Excursion 16 Upper Old Red Sandstone of the Firth of Clyde

Key details

Author	B.J. Bluck
Theme	Recognition of different alluvial deposits in the Upper Old Red Sandstone.
Features	Characteristics of channel-bar sediments and features distinguishing them from floodplain-floodbasin sediments; the upward coarsening unit, and its significance in recognition of the deposits of river bars; the diverse types of alluvium and the use of related channel bar and floodplain sediment to determine the nature of the alluvial sequence; the significance of the range of alluvial types in terms of environmental and tectonic controls; recognition of the scale of rivers and its significance in palaeogeography; megasequence stratigraphy and its meaning in terms of basin type and evolution; the structure and significance of carbonate palaeosols (caliche) and the stratigraphical evolution of the Upper Old Red Sandstone in the Firth of Clyde.
Maps	O.S. 1: 250 000 Sheet RM 3 Western & Central Scotland 1: 50 000 Sheets 63 Firth of Clyde B.G.S. 1: 50 000 Sheet 29 Rothesay 1: 50 000 Sheet 22W Irvine 1: 50 000 Sheet 30W Greenock
Terrain	Coastal pathways and low coastal cliffs. Some walking on rough and sometimes slippery coastal sections.
Distance and Time	c.30 km from Localities 1–10; 6–8 hrs. Most localities are near the roadside but Localities 5–8 will require a walk of 2 km. Short itinerary, localities 3, 5, 6, 7, 10 ; time 4 hrs. Car travel is assumed in these times, but at the time of writing there is a bus service which passes close-by all localities.
Access	No restriction

Introduction

a. Stratigraphical setting of the sequences

The Upper Old Red Sandstone deposits of the Firth of Clyde range in thickness from c.4 km in the region of Helensburgh, to <100 m in the southern Midland Valley. Their age is not known precisely , but they are older than the Carboniferous lavas which rest on them and younger than the oldest rocks (upper Lower Devonian) of the Strathmore syncline, upon which they rest.

The rocks comprise a series of mega-sequences which fine upwards, beginning with coarse conglomerates and ending with a blanket deposit of quartz-rich sandstones and comstone (caliche), the latter being themselves overlain by the Clyde Plateau Lavas (Figure 16.1). There are three upward fining mega-sequences within the Clyde district: between Helensburgh and Rosneath (not seen on this excursion), at Wemyss Bay (Locality 3) and at Portencross (Locality 7). Only at Portencross can the Upper Old Red Sandstone be seen to rest on certain Lower Old Red Sandstone; there is an unconformity at the base of the sequence at Wemyss Bay, but the rocks beneath the unconformity are almost certainly Upper Old Red Sandstone belonging to the top of an earlier cycle of upward fining sediment, possibly the one which begins between Helensburgh and Rosneath.

The general tectonic regime within which the sediment has accumulated has been discussed by Bluck (1978, 1980), who favoured deposition in an extensional basin which opened along a series of normal faults. Each fault created in the basin a megasequence beginning with conglomerate and ending with sandstones and caliche. In addition, as the basin extended to the SW, younger faults were created and younger megasequences produced at the foot of them ((Figure 16.1) A, B). The conglomerates produced at each fault scarp during the early stages of fault growth have their own distinctive clast assemblages related to the particular source. This migrating fault margin to the basin is thought to have been produced during a sinistral movement of the Highland Boundary Fault or a fault related to it (see below). It is thought likely that the Fault entered a locking segment in the region of the Firth of Clyde (the Fault trace bends to the SW). If the ground to the south of the Fault is then stretched to the NE, but is locked in the Clyde region, the result is extension of the south (Midland Valley) side. The southern side responds to this extension by developing a series of normal faults lying roughly perpendicular to the Highland Boundary Fault, with each being the margin to successive basins which extended towards the SW ((Figure 16.1)C). This explanation, however, still requires more factual evidence before it can be accepted with any confidence, and as the Highland Boundary Fault may itself be a Late Devonian or Carboniferous structure, the main fault responsible may be an earlier but related fracture which has been obscured by this later movement.

b. The structure of alluvial deposits

The structure of a wide range of alluvial deposits can be seen in this region of the Firth of Clyde, and this introduction merely sets out to discuss some of the most common types so that their significance can be better appreciated at outcrop. Details of the interpretation of the alluvial sequences will be discussed at the appropriate localities, but there are some general points which need to be stressed about the general way in which ancient alluvium should be critically examined and assessment made of the significance of its presence at any one locality.

The processes which transport and deposit sediment in terrestrial environments generally vary in characteristics with their distance from source. Areas of sediment accumulation close to source are dominantly under the influence of the steep slopes and the often abundant supply of coarse sediment. Where there is high relief, the area of drainage is fairly small, the supply of sediment abundant and the rainfall occurs in heavy bursts, so that alluvial fans are likely to form. Depending on the ratio of sediment to water, these may be sites of mass flow deposition, where a chaotic jumble of sediment is laid down, or sheet-flood deposition, where shallow sheets of sediment-laden water spread out over the fan surface to deposit thin, laterally persistent, gravel beds. Both mass flow and sheet flood deposits can be seen at Localities 1 and 7.

When the area of drainage expands, a more regulated flow is attained in a longer and more stable channel system. In areas of high sediment discharge, and/or high channel slope, there is a non-sinuous wide zone of channels (braided river) flanked by an often poorly defined floodplain which is subject to flooding and sediment accretion only during high flow stages. Deposits from these river systems comprise many well defined gravel bars which dominate the channels and which grow generally in a downstream direction. The flood plains bordering these charnels are frequently liable to flooding and are normally devoid of fine sediment, which has either been eroded away or was not deposited from the fast-flowing flood waters. Braided sediment bars of this kind are illustrated at Locality 8.

Farther away from the source where there are often slopes of lower gradient, drainage is often confined to one main, fairly deep channel which can be either straight or sinuous, flanked by a well defined floodplain which, if very extensive, may form a floodbasin. The channels are characterised by many sediment bars which either form the central zone or are attached to one of the banks. With increasing depth of the river the bars become very thick units of sediment which reach down to the deepest parts of the channel and up as far as the top of the bank. Thick sediment bars in confined channels can be seen at Localities 4, 9, 10.

Another result of the deeper, confined flow of the river is that the floodplain is quite distinct from the channel, and is typified by flat sheets of sediment which overspill from the channel during flood events. On river systems we see around Glasgow today the floodplains are grassed over, but in Devonian times plants were not well developed and the climate was fairly arid, so floodplains were bare. Where the floodplains are well drained and not subject to a great deal of flooding, as when the rivers are near low upland areas, a particular palaeosol may develop on them which is typically found in arid and semi-arid regions today. This 'soil' is called caliche or cornstone, and is made up of carbonate. It is particularly well seen at Locality 2. Where there are wide floodplains with a good supply of flood sediment and a dry windy climate, then dunes may form. The floodplains and floodbasins associated with the deep rivers at Seamill (Locality 11) have dune deposits in the floodplain sequences. It is a characteristic of most river systems which have a source separated from the basin, that the grain size of the sediment bed-load decreases downstream. This grain-size difference, coupled with the factors discussed above, result in the alluvial facies acquiring a wide range in structure; there is not only the diversity associated with the differences between floodplain and channel-bar sediment, but also the differences in both these regimes when traced from source. These differences in the structure of alluvium are very clearly demonstrated in the sediment of the Clyde coast.

Channel-bar deposits, despite their heterogeneity in structure, are all united by one characteristic: they comprise units of sediment which coarsen upwards from a recognisable base. This coarsening upward is brought about by the presence of an areal grain-size segregation within the channel (Figure 16.3). There is very little known about why this segregation has taken place, or indeed its significance in the mechanics of bed-load transport. Nevertheless this type of segregation is found abundantly in recent sediment throughout the world. When the coarse-grained part of the bar (the head) moves or extends downstream it often builds over the fine downstream part (the tail). The resulting structure is a unit of sediment which coarsens upward (Figure 16.3): this coarsening upward sequence may take place in sandstones (coarse sandstone overlying fine sandstones (Localities 4, 9, 11); or conglomerate (coarse conglomerate overlying fine conglomerate or sandstone (Localities 3, 8). The two sequences are at greatly different scales and have radically different appearances, but they share this common and fundamental attribute. Upward coarsening units abound in the Firth of Clyde, and will be a special feature of this excursion.

Locality 1. North end of Lunderston Bay [NS 202 748]: Breccias with Dalradian clasts (Figure 16.4)

Parking is quite easy here, as there is a large car park on the west side of the road. The hills to the NE above the garden centre are in thick caliche and white sandstone. They belong to the upper part of the Upper Old Red Sandstone sequence, and the breccias which occur on the shore here and in the raised beach along the road are stratigraphically below these caliche beds. The breccias are therefore also high in the sequence, and imbrication and cross stratification show a dispersal towards the SE, away from the Dalradian block to the NW. The breccias contain slates and psammitic clasts which are very similar to the local Dalradian, and Bluck (1980) believed that they were from this source. The clasts show convincingly that the Dalradian block was in contact with the Midland Valley by Dalradian times and that it was in sufficient relief to shed debris to the south.

These breccias are laid down in sheets which can be traced for some distance over the outcrop. They are probably the result of sheet-flows, where sediment-laden water disperses over a surface which has little relief. The flat shaped clasts are well oriented and in some instances can be seen to be aligned in a swirling pattern suggesting that the flow was sometimes quite 'viscous': in this case the breccia sheets may be thought of as mass-flows.

Locality 2. Inverkip [NS 200 718]: Caliche (Figure 16.4), (Figure 16.5), (Figure 16.6)

This exposure occurs on the shore just below the car park (with toilet, but not open continuously) on the headland, and can be reached at high tide, although it may be examined to much greater advantage at low tide. The rocks comprise white quartz-rich sandstones, red muds tones and carbonate beds (caliche). The sandstones are cross stratified and have occasional clasts of a fine, dense carbonate which resembles the caliche layers to be discussed below. These sandstones are channel deposits of small-scale river systems which are either at some distance from source or are near to low-lying source blocks which were yielding very little coarse sediment. The interstratified mudstones and carbonates are the overbank floodplain deposits to the same or allied systems.

