formation. Photo looking south. Scale: image displays approx 1.5m of the sedimentary sequence. © BGS, NERC.

(ELC\_4\_P3) View looking east across the bay north of Winterfield Golf Course, displaying gently dipping strata belonging to the Ballagan Formation of early Carboniferous age. The sequence is made up of interbedded mudstones and cementstones, dissected by numerous faults and igneous intrusions (vents and dykes). © BGS, NERC.

(ELC\_4\_P5) Symmetrical ripples with rounded crests, preserved on the top surface of a bed within the Ballagan Formation. This type of ripple is indicative of a bi-directional flow, possibly shallow marine environment. Note also the finer cross-cutting trace fossils on top of the ripples, these are markings/impressions left by organisms travelling across or through the substrate. © BGS, NERC.

(ELC\_4\_P6) Quartz-dolerite dyke (dark coloured) intruding the paler sedimentary sequence of the Ballagan Formation. Note the sharp, sub-vertical margin between the two rock units, intrusions will often exploit natural weaknesses in the rock and may intrude along the plane of an existing fault or fracture. There is also evidence of a chilled margin being present, which would have formed as the hot magma cooled quickly against the cold rocks it intruded. Photo looking north. © BGS, NERC.

(ELC\_4\_P7) An excellent example of columnar jointing (similar to the spectacular Giant's Causeway in Ireland) is displayed in an outcrop of basalt at The Battery, Dunbar. Columnar jointing is a network of closely spaced joints/fractures in the rock, which formed as the hot basaltic magma cooled, contracted and fractured (typically into hexagonal columns) as it solidified. Although closed to the public at the time of visiting, the site is said to have extensive views of Dunbar, the Victoria and Cromwell harbours and have long range views to the Bass Rock and islands in the Firth of Forth. Photo looking north. © BGS, NERC.

(ELC\_4\_P8) Typical view of the red and brown bedded tuff and breccias, probably part of the volcanic cones associated with the Parade Vent, the largest of the early Carboniferous volcanic vents in the Dunbar area. The material has allowed

the development of some superb rocky coastal landforms including an extensive shore platform which backed by high cliffs along which the coastal path meanders, allowing excellent views across to the cliff faces and down to the foreshore. Photo looking north-east. © BGS, NERC.

(ELC\_4\_P9) Close-up of lithified volcanic ash (tuff). Tuffs and breccia typically infill the numerous vents visible along the Dunbar coastline. This example is from within the Kirk Hill Vent and displays white feldspar crystals which have been incorporated into a fine-grained red-brown ash matrix. © BGS, NERC.

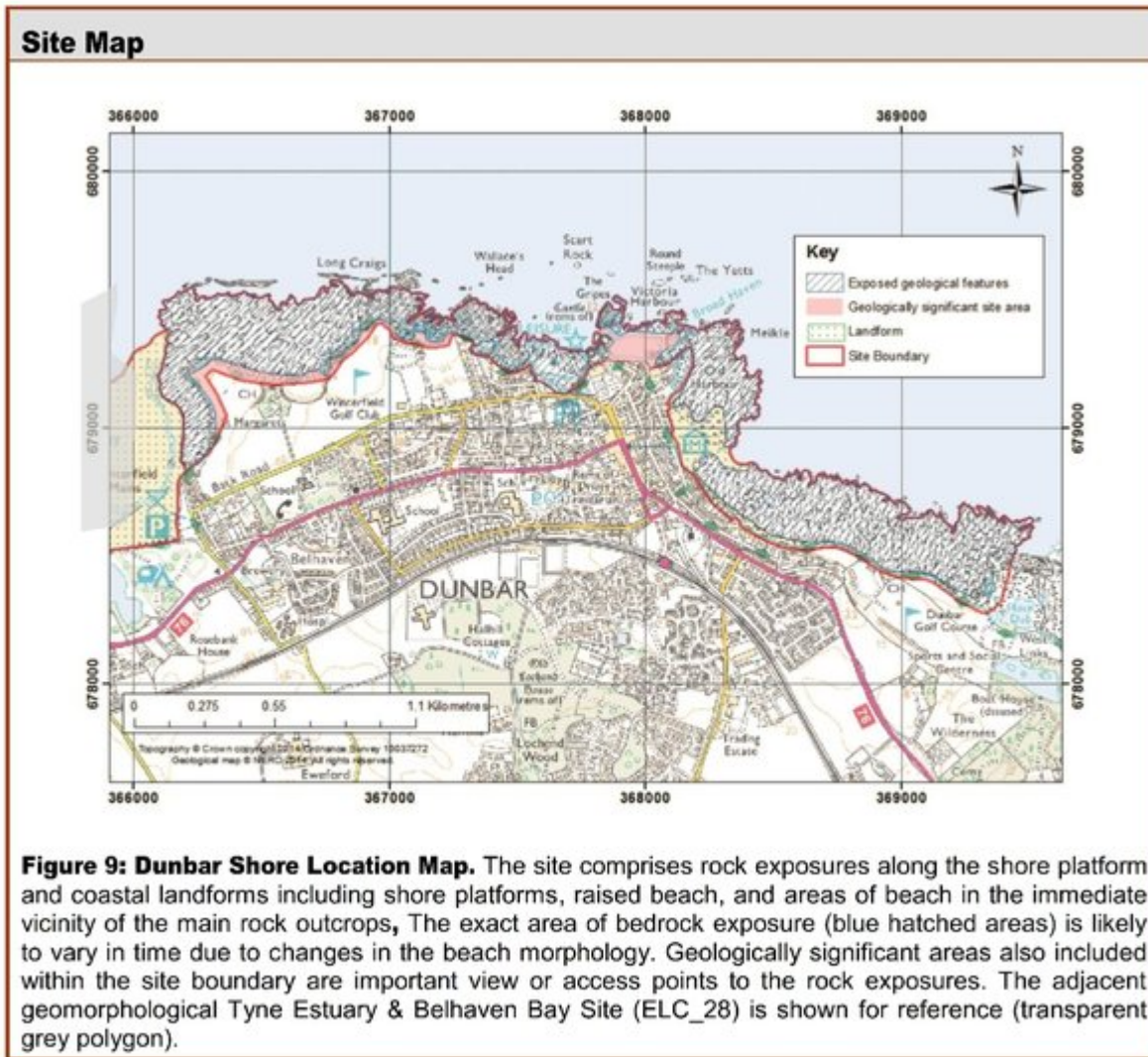
(ELC\_4\_P10) Small cliff section at the eastern side of Belhaven Bay, displaying raised beach deposits on top of reddened mudstones and cementstones of the Ballagan Formation. The beach deposits in the section are well-bedded and consist dominantly of shingle, sand and shells, and are representative of a time when sea level was higher than it is today. The contact between the two units can be described as an angular unconformity; 'angular' because the overlying sediments lie at a different angle to the strata below and 'unconformable' because the surface separating the two units represents a period of non-deposition or erosion. Photo looking north. © BGS, NERC.

