24 Sedimentology of the Ythan Estuary, beach and dunes, Newburgh area

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Purpose

The object of the excursion is to examine recent sedimentological features of the Ythan estuary and adjacent coast. Sedimentary environments include sheltered estuarine mud flats, exposed sandy beach and both active and stabilised wind blown sand dunes.

Many of the sedimentary features to be described are dependent on local effects of tides, winds and currents. The features described are thus not always present, and the area is worth visiting under different weather conditions particularly during