Geology of Siccar Point and Pease Bay - an excursion

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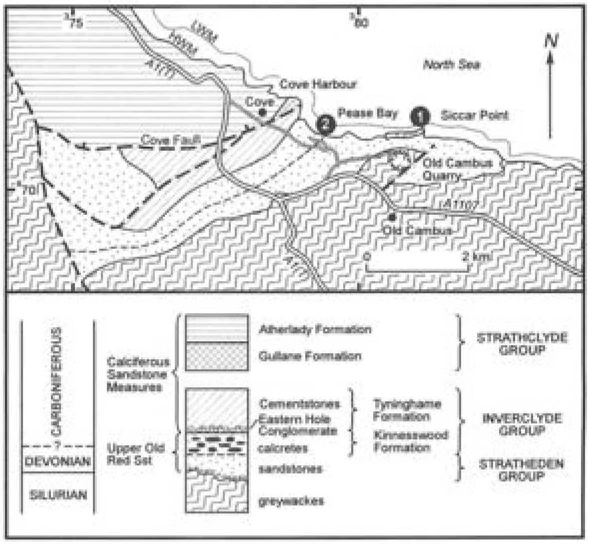

Figure 1.1 Generalized geological map of the Pease Bay–Siccar Point area.

Figure 1.2 Siccar Point: 'Hutton's Unconformity'. Near vertical Silurian greywackes unconformably overlain by gently dipping Upper Old Red Sandstone breccia and sandstone. Photo: C. T. Scrutton.

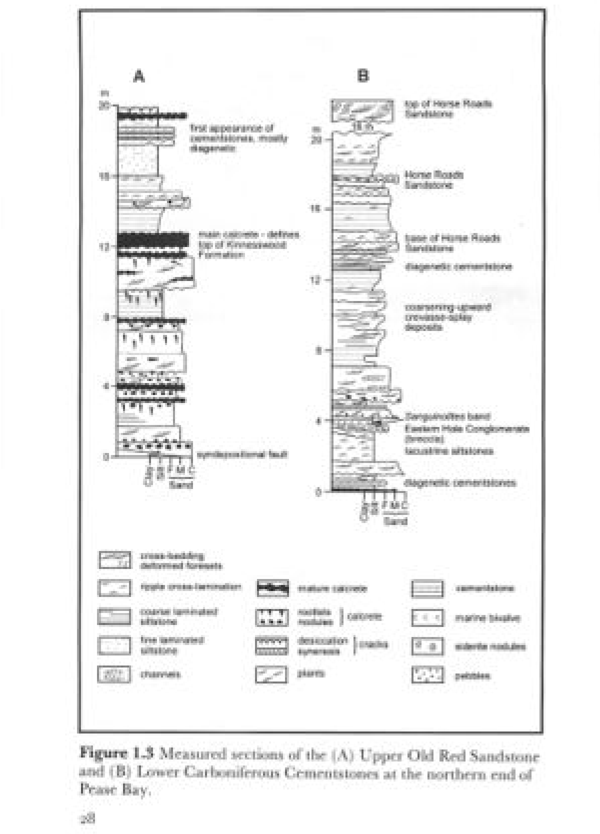

Figure 1.3 Measured sections of the (A) Upper Old Red Sandstone and (B) Lower Carboniferous Cementstones at the northern end of Pease Bay.

Figure 1.4 Rippled lacustrine siltstones overlain by cementstone breccia (Eastern Hole Conglomerate) within the Eastern Hole Beds at the base of the Tyninghame Formation, Pease Bay. Photo: B. R. Turner.

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Purpose

This excursion will examine the spectacular and historically important 'Hutton's **Unconformity'**, between Silurian **greywackes** and Old Red Sandstone at Siccar Point, and the stratigraphy and sedimentology of the fluvio-**lacustrine** Upper Devonian red beds and Lower Carboniferous Cementstone Group coastal alluvial plain sediments at Pease Bay.

Logistics

This section was compiled in 2006 when the printed guidebook was published. Before visiting this site please ensure you have up-to-date contact and access information.

The excursion, which is not recommended for large parties, can be completed in one short day. Private transport is essential. Siccar Point involves a steep descent, less daunting than it appears, down a 70 m high cliff. However, the unconformity can be seen clearly from the cliff top, from which there is an excellent view of the geology to the north. The Pease Bay section is tide-dependent and ***should not be attempted during a rising tide***. It involves rough walking and scrambling, mostly over a boulder-strewn wave cut platform. The seaweed-covered rocks of the foreshore are slippery. The total distance covered is about 1 km and hard hats and waterproof footwear are strongly recommended.