(ELC\_4\_P11) A natural arch, located at the western end of Dunbar Castle, has formed in a promontory of rock jutting out from the coastline. Coastal erosion has selectively removed an area of softer/weaker rock to the extent that it has created a hole completely through it, leaving an 'arch' or 'bridge'. As erosion continues, the arch will enlarge and the roof eventually collapse and form a 'stack', examples of which (including the Dove Rock) can be seen further west along the coastline, along with other coastal erosion landforms such as caves and shore platforms. Note the old foundations of the castle still clinging to the cliff and one of the gun ports which helped defend the castle during its long and turbulent history. Photo looking north- west. © BGS, NERC.

(ELC\_4\_P12) Small-scale structural features can be studied within the Devonian strata east of Dunbar, above high water mark. The pale streaks running through the red sandstone highlight the presence of fractures/joints within the strata. As ground water migrated along the fractures and the adjoining strata it has caused reduction of some of the ferric oxide to ferrous oxide, which is slightly soluble. Leaching of the reduced iron has resulted in the red sandstone losing its colour. Such 'halos' form distinctive streaks in fractures cutting porous sandstones, the same effect is not seen in fractures cutting through mudstone due to their lack of available pore space. Photo looking south. © BGS, NERC.

(ELC\_4\_P13) View across the intertidal area east of Dunbar, the shore platform exposes many faults cutting through the Devonian sedimentary rocks. this example shows evidence of strike-slip movement. Within the fault plane the rocks tend to be ground up and broken, and so more easily eroded, leaving naturally formed linear gullies in the shore platform. Photo looking east. © BGS, NERC.

## [References](#)



(Figure 9) Dunbar Shore Location Map. The site comprises rock exposures along the shore platform and coastal landforms including shore platforms, raised beach, and areas of beach in the immediate vicinity of the main rock outcrops. The exact area of bedrock exposure (blue hatched areas) is likely to vary in time due to changes in the beach morphology. Geologically significant areas also included within the site boundary are important view or access points to the rock exposures. The adjacent geomorphological Tyne Estuary & Belhaven Bay Site (ELC\_28) is shown for reference (transparent grey polygon).





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*(ELC\_4\_P3) View looking east across the bay north of Winterfield Golf Course, displaying gently dipping strata belonging to the Ballagan Formation of early Carboniferous age. The sequence is made up of interbedded mudstones and cementstones, dissected by numerous faults and igneous intrusions (vents and dykes). © BGS, NERC.*



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finer cross-cutting trace fossils on top of the ripples, these are markings/impressions left by organisms travelling across or through the substrate. © BGS, NERC.



(ELC\_4\_P8) Typical view of the red and brown bedded tuff and breccias, probably part of the volcanic cones associated with the Parade Vent, the largest of the early Carboniferous volcanic vents in the Dunbar area. The material has allowed the development of some superb rocky coastal landforms including an extensive shore platform which backed by high cliffs along which the coastal path meanders, allowing excellent views across to the cliff faces and down to the foreshore. Photo looking north-east. © BGS, NERC.





*(ELC\_4\_P9) Close-up of lithified volcanic ash (tuff). Tuffs and breccia typically infill the numerous vents visible along the Dunbar coastline. This example is from within the Kirk Hill Vent and displays white feldspar crystals which have been incorporated into a fine-grained red-brown ash matrix. © BGS, NERC.*



*(ELC\_4\_P6) Quartz-dolerite dyke (dark coloured) intruding the paler sedimentary sequence of the Ballagan Formation. Note the sharp, sub-vertical margin between the two rock units, intrusions will often exploit natural weaknesses in the rock and may intrude along the plane of an existing fault or fracture. There is also evidence of a chilled margin being present, which would have formed as the hot magma cooled quickly against the cold rocks it intruded. Photo looking north. © BGS, NERC.*





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(ELC\_4\_P10) Small cliff section at the eastern side of Belhaven Bay, displaying raised beach deposits on top of reddened mudstones and cementstones of the Ballagan Formation. The beach deposits in the section are well-bedded and consist dominantly of shingle, sand and shells, and are representative of a time when sea level was higher than it is today. The contact between the two units can be described as an angular unconformity; 'angular' because the overlying sediments lie at a different angle to the strata below and 'unconformable' because the surface separating the two units represents a period of non-deposition or erosion. Photo looking north. © BGS, NERC.





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