The caliche is preferentially found in the muds tones of the floodplains, although it can also be seen in some of the sandstone units. The most complete profile can be seen at the NE end of the exposure, where sparse, nodular carbonates are replaced upwards by elongate carbonate pillars and finally by massive, irregular carbonates ((Figure 16.5) A). This is a section through an almost complete caliche profile. The nodular phase represents the immature, early stages of caliche development: the dense, massive unit represents the final most mature stage. Other sections at this outcrop have only immature profiles which are at the pillared or nodular stages.

Caliche occurs when water, usually from rainfall seeps down through the surficial layers of sediment only to return towards the surface because of the intense evaporation at the surface. It therefore characterizes arid or semi-arid regions of the world where the rainfall is low and the ground surface is hot. Carbonates are dissolved as the waters pass down and are then precipitated as they migrate up towards the surface ((Figure 16.5) B). At first only nodules develop, then the nodules grow to coalesce in the zones where the water is more concentrated. Where there are spaces along which water may move easily, as along mudcracks, carbonate is concentrated to form pillars. The next stage is reached where the nodules have amalgamated into a massive unit of carbonate which will no longer allow the water to percolate through. At this stage the rainwater concentrates on the surface as pools in which pisoliths may form.

Caliche grows very slowly, normally far more slowly than the rate of sedimentation. It only develops on fairly stable surfaces, such as river floodplains, rather than channels which have mobile sediment which is not stationary long enough for caliche to develop. The depth to which the rainfall percolates below the surface is fairly constant, and the depth below the surface reached by the return flow is fairly constant too, so that there is a distinctive zone in which the nodules grow below the surface ((Figure 16.5) C, Z). If the surface is building up by sedimentation, then the depth to which the rainfall descends below the surface rises all the time, as does the depth of nodule growth. By this means, the profile is hindered in its development of maturity, and remains an immature profile. There are a number of such profiles at this outcrop.

This section occurs towards the top of the Upper Old Red Sandstone, where there are many such profiles, some of which are > 5 m thick. On the basis of other evidence there was slow subsidence in the entire Upper Old Red Sandstone basin across the Midland Valley towards the end of its development and floodplain surfaces were exposed for a long period before being buried. For this reason caliche surfaces are well developed in floodplain sediments at this time and can be traced for kilometres where the oucrops are favourable; the presence of thick caliches is an indication that the sequence is at the top of the Upper Old Red Sandstone.

Locality 3. Wemyss Bay [NS 189 699]

Unconformity, megacycle and faulting (Figure 16.6). Parking at this locality is difficult as the road leading to the outcrops is private but no permission is needed to go down the road on foot. However, there are parking facilities just outside the grounds (See (Figure 16.6)). The rocks at Wemyss Bay illustrate a number of important issues which are essential to the understanding of the Upper Old Red Sandstone history:

1. Unconformities within the Upper Old Red Sandstone.
2. The initiation of an upward fining megacycle and the sequence of facies associated with it.
3. Faulting.

There are 4 sub-localities which are used to illustrate these points.

a. A cross stratified conglomerate rests discordantly on bright red sandstone. The red sandstone has been extensively used for building, and to the north of this outcrop a small harbour has been quarried into it. The sandstones are best seen in the low cliffs to the north of this quarry, at the foot of the wall which runs along the road. Here they comprise alternations of flat stratified, rippled and mudcracked sediment and cross stratified sandstones. The environment of origin of this sandstone unit is uncertain; it is probably aeolian, with the flat stratified irregular beds being interdune deposits (see Locality 9).

b. The conglomerates have large-scale cross strata which dip towards the NNW. They are associated with more gently dipping strata some of which dip at low angles to the SSE. These are backset beds, and in combination show that these sediments were deposited from gravel-dominated sediment bars the height of which was equal to the thickness of the foresets and backsets (Figure 16.3), (Figure 16.10), (Figure 16.11). The bar height is the minimum depth of the stream, and in this instance streams of about 2–3 m depth are likely to have laid down this alluvium. They flowed to the NNW. On the basis of data collected here and on the outcrops to the south of the pier at Wemyss Bay, the rivers are thought have been braided and fairly near to source.

The conglomerates contain a wide variety of clasts which include white vein quartz, quartzite, schist, amphibolite, acid-intermediate volcanic rocks, and very few granites. Many of these clasts are well rounded and those of the more durable lithologies such as vein quartz and quartzite are probably in their second or more cycles.

c. These beds are discordantly overlain by cross stratified pebbly sandstones which contain the same assemblage of pebbles as the lower conglomerate. This overlying conglomerate has upward coarsening sediment units (see (Figure 16.3) for explanation) which were deposited by river systems flowing towards the NNW.

The beds are repeated by two faults, one of which can be seen at (d) in (Figure 16.3).

Interpretation: This is the lower part of an upwards fining mega-sequence which has been cut by a number of roughly N–S fractures. The sequence ends with caliche and sandstones which can be seen in the region of Leap Moor.

Locality 4. Shore at Knock Castle [NS 1913 6303]

Cyclical sediments of channel-bars and floodplains (Figure 16.7): (Figure 16.8). These exposures can be visited at any state of the tide, but are best viewed at low tide. From just north of Largs to this locality they comprise numerous alternations of coarse cross stratified sandstones and conglomerates (coarse member), with flat stratified sandstones in alternation with thin mudstone bands (fine member). Together they form units 2–10 m thick.

The exposure under consideration is 330 m north of the lodge at the entrance to Knock Castle and is situated below a car park on top of the low-lying cliff and can be easily identified by its presence beneath a wall. Here a coarse member, resting erosively on a fine member, begins with units of upward coarsening sediment which are 0.5–1.0 m thick. In its upper part, the coarse member comprises a unit which is a level of organization above that of the basal, in that it comprises four different lithologies (Figure 16.7) A:

b1 A wedge of ductile folded and refolded sandstone which thins to the east;

b2 A unit of cross stratified sandstone in the middle of the outcrop, which also wedges out to the east;

b3 A sheet of coarse pebbly sandstone which underlies the wall and caps the outcrop to form an upward coarsening unit;
b4 A coarse grained unit of uncertain affinities.

All three units, b1–3, are in part transitional or interfingering.

An explanation for this outcrop (Figure 16.7) B involves the following lines of reasoning:

1. The cross strata dip towards the NW indicating that the flow was in that direction.
2. With the divisions b1–3 being transitional or interfingering, then the coarse sediments of b3 are partly equivalent to the finer sediments of b2 and bl, and all divisions were therefore laid down at the same time. The palaeoflow is towards the NW and the whole outcrop becomes finer in that direction, i.e. downflow, so that there was on the river bed a pile of sediment which became finer downstream. This type of size-segregation within alluvial channels is typically found in sediment bars (see Introduction).
3. The sequence coarsens upwards indicating that the sheet of coarse sediment of the upstream margin (to the SE) has migrated over the fine to give an upward coarsening unit (compare (Figure 16.3)); and the direction of coarse sediment migration was in the direction of stream flow.

4. Such mechanisms of sediment migration and the sequences they produce are typically found when bars of sediment migrate downstream. Sequences like this can be seen, for example, now forming in the End rick Water.
5. The whole sediment sequence thickens downstream and this may be due either to the bar migrating into deeper water, or the whole sediment bar building up on the stream bed. It is clear that if this explanation applies then the minimum depth of the river is given by the height of the bar, which in this instance is c. 3 m

Locality 5. Farland Head [NS 178 484]: Faults (Figure 16.9)

There is a free car park at the first farm entering Portencross. The exposures lie on the coast in front of the car park and extend to the south. Walk south beyond Sandy's Creek to the begining of the sandy beach of Ardneil Bay (Figure 16.9) (a). This beach is underlain by fairly gently dipping (up to 35°), bright red sandstones of the Upper Old Red Sandstone which patchily emerge from beneath the beach sands. To the west of the sandy bay, these fairly gently dipping sandstones are in fault contact with steeply dipping, and sometimes overturned, bright red, flat-stratified sandstones rocks of uncertain age, but which are provisionally regarded as belonging to the Upper Old Red Sandstone.

To the west are fault bounded, sheared grey siltstones and lithic arenites at Sandy's Creek. These beds are c. 501n thick, and on spore evidence are considered to be Lower Devonian or possibly Late Silurian in age (Downie and Lister 1969).

The Upper Old Red Sandstone rocks of Ardneil Bay do not appear within the Upper Old Red Sandstone sequence to the north where the basal Upper Old Red Sandstone rests on the Lower (Locality 7). The beds in Ardneil Bay belong to a group of sandstone which extends at least to Ardrossan and was built by a large, contemporary river system (Localities 9, 10, 11). If these sandstones once overlaid the sequence north of Portencross (as seems probable) the throw of the fractures at Arneil Bay and Sandy's Creek would therefore be substantial, since they fault out not only the Lower Old Red Sandstone sequence but also the whole of the upward fining megasequence at Portencross. The nature of the faulting is not clear, but elswhere in the sequence there is evidence for much high angled reverse faulting (see (Figure 16.9), section A-B).

Locality 6. Car park: Lower Old Red Sandstone (Figure 16.9)

These rocks form the foreshore and the raised beach platform from the car park to the castle. They are a brown-red colour and are thought to belong to the Lower Old Red Sandstone. They comprise alternations of flat stratified and cross stratified sandstones and conglomerates. There is a wide variety of sedimentary structures to be seen in these deposits: sedimentary lineations, mudcracks (seen in section as pillars of sand in shale but as polygonal surfaces in plan), and a wide variety of cross stratification. Some of the cross strata are in tabular sheets with mudstone drapes over the foresets and mudstones at the base (bottom sets) and rippled strata at the top (top sets). These deposits resemble the flat-topped bars of sandy sediment described from recent braided stream deposits, representing a facies not depicted in (Figure 16.2).

The interstratified conglomerates which can be readily seen on the northern margin of the outcrop near the castle, comprise clasts of mainly volcanic rock which include andesite and andesitic tuff as well as basic volcanic rocks. Clasts of a green sandstone present here are particularly abundant further up in the sequence.

The palaeoflow for these sediments is from the south in which direction we can infer from the composition of the sandstones and conglomerates there was a source made up of dominantly volcanic rock.