Prior permission for access to Siccar Point should be sought from the proprietor of the processing and packing plant for local swedes at Old Cambus Quarry. Note that the road into the quarry is used by heavy lorries.

Maps

O.S. 1:50 000 Sheet 67 Duns, Dunbar and Eyemouth; B.G.S. 1:50 000 Sheets 34 Eyemouth and 33E Dunbar.

Geological background

The area comprises folded and faulted Silurian greywackes of Llandovery age, unconformably overlain by Upper Old Red Sandstone which passes gradationally and conformably upwards into Lower Carboniferous Cementstones (Figure 1.1). During Lower Palaeozoic times the area was located on the northwestern edge of the Iapetus Ocean. The ocean floor was being **subducted** beneath the Laurentian continental margin (Figure 3a), with sediments of northerly derivation being deposited by **turbidity currents** in front of the subduction zone or alternatively in a **back-arc** basin. These Lower Palaeozoic greywackes contain **graptolites** and good examples of **Bouma sequences** indicative of a distal depositional setting. Whatever the origins of the sediments the ocean finally closed in late Silurian times resulting in the folding and faulting of the beds which show a steep northwesterly **dip**, becoming younger in that direction. However, the structure in this area is relatively simple and characterized by upright open folds with broad limbs and narrow hinge zones, and numerous high angle faults. When traced south towards Eyemouth the structure becomes more complex with shearing and fold axial thickening, amongst other complications. Ocean closure was also accompanied by volcanism, but evidence of this is not seen in this area.

This end Silurian **Caledonian Orogenic** event resulted in uplift and the establishment of continental conditions, followed by erosion, peneplanation and deposition of the fluviatile Upper Devonian red beds by ephemeral (flash-flood) braided streams, under semi-arid climatic conditions. By the beginning of the Lower Carboniferous the area was subjected to renewed **tectonism** and subsidence, with sediment derived from source areas to the north and east being deposited on a coastal alluvial plain. Climatic conditions remained unchanged from the Devonian to the early Carboniferous, as evidenced by the persistent presence of red beds in the Cementstones (see Excursion 2).

Stratigraphical interpretations vary, but the one adopted here is to place all the locally exposed Old Red Sandstone and Lower Carboniferous sediments in the Kinnesswood and part of the Tyninghame Formations of the Inverclyde Group, which range in age from late Devonian to early Carboniferous. The Kinnesswood Formation straddles the Devonian–Carboniferous boundary, with the top of the formation defined by a distinctive **calcrete** bed (Figure 1.3A). In the past a thin **cementstone** breccia called the Eastern Hole **Conglomerate** has been taken as the **lithological** boundary between the Devonian and Carboniferous. This is now included in the Eastern Hole Beds of early Carboniferous age at the base of the Tyninghame Formation.

The area has a spectacular coastline characterized by steep rocky cliffs up to 70 m high, overlooking narrow rocky foreshores and occasional sandy beaches such as Pease Bay. Away from the coast the area has been terraced and extensively affected by glaciation, with most of the lower ground covered by **drift**. The higher ground behind has a typical rounded topography due to glacial erosion of the underlying solid bedrock, especially the Silurian greywackes. Mounds of coarse gravel, thought to be ice contact deposits (?**eskers**), stand up above the general level of the glacial terraces and at Pease Bay the glacial deposits are predominantly **till** overlying sands and gravel. Behind the sandy beach at Pease Bay is a shingle beach, now mostly grass-covered, which is one of the few examples of a raised post-glacial shoreline. Channels formed by glacial meltwater are common. Some are oriented perpendicular to the coastline and others, such as the one leading to Old Cambus Quarry, are oriented parallel to the coastline.

Excursion details

Locality 1, Siccar Point [NT 813 710], S.S.S.I., hammering prohibited

From the A1 just south of Cockburnspath take the A1107 towards Coldingham, turning onto the single track road to Pease Bay at NT 795 702. Where the road turns sharp left downhill, continue straight on, along a single track road through an excellent example of a sub-glacial drainage channel into Old Cambus Quarry. The quarry and drainage channel are cut into a spur of Lower Silurian greywackes. Vehicles can be parked in the quarry by prior permission (see Logistics). Walk round the left-hand side of the buildings along the quarry wall, through the gate, and where the drainage channel broadens out, take the track slanting up the hill to the left and cross the fields to the cliff top at Siccar Point (the Scottish word *siccar* means safe).

The view from the cliff top is spectacular, especially to the northwest where dark grey, folded and vertical Silurian greywackes can be seen, succeeded by brightly-coloured Old Red Sandstone sediments grading up into drab Lower Carboniferous Cementstones of the Pease Bay section. Further north beyond Pease Bay is Torness Power Station, one of the first nuclear power stations to be built in this country, the lighthouse at Barns Ness situated on Lower Carboniferous Limestone Group strata, and in the far distance the Bass Rock, a plug of **phonolitic trachyte** jutting sharply out of the sea.

The unconformity at Siccar Point (Figure 1.2) was discovered by James Hutton (1726–1797), in the company of Sir James Hall and Professor John Playfair. Hutton, who farmed locally at Slighhouses for some 14 years, had long suspected the presence of an unconformity along this stretch of coast having already seen others at Arran in 1786 and Jedburg in 1787. In 1788 he and his companions sailed south from Dunglass, keeping close to the shore in order to examine the succession for signs of primary and secondary strata, and the contact between them. On landing at Siccar Point, they found near-vertical Silurian greywackes overlain by gently dipping Old Red Sandstone, the contact between them being marked by a distinct breccia. This locality enabled Hutton, one of the great pioneers of geological science, to develop his ideas on the cyclicity of major geological processes. Historically therefore, Siccar Point is a geological site of international importance, attracting geologists from all over the world.

A rough track leads down the cliff across the contours and the descent is easier than it appears at first sight from the cliff top, and well worth the effort. The exposures are on a seaward-dipping wave cut platform, where near-vertical Silurian greywacke sandstones, siltstones and shales, are unconformably overlain by a continental breccia and sandstone of Upper Old Red Sandstone age dipping gently seawards at about 15° (Figure 1.2). The unconformity is estimated to represent a time gap of about 20 **Ma**. The Silurian rocks form laterally persistent beds of constant thickness, in which the sandstones form distinct ridges weathering out from the softer siltstones and shales. Lithological markers are lacking and correlation is difficult. The sandstones are predominantly medium to coarse-grained, normally graded, **quartz**-rich greywackes, containing a variety of sedimentary structures typical of turbidity current deposits, including horizontal laminations, ripple **cross-lamination**, **sole marks** such as **flutes** and grooves, and convolute lamination. Bedding surfaces are commonly covered with ripple marks which are straight, sinuous and **linguoid** in plan. The succession consists of vertically stacked classic turbidite units in which the younging direction can be readily established. Graptolites, collected from the shales near Siccar Point and at the quarry, indicate an upper Llandovery age for the sediments.

The basal breccia, which commonly fills in local hollows and depressions on the original depositional surface, varies in thickness up to a maximum of about 6 m. It contains mainly angular, locally **imbricate** elongate **clasts**, deposited by currents flowing to the south and southeast. The clasts are predominantly of the underlying greywackes but with some **arkosic** sandstone, all set in a pink to red, coarse-grained **feldspathic** sandstone matrix. The overlying sandstone is a red, poorly sorted, feldspathic **arenite**, containing poorly defined laminations, small-scale cross-bedding and local **chert** lenses. The sandstone was deposited by braided, possibly ephemeral streams draining a semi-arid alluvial plain.

Return to the quarry, and at the end of the access road, turn right down hill to the Pease Bay caravan site.

Locality P, Pease Bay [NT 795 712]

Parking for visitors is available at the caravan site free of charge. The Upper Old Red Sandstone and conformably overlying Lower Carboniferous Cementstones exposed in the cliffs and along the foreshore at the northern end of Pease Bay dip northwestwards at between 15 and 20° (Figure 1.1). The sediments were deposited within the fault-bounded Oldhamstocks Basin on the northeast flank of the Southern Uplands. The age of the succession is poorly constrained and the Upper Old Red Sandstone here could be early Carboniferous in age.

The Old Red Sandstone consists of erosively based, multilateral and multistoried fining-upward sequences up to 4 m thick, composed of sandstone and siltstone. A **lag** of shale and siltstone **intraclasts**, with occasional small quartz pebbles and granules overlies the erosive base. Reworked calcrete nodules occur in channel lags higher in the succession. The sandstones above are predominantly pale red to maroon, locally mottled, fine to coarse-grained, immature and poorly sorted feldspathic arenites containing a patchy **dolomite** cement. Locally there is evidence of displacement along small faults and fractures. A small non-marine **bivalve** has been recovered from the sandstones at the northern end of Pease Bay. The sandstones contain mainly trough cross-bedding and show an overall fining-upward trend. Fine-grained, better sorted, friable white sands with well rounded grains are locally developed within the coarser-grained cross-bedded sands. These are interpreted as **deflation** deposits on the top of fluvial channel sand bars. The sandstones are sharply overlain by grey to purple overbank siltstones and silty mudstones showing red and green mottles and lenses, reflecting the oxidation state of the iron they contain. Some of the green mottles have carbonaceous plant material at their centres which gave rise to local reducing conditions within a predominantly oxidising environment. More extensive lenses probably owe their origin to shifts in position of the palaeo-watertable. The siltstones are mostly ripple cross-laminated, and increase in abundance towards the top of the Old Red Sandstone succession where the sandstones and siltstones become noticeably less red in colour. Here they are interbedded with hard, red to black calcrete which occurs in a number of forms according to its position in the succession.