Locality 7. Northbank

Unconformity between Lower and Upper Old Red Sandstone and an upward fining megacycle (Figure 16.9). Follow the path northwards through the gap in an E–W Carboniferous dyke. The faulted unconformity between Lower and Upper Old Red Sandstone is exposed on the rocky foreshore. The Lower beds are mainly dark red sandstones which range in dip direction from north to NW. They are overlain by a quite distinctive conglomerate which contains clasts of quartzite, sandstone, vein quartz and minor amounts of green sandstone, chert and lavas. At the base of the sequence these conglomerates are coarse and massive; they were probably laid down by some mass-flow mechanism. Cross stratal dip and clast imbrication show that they were laid down by a flow running from south to north, and the source block was almost certainly a pre-existing conglomerate with abundant clasts of quartzite. The quartzite clasts are generally very well rounded, but some have been broken before entering this sequence. Some of these broken clasts have rounded edges suggesting transportation after being broken.

This basal unit fines upward and is replaced by muds tones with mudcracks, minor caliche beds and thin conglomerates and sandstones. These strata form a distinctive hollow on the shore and are succeeded to the north unconformably by a sequence of cross stratified conglomerates and sandstones. These conglomerates are particularly rich in green sandstone clasts.

Locality 8. Hunterston

Gravel bar of a braided river (Figure 16.9), (Figure 16.10), (Figure 16.11). This locality is reached by following the track along the top of the shoreline beyond Jenny's Dyke to the boundary fence of the Hunters ton power station. The section under discussion occurs in a distinctive hollow south of this fence and in the present-day cliffs exposing sandstone. The map (Figure 16.10) is of the top of the low cliff section south of this hollow and includes most of the low cliffs along the shore. These beds are gently dipping to the east in contrast to the beds near the unconformity and are roughly equivalent in stratigraphical position to the conglomerates and pebbly sandstones of the section south of Jenny's Dyke.

There are three lithofacies to be seen at this outcrop (Figure 16.9): (d), a flat stratified alternation of sandstone and conglomerate; (c), a sheet of cross stratified conglomerate and pebbly sandstone and (b), a wedge of cross stratified sandstone. Lithofacies (a) is below this outcrop and is exposed in the cliff on its western side.

The sandstone is overlain by the cross stratified conglomerate and itself wedges out to the south where the overlying bed replaces it. Further to the south the cross stratified sheet of conglomerate is replaced gradually by the overlying flat to gently dipping alternation of sandstone and conglomerate (see (Figure 16.10)). The cross strata and clast imbrication indicate a flow to the north, and the dips of the cross strata are in a fairly constant direction in the case of the conglomerate, but variable in the case of the sandstone.

Bluck (1986) has interpreted these rocks in the following way (Figure 16.11):

The cross stratified conglomerate (c) represents the successive lee faces of a bar which migrated to the north. On the upstream margin of this bar were the back sets and top sets of the flat stratified unit (d), and on the downstream margin were the fine grained sands of the bar tail (b). The lee face over the bar climbed over the tail to produce an upward coarsening sequence as seen at Locality 3. The lithofacies (a) represents the channel deposits below the bar.

Locality 9. Bastion Craig: Channel sand body (Figure 16.12)

This locality at Bastion Craig may be reached by foot from Farland Head or by car by driving past the golf club and down to the shore. On no account should buses go down this road. They may park elsewhere e.g. just south of Seamill where parking is suggested for Locality 11. This part of the coastline is made up of low ground underlain by fine, soft sediments, of large-scaled cross-stratified sandstones and alternations of red mudstone and sandstone and upstanding outcrops of red cross-stratified pebbly sandstone.

Bastion Craig is a sand body the top part of which comprises, at its western margin, pebbly sandstone and conglomerate (C5) , and at its eastern margin mainly sandstone (C3) overlain by pebbly sandstone (C4). With the dispersion of sediment being from SW to NE the coarse sediments belong to the head and the fine to the tail, but as with other bars, the coarse head has migrated over the fine tail to give an upward coarsening sequence and the gradation between the lithofacies C4–05 is seen at (b); and between C4 and C3 at (a). At (a) it is possible to trace this gradation by reference to bands of conglomerate, where between two conglomerate units C4 grades downstream into C3. The whole structure is best viewed from a vantage point near the golf course where this latter gradation in facies is particularly well seen (Figure

16.9), (Figure 16.12). C1 and C2 do not appear on the map; they refer to facies which, although seen here are best seen at Locality 11, where the lithofacies notation (C1 etc.) is the same as for this bar.

The mid-part of the bar comprises trough cross strata, sometimes organised into small upward coarsening units, and the tail of the bar comprises planar cross strata which wedge out towards the west (Figure 16.12). This sandstone is enclosed in beds which comprise alternations of sandstone and mudstone and which outcrop to the south and west.

Locality 10. Bell Stane [NS 190 476]

Floodbasin deposits, dunes overbank deltas (Figure 16.13). The foreshore to the north and west of Locality 9 is interpreted as floodbasin deposits and these can be examined on the foreshore. The floodbasin comprises a number of lithological elements each of which can be related to the processes known to take place in present-day floodbasins:

F1, Thinly stratified (1–10 cm) alternations of siltstone and rippled sandstones. These are interpreted as thin overbank sand sheets dispersed out of the channel either during a slight flooding or the distal ends of thicker sand sheets such as described under F_2, or simply lacustrine sediment accumulated during periods of flooding.

F2, Cs cross stratified, pebbly sandstone sheets which occur amongst 1 and represent crevasse splays. These occur quite near to the bank of the river and were produced during times of flooding in the main channel and breaching of the river bank followed by the spread of sand sheets onto the adjacent floodbasin area. They can be seen at several positions as marked on the map of the foreshore.

F2, De large-scale sand sheets which are upward coarsening and contain abundant wedge-shaped cross strata. These could be confused with channel deposits (ch) but are thought to be deltas of sand produced when there was a strong overbank breach during flood so that the floodwaters and their entrained sediment filled the lakes and other bodies of standing water which was in the low ground in the floodbasin (Figure 16.14). They may be the distal terminations of F2 Cs above.

F3, very large scale, often trough-like, cross strata in soft friable and pebble-free sand. These lithologies are thought to be the lower parts of aeolian dunes which transported sediment on the floodbasin when it had dried out. This suggests that the floodbasin and river system existed in a fairly dry climate. Beneath these large-scale cross strata are often very irregular red sandstone and claystone beds with indistinct ripples. These are interdune sandstones and mudstone which occur between the dunes and are therefore more likely to be buried and preserved than any other of the dune lithologies.

Locality 11. Seamill

Large-scale sand body (Figure 16.15): (Figure 16.16). Park cars on the main road just south of Seamill, and approach this locality by following the pathway, south of the river and alongside a large, red sandstone house which backs onto the shore. This locality is in a major sandbody which may be 8–10 m thick. The far distant, west (seawards) side of the sheet (C5, (Figure 16.15)) can only be examined at low tide and comprises planar cross stratification in coarse pebbly sandstone. As the section is traced to the east (landwards) these cross strata are replaced by trough cross strata (C4i, C4ii, (Figure 16.15)) and the zone of transition can be seen at (c). These trough cross strata are seen to overlie planar cross strata which form the upper part of the cliff section at the most landward margin (C3) of the sand body. Below the planar cross strata, soft, cross stratified sandstones (C2) are seen to interfinger with the overlying planar cross stratified beds (Figure 16.15), a, and form the more deeply eroded part of the cliff section, and the low ground to the north of this outcrop.

There is a prominent pebbly sandstone unit on the foreshore north of the main outcrop and south of the stream. This sandstone is easily recognised by the presence of concrete all along its outcrop (there is a pipe-line buried here). In the notation for these lithofacies this is Cl and may belong to the same bar-channel system as the main outcrop being discussed.

A detailed examination of the outcrop shows a number of important Features at (bi) the trough cross strata of C4i interfinger with the planar cross strata of C3. At (di) a mass-flow of sandstone has probably been produced during the de-watering of a sandstone at (dii).

The cross strata dip in the same direction as the lithofacies change and from these observations a number of significant points can be made (Figure 16.15): the large scale foresets on the seaward side of the outcrop (C5) are replaced, when traced landward, by the trough cross strata of the main part of the outcrop (C4). These trough cross stratified sandstones overlie the planar cross strata of C3 with which they also partly interfinger. C3 dominates the outcrop on the eastern (landward) side of the map (Figure 16.15). Together the whole section forms a large upward coarsening unit some 8–10 m thick, which has C5 at its upstream end C4 in the central areas and C3 in the downstream regions; and all these facies overlie the sediments of C2 to which they are related by interfingering. The position of C1 in this scheme is uncertain but may be the basal channel deposits as illustrated in (Figure 16.16). The whole sequence is interpreted in terms of a large river bar with head and tail regions (Figure 16.16) and which migrated downstream to build up the upward coarsening unit.

The whole development of this bar complex is similar to that described at Localities 4 and 8, but because now the scale of both the bar and the river is much greater so the lithofacies are thicker, more complex and the transitions take place over a greater distance.

Trough cross stata in the main part of the outcrop are beautifully exposed in 3-D: they are themselves arranged in upward coarsening units which can be as much as 1 mthick. The top of this sequence is gradational upwards into overbank deposits exposed on the rock platform to the south and which comprise very large aeolian dunes and interdune sediment as described at Locality 10.

These sediments were laid down by a river which was at least 6 m deep, and was fairly distal, being in its floodplain-floodbasin reach (see (Figure 16.2)). It flowed to the east through the Midland Valley and out towards the North Sea. Deep rivers are normally also wide and carry a considerable quantity of water and sediment; and there is now a good deal of evidence to suggest that the Old Red Sandstone rocks were deposited under the influence of large-scale river systems. Large scale rivers normally have large catchment areas to supply the great sediment and water loads and usually drain to the sea; an inland lake would soon be filled by these rivers (see Introduction).

The palaeogeography of the whole North Atlantic region for Devonian times involved a large sea to the south, in England, and very high mountainous areas to the north in Greenland and Scandinavia. It is probable that the large river which built these Upper Old Red Sandstone bars at Seamill drained these northern mountains, was diverted through the Midland Valley and then drained southwards through the North Sea to the Devonian coast in the south.

Summary of excursion and significance of observations

1. In terms of the distribution of alluvial facies as shown in (Figure 16.2), alluvial sediments have been examined from the proximal regions (mass-flow deposits, probably on alluvial fans; Localities 1 and 7: proximal braided alluvium; Localities 3, 7 and 8: mid-distance alluvium; Locality 5: and distal alluvium: Localities 9, 10, and 11. These localities show a proximal-distal increase in bar thickness from c. 2 m in the proximal; 3–4 m in the medial and 8–10 m in the distal. This almost certainly reflects an expected change in river depth from proximal regions. At the same time as there is a change in the scale and complexity of the bars there is also a change in the nature of the overbank sediment: from little or no overbank sediment in the proximal sediments of Hunterston (Locality 7) and Wemyss Bay (Locality 3) to a greater thickness of overbank sediments in the bars north of Largs (Locality 4), to well developed floodbasins in the Seamill area (Localities 10, 11, 12). It is emphasised however that this sequence of alluvium does not belong to the same river system: the very large river system which occurs at Seamill (Locality 12) had its drainage well outside the present Midland Valley, whereas the river systems which deposited the conglomerates north of Inverkip (Locality 1) and Portencross (Locality 6) were clearly local.

2. The clasts in the conglomerates at Portencross differ greatly from those at Wemyss Bay. It is therefore inferred that the nature of the source which gave rise to these sediments also differed. However both were deposited by river systems

draining areas from the south: they share the same dispersal direction but they clearly do not belong to the same dispersal system, so a source block is inferred to have existed between Wemyss Bay and Portencross. It is on this and other evidence that Bluck (1980) postulated that the conglomerates were deposited in separate basins. With each conglomerate belonging to an upward fining sequence, each was thought to form at the foot of a fault scarp (see (Figure 16.1)). One explanation for a series of fault bounded basins is that they formed as a result of a shear movement along the Highland Boundary Fault or its equivalent.

3. There is ample evidence for post-Upper Old Red Sandstone N–S faulting, and this late-stage fracturing has controlled the orientation of the coastline and may have been responsible for the development of the Clyde Basin.

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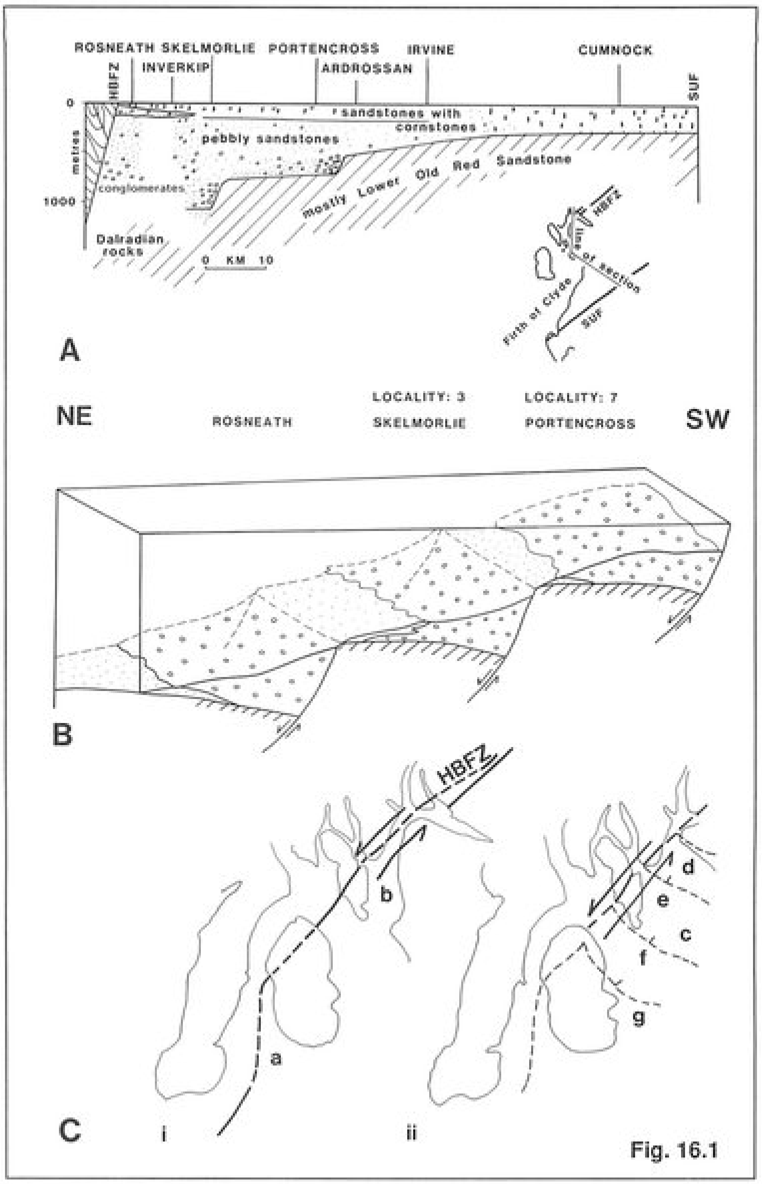
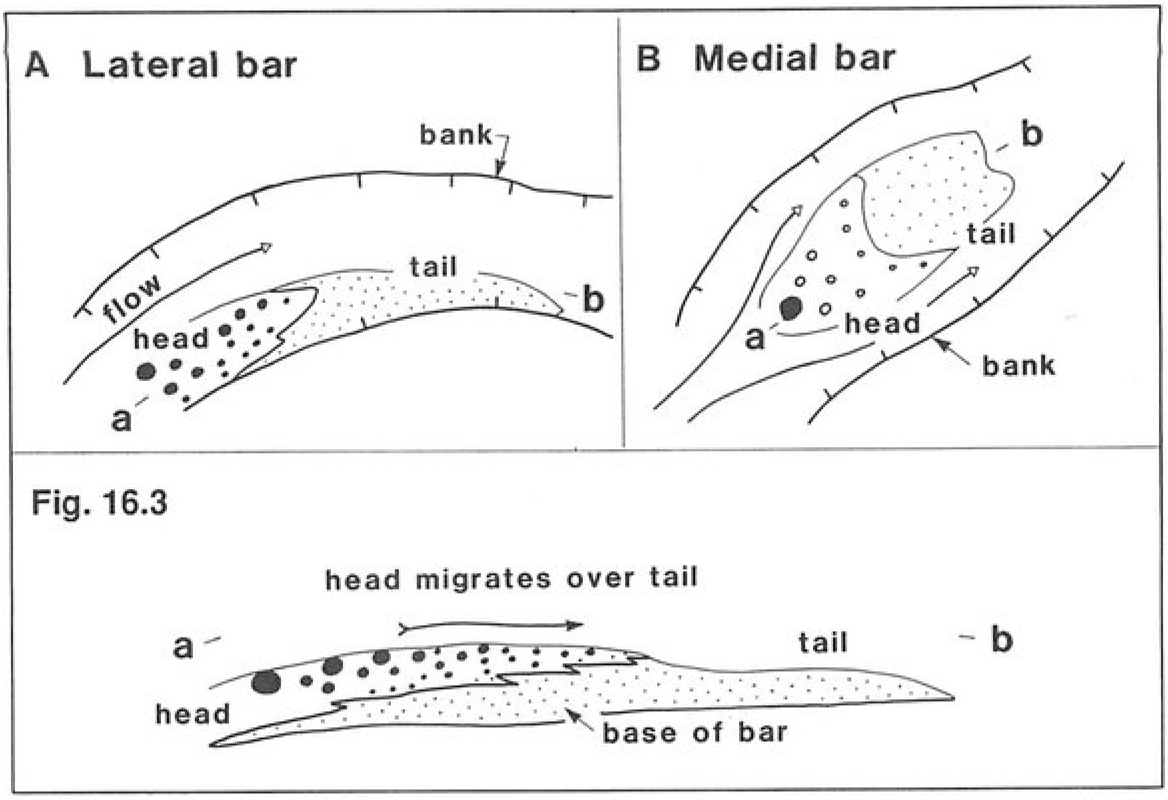
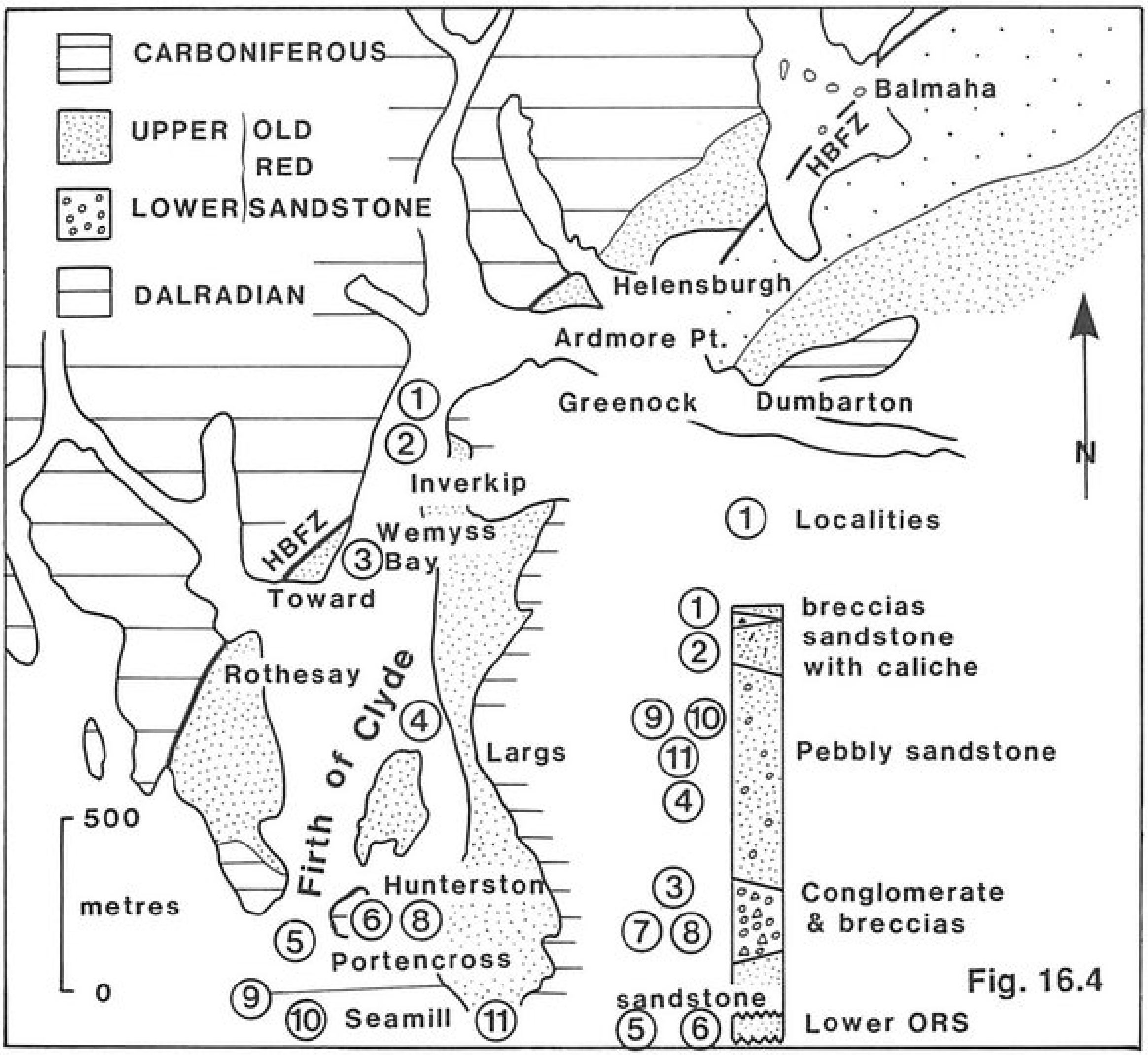


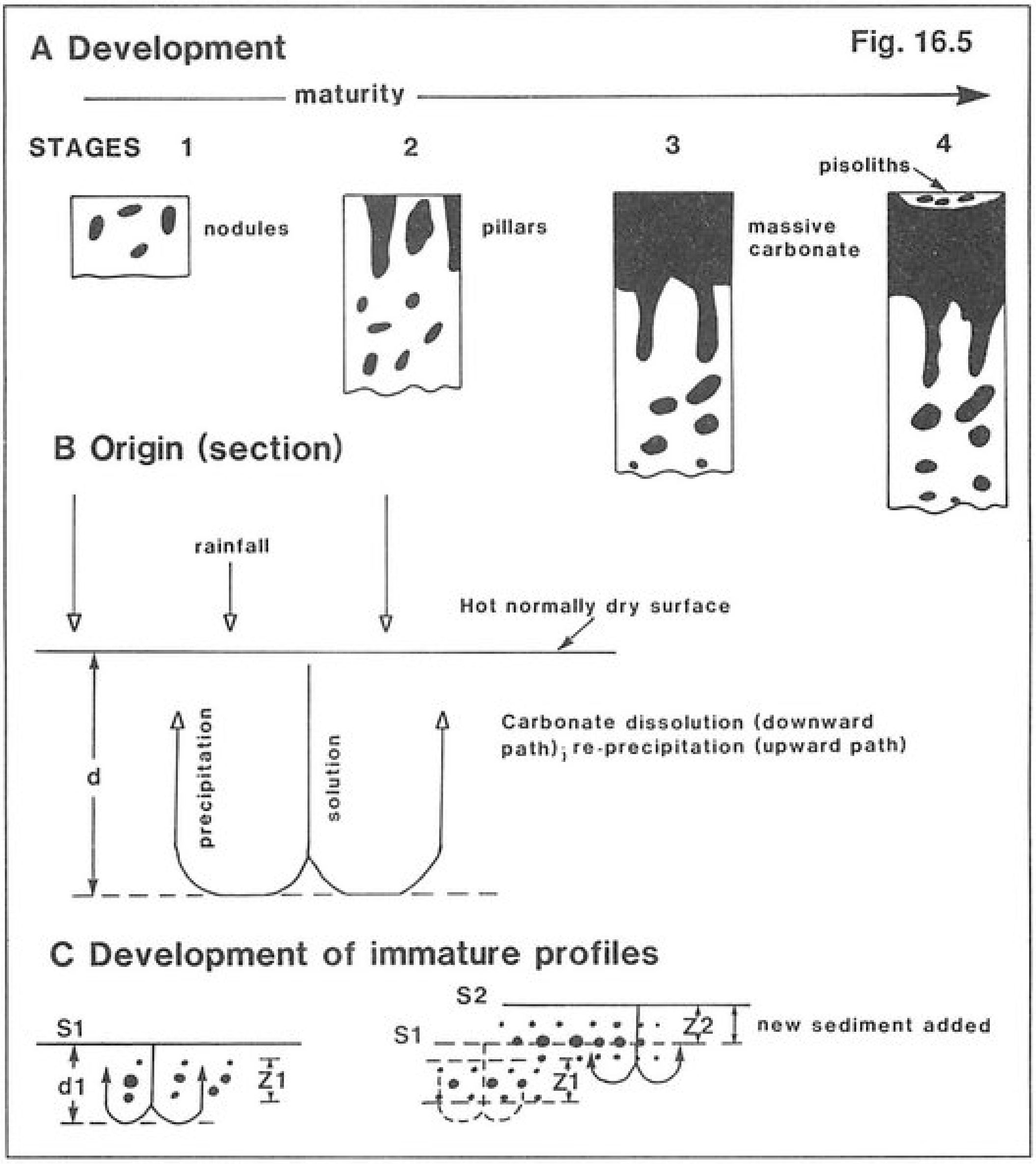
(Figure 16.1) Explanation of the structural and stratigraphical context of the Upper Old Red Sandstone basin. A, Cross section, B, Interpretation of the upward fining megacycles in terms of contemporary faulting, C, Explanation of the regional control on the basin formation. A sinistral movement on a fault (the Highland Boundary Fault or some fault which may be associated with it) which has a bend in the region of Arran, caused extension in the areas a-b in Ci. There is extension here because it is difficult to move material on the south side of the fault around the bend at (a) Because of this extension there is a sequence of normal faults developed which form the basins at (d, e, f, g) (Cii) where (d) is the basin at Rosneath, (e) at Wemyss Bay and (f) at Portencross. (g) is a remaining source block on Arran. HBFZ, Highland Boundary Fault Zone; SUF, Southern Uplands Fault



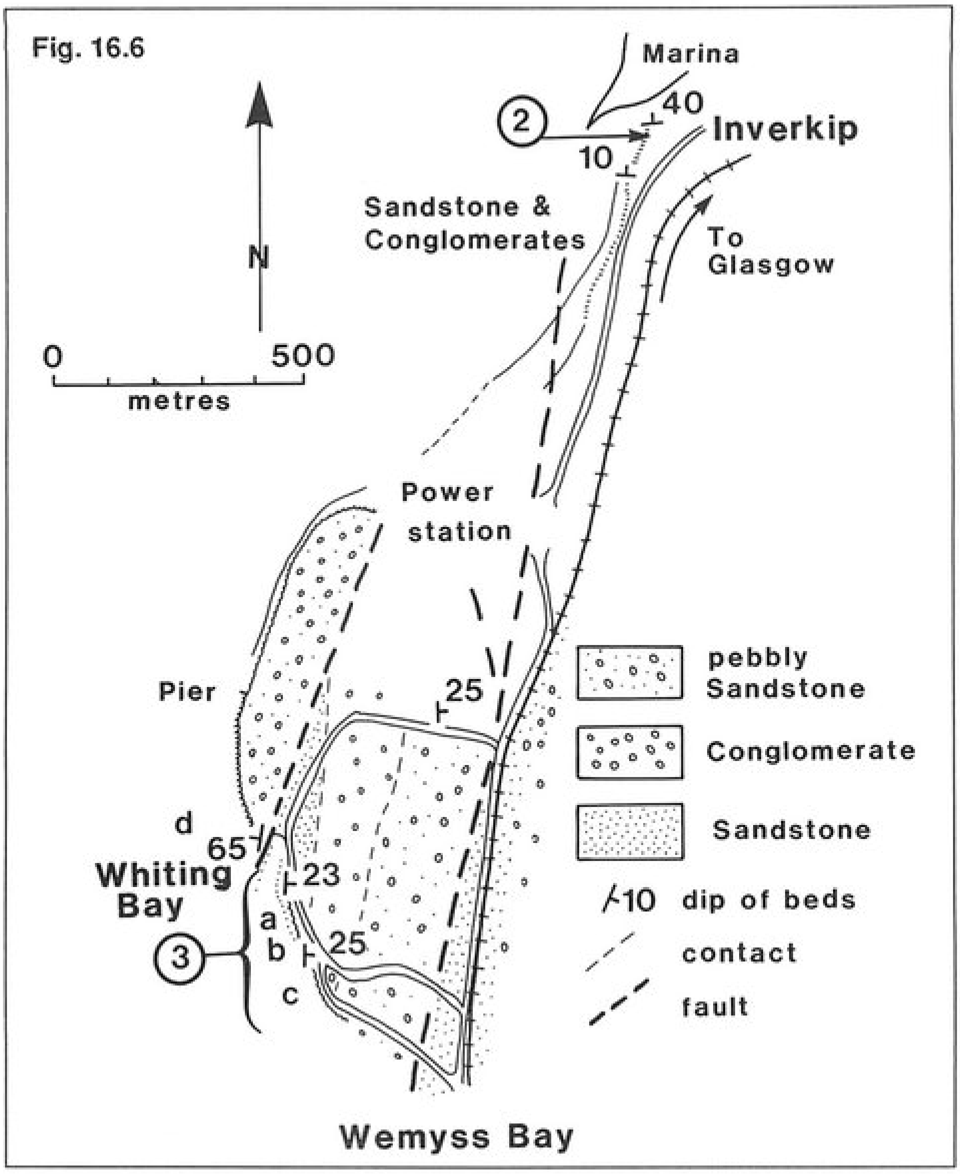
(Figure 16.3) Explanation of upward coarsening units with head (coarse) differentiated from the tail (fine) and with the head migrating over the tail to form the upward coarsening structure.



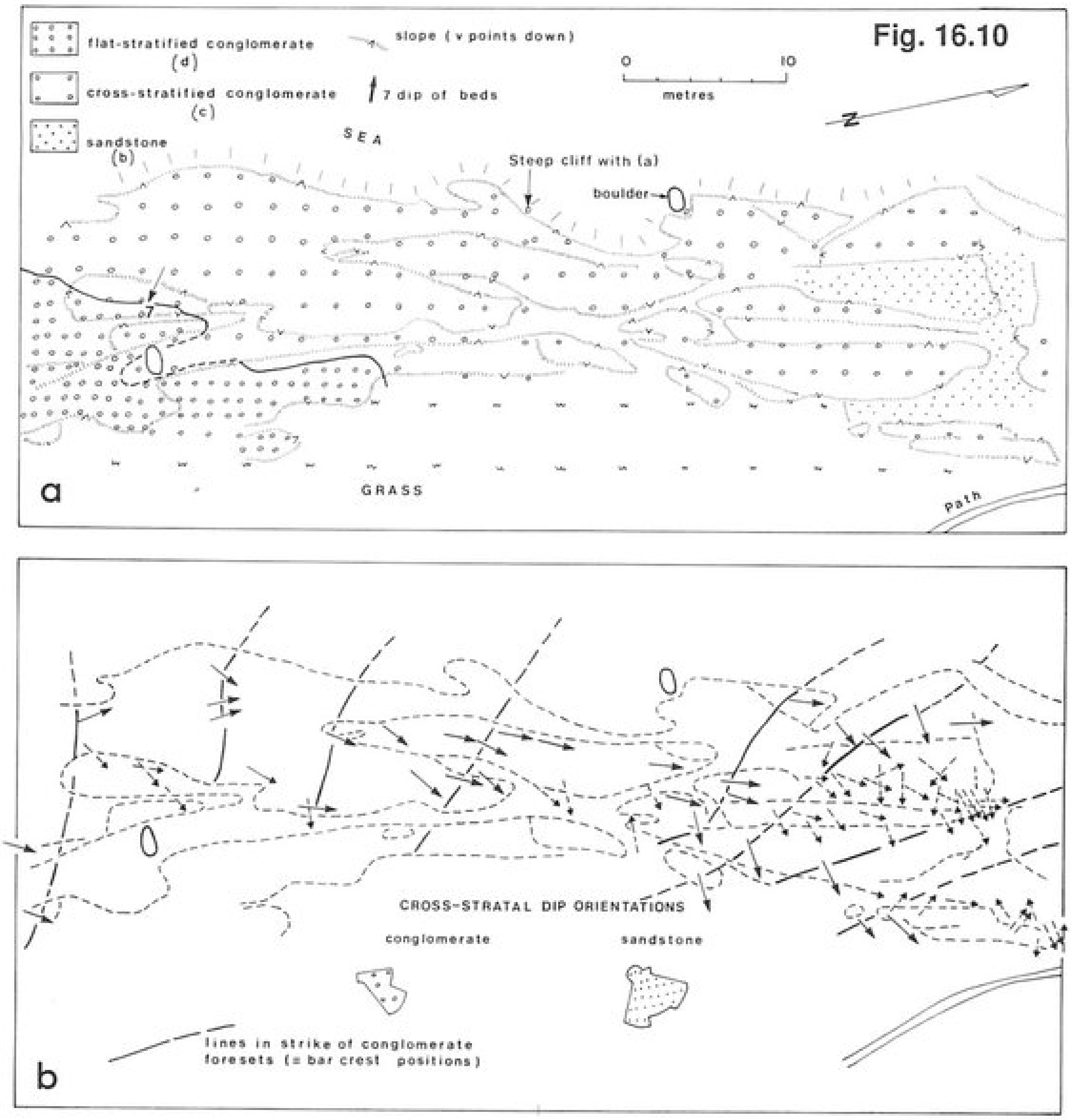
(Figure 16.4) Map of localities along the Firth of Clyde, which are also positioned on a composite stratigraphical sequence.



(Figure 16.5) Explanation of the development of caliche. A traces the stages in its development through time in section. Stage 1, at the initial stage only nodules form but as time proceeds the nodules coalesce into pillars if the muds are mudcracked or into larger nodules if not. Stage 3 occurs when the pillars and nodules grow into a massive bed; and stage 4 occurs when the massive bed no longer lets water through and pools appear on the surface in which pisoliths form. B, provides an explanation for the growth of caliche; d refers to the depth to which percolation of the rainwater normally goes. C, the development of thick beds of stage 1 or 2 etc occurs when there is a continous addition of sediment to the surface, so that the depth of water percolation dl, and the zone of nodule formation Z1 rises as the sediment is added. The surface does not mature because the process is not operating in the same zone (Z1) for a sufficient length of time.



(Figure 16.6) Map of the region: Inverkip–Wemyss Bay.



(Figure 16.10) Map of gravel bar (a) at Locality 8 together with cross strata) dip orientations (b).

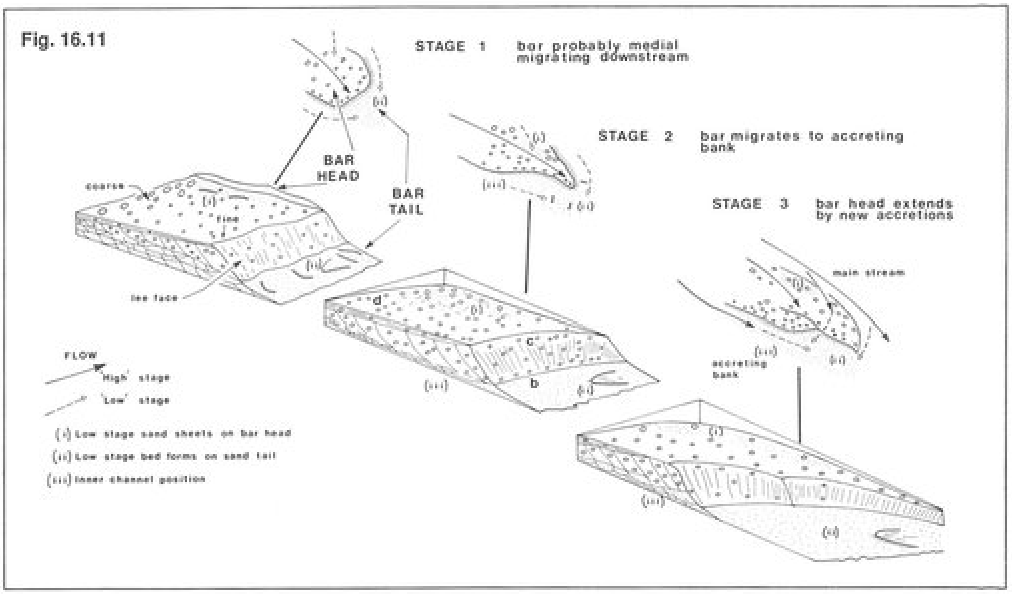
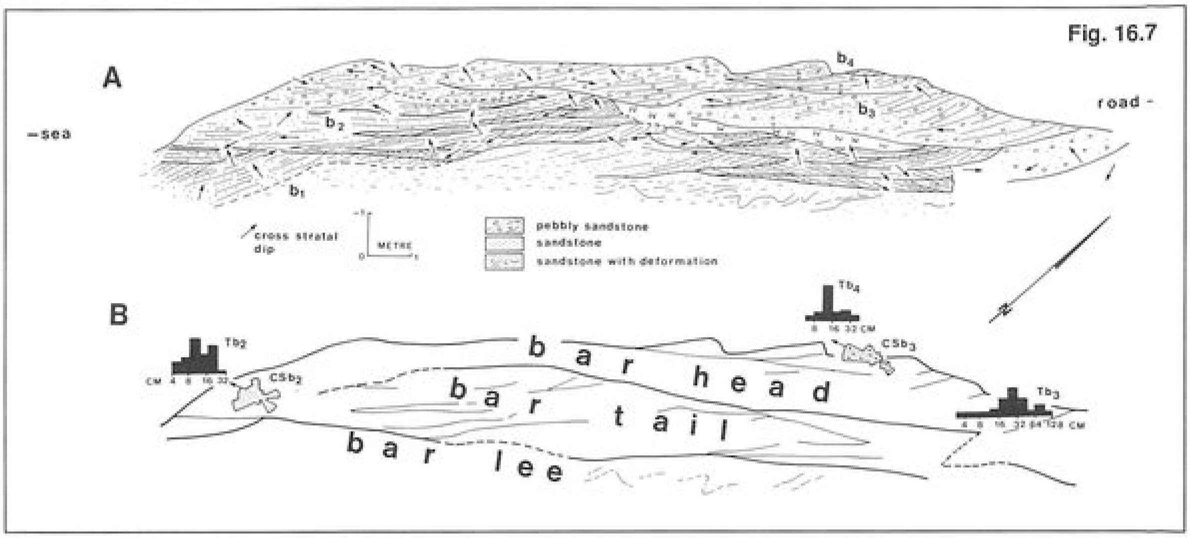
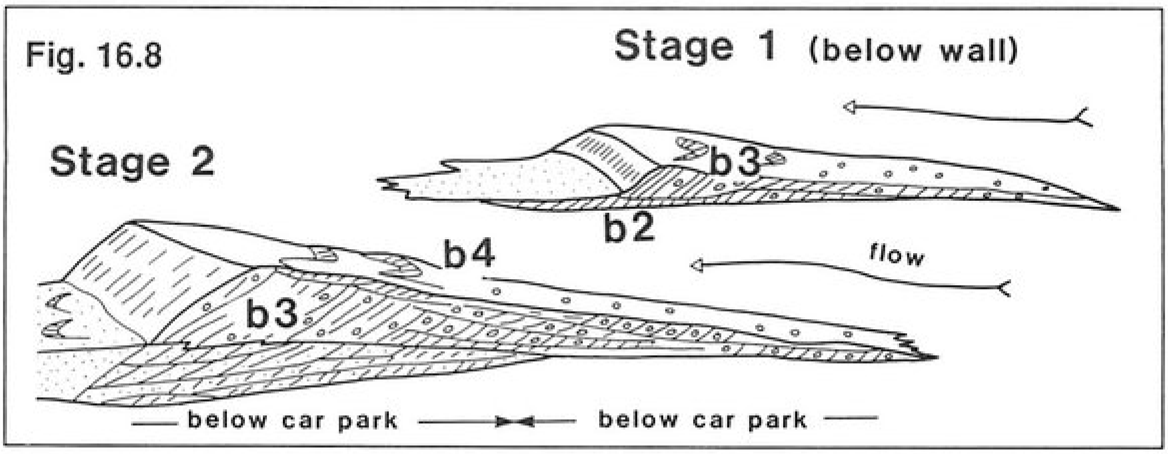


Figure.16.11. Explanation of the development of the gravel bar at Locality 8; **a, b** etc refer to the location of lithofacies discussed in text and shown in Figure 16.10.

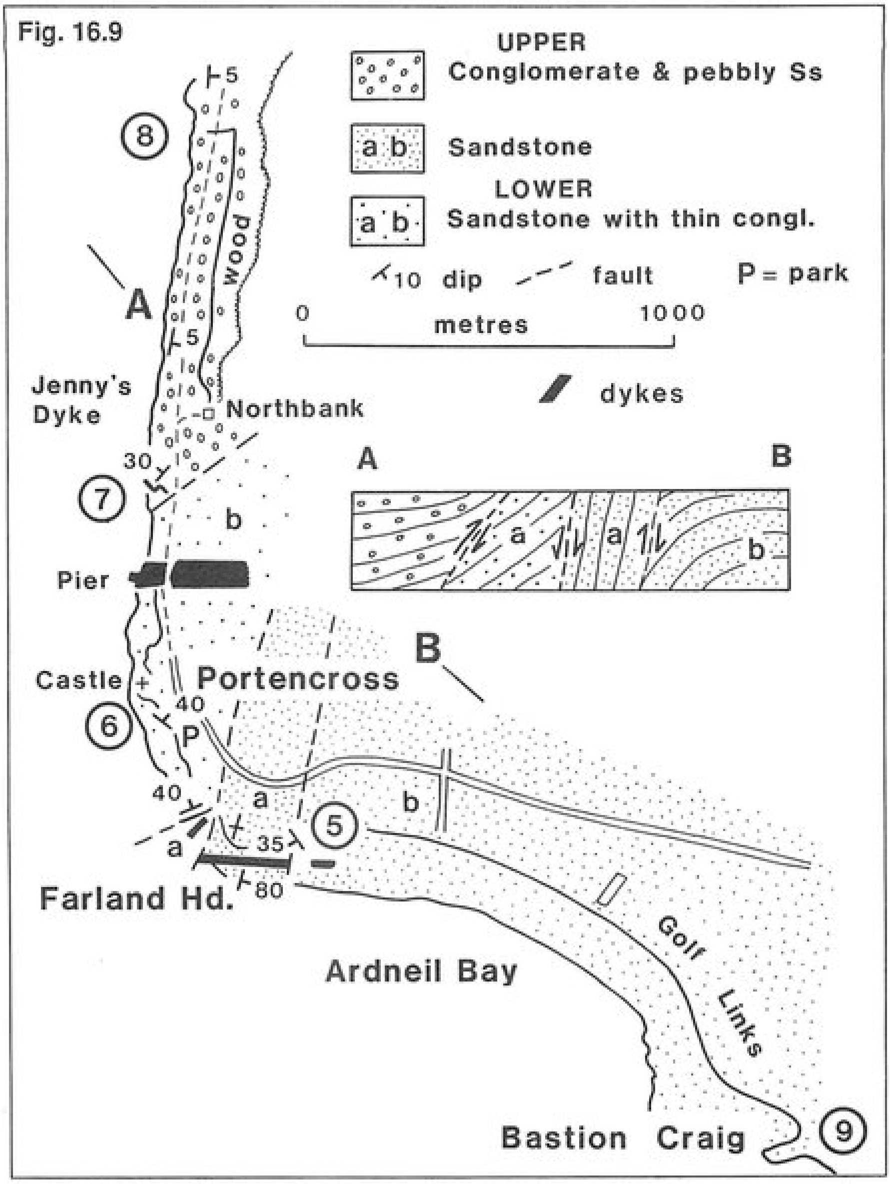
(Figure 16.11) Explanation of the development of the gravel bar at Locality 8; a, b etc refer to the location of lithofacies discussed in text and shown in (Figure 16.10).



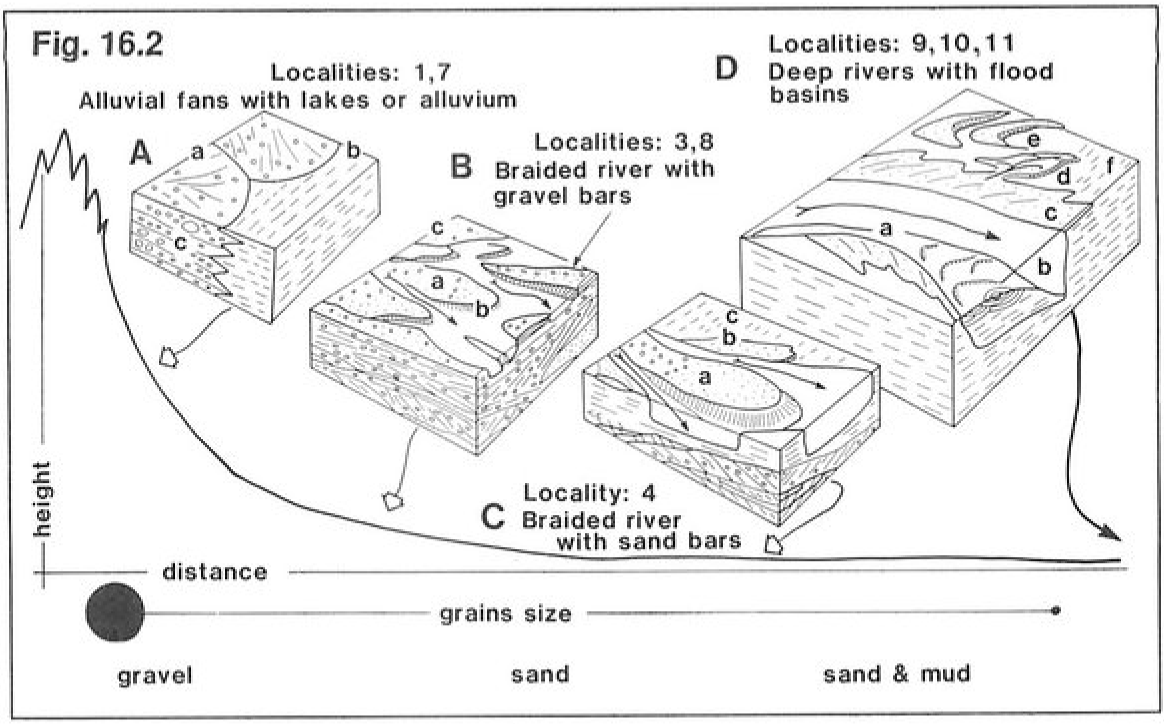
(Figure 16.7) A, Section through sediment bar, Locality 4. b1 etc. refers to lithofacies described in the text B, interpretation in terms of an alluvial bar where the head refers to the upstream (coarse) segment and the tail, the downstream fine. The farthest downstream facies is the bar lee where the finest sediment accretes. T=thickness of cross strata; CS=cross strata! dip orientation, both given for the lithofacies (b2 etc) The wall is to the right of the section.



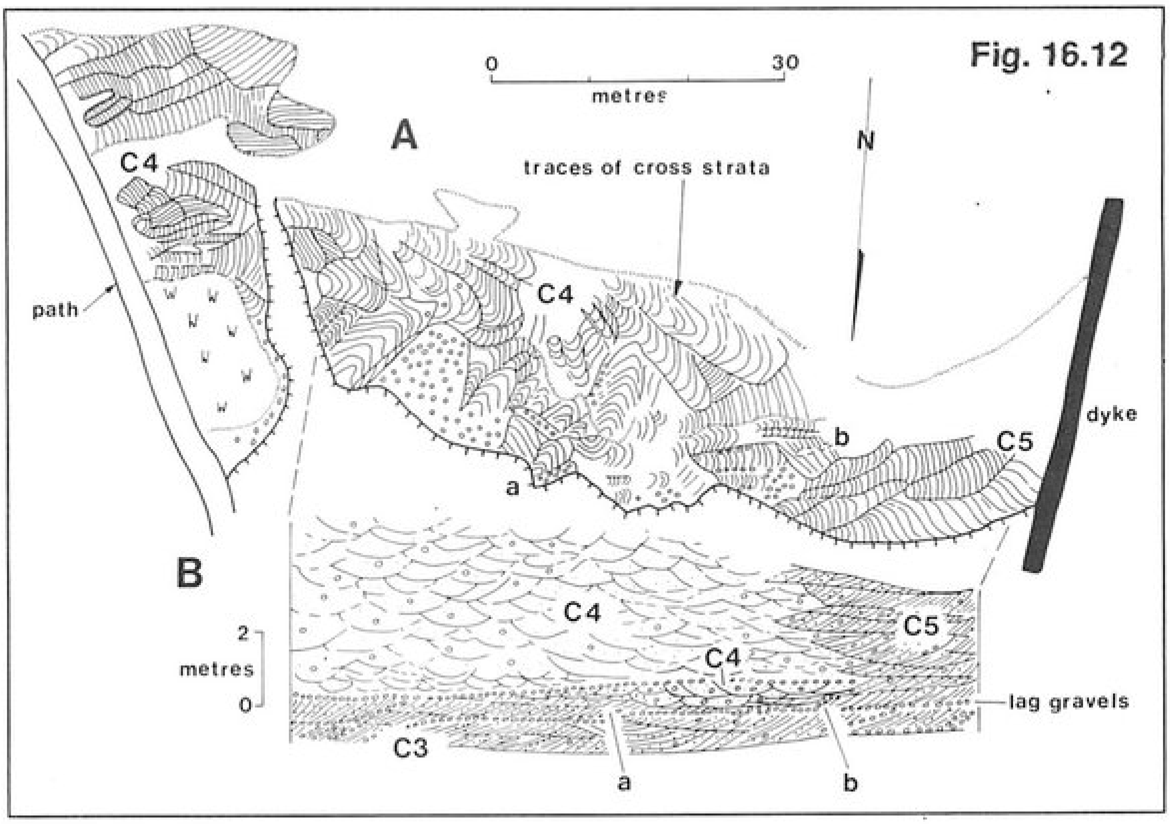
(Figure 16.8) Interpretation of the development of the bar complex at Locality 4; b2 etc. refer to the lithofacies discussed in the text and in (Figure 16.7).