Prominent calcretes first appear at the northern end of the small fault-controlled bay north of Pease Bay beach, as deep red to maroon and black nodules and thin nodular lenses, sometimes containing **pedogenic** tubules (rootlets). Higher up, the calcrete forms more continuous beds up to 1 m thick, the most mature containing irregular lenses of chert. They show a gradual increase in maturity towards the top of the succession (Figure 1.1A), and even within individual calcretes there is often a vertical variation in the dominant form. Reworked calcretes are commonly concentrated on cross-bed foresets, at the base of sets and along the base of channel sands. In places long pedogenic tubules extend down through foresets for distances of more than 50 cm.

Because of their resistance to weathering the calcretes stand proud of the softer host rocks producing a typical knobbly surface texture, and unlike modern calcretes they have been dolomitized. The calcretes formed by leaching of **carbonate** from the upper part of the soil profile and its reprecipitation lower down. For extensive calcretes to develop extended periods of non-deposition are required, together with a warm, dry climate where the rainfall is not too seasonally peaked otherwise the carbonate may be leached from the soil profile. Geochemical analysis of selected calcretes and cementstones indicate that they formed from saline pore fluids (<100 ppm strontium).

Thin, laterally persistent cementstones also begin to make their appearance towards the top of the succession (Figure 1.3A), which includes a well developed ripple cross-laminated, internally scoured lacustrine siltstone, located immediately below a thin, erosively-based cementstone breccia (Figure 1.3)B, (Figure 1.4). This breccia, c.20 cm thick, was formerly regarded as the lithological

Devonian–Carboniferous boundary. It contains flat, angular clasts of cementstone, laminated calcretized cementstone (?**algal**), pieces of carbonized wood and fish scales. The clasts are locally imbricate and cemented by ferroan dolomite giving the rock a distinctive yellowish-brown colour. The breccia now forms part of the Tyninghame Formation (Figure 1.3)B and is thought to have been deposited on the dried-up bed of a lake, scoured by a major, but short-lived flood event that reworked and locally transported some of the dried-up lake bed material. Above the breccia is a thin, hard calcareous bed containing the bivalve *Sanguinolites,* recording the first fully marine conditions in the succession. Above, carbonaceous-rich, laminated siltstones and cementstones, some containing fish scales, fish spines and plant material, are composed of impure ferroan dolomite, pale grey in colour, and very hard and flinty. They consist of laminated cementstones of probable primary origin, and **concretionary** cementstones of early diagenetic origin. The latter type require pauses in sedimentation of hundreds of thousands of years for their formation, and unlike the cementstones 20 km to the south in the Tweed embayment, they are not associated with **evaporite** minerals.

At the northern end of the wave-cut platform, overlooking the entrance to Cove Harbour, a 47 m thick composite channel sandbody called the Horse Roads or Horse Road Sandstone cuts down into the underlying rippled siltstones (Figure 1.3B). It is an **argillaceous**-rich, medium to coarse-grained sandstone with locally developed large brownish ironstone concretions which can be traced at intervals in the cliff face above the foreshore. Internally the sandstone is complex, containing trough cross-bedding, ripple cross-lamination, horizontal laminations, channelling and scouring, and locally deformed and overturned cross-bed **foresets**. Immediately north of the sandstone the Cove Fault **downthrows** strata some 900 m to the north, bringing in younger formations of the Strathclyde Group.

The Old Red Sandstone succession at Pease Bay was deposited by southwesterly flowing, distal sandy braided rivers, suggesting a source area, possibly including **granite**, somewhere in the present day North Sea. Deposition was interrupted periodically by contemporaneous tectonism diverting the river system to another part of the basin, thereby allowing time, and freedom from active sedimentation, for the formation of calcrete. Towards the top of the succession lakes were established on the braid-plain which received short-lived pulses of sediment during stream and sheet flood events. During drier periods the lake waters receded, resulting in increased salinities and the formation of cementstones. Fluvio-lacustrine conditions continued to dominate deposition in the Lower Carboniferous, with thin, overbank **crevasse-splay** sands and silts giving way towards the top of the succession to a thick deltaic or low sinuosity distributary channel sandbody deposited on the Lower Carboniferous coastal alluvial plain.

Glossary

Bibliography

At all times follow: The Scottish Access Codeand Code of conduct for geological field work

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