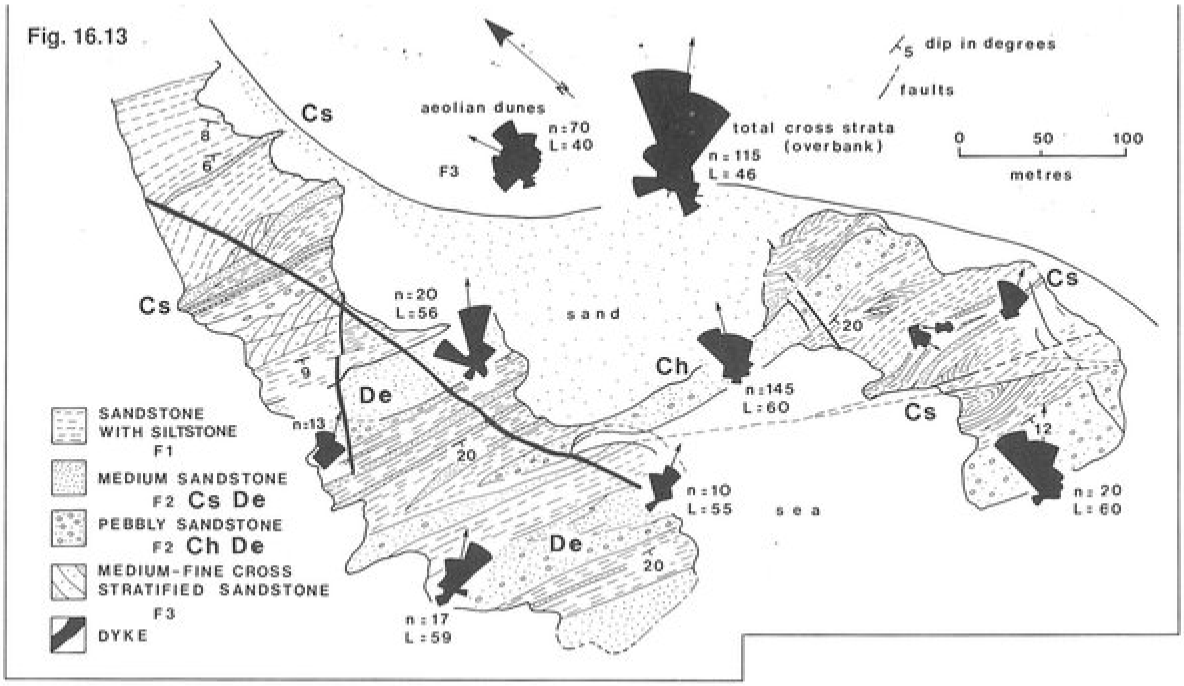
(Figure 16.9) Map of Farland Head with localities and a simplified cross-section A-B.



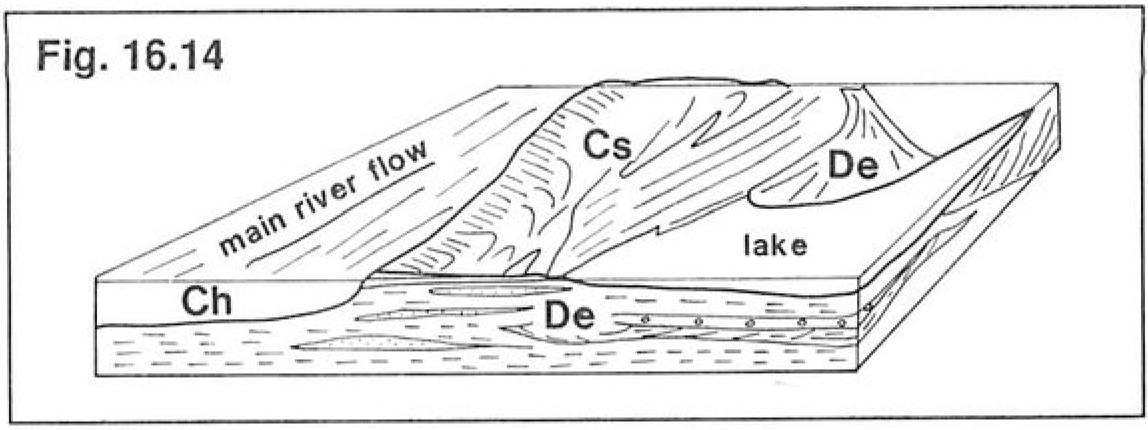
(Figure 16.2) The effects of changing slope, distance from source, grain-size and the water depth on the structure of alluvium. These changes are seen not only in the structure of the bars but also in the structure of the overbank (floodplain) areas. A, alluvial fans (a), lakes or alluvium (b) and internal structure (c) B, gravel bars with coarse heads (a) and fine tails (b) and with coarse floodplain sediments (c) C, deeper channels than B, with well defined bars (a) and splays of sand (b) into the floodplain areas (c) D, deep channels (b) with sandy bars (a) and crevasse splays (c); deltas (d), dunes (e) and temporary lakes (f).



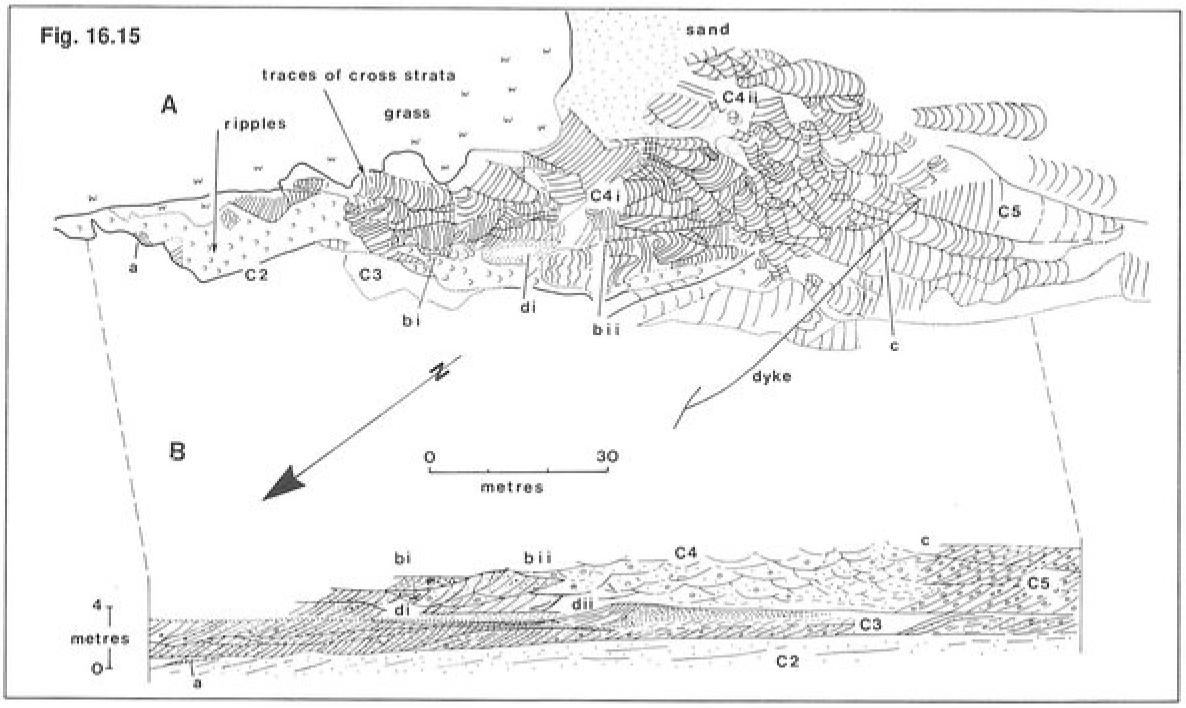
(Figure 16.12) Map of Bastion Craig (A) together with section (B) Letters in bold capitals refer to lithofacies; letters in lower case to localities. C3 refers to tabular cross strata at the base of the section; C4, to trough cross stratified sands which are the main part of the outcrop; C5 to the thick, coarse-grained tabular cross strata which can be seen only at low tide. At (a) there is a transition between the tabular cross stratified sands of C3 and the trough cross strata of C4; at (b) the C5 the tabular cross stratified pebbly sandstones of C5 grade into the trough cross strata of C4. P = the point from where it is best to see the transitions.



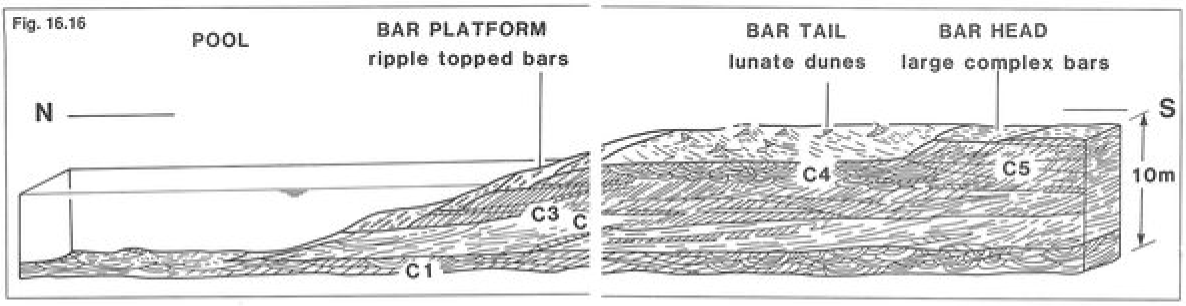
(Figure 16.13) Map of the floodbasins sediments. The lithologies are mapped as set out in the legend, but in addition an interpretation of these lithologies is given by the following codes: Cs=crevasse splays; De=deltas; ch=channels. In this notation deltas (which are the result of crevasse sands building onto the floodplains) are a combination of two gradational or interfingering lithologies- medium grain-size sandstone and pebbly sandstone. Rose diagrams refer to the cross stratification dip directions n=number of readings, L=vector magnitude (which is inversely related to the standard deviation of spread of the data) The diagram total cross strata (overbank) refers to dip directions of the cross strata in the sandstone sheets which have originated as sandstone crevasse splays i.e. De and Cs.



(Figure 16.14) A model of floodbasin deposition for the Bell Stane region. Cs etc refers to text and (Figure 16.13).



(Figure 16.15) Map (A) and cross section (B) of the sandstone body at Seamill, Locality 11. Letters in capitals refer to lithofacies, letters in lower case to localities. C2, refers to the soft, friable large-scaled cross strata; C3, to the tabular cross stratified sand sheets; C4, the trough cross stratified deposits and C5 the tabular, pebbly sandstones. At a, C2 interfingers with C3; at bi and bii C4 interfingers and grades into C3; and at c, C5 grades with C4.



(Figure 16.16) Explanation of the Seamill sandstone body, Locality 11. C2 etc as for (Figure 16.15) and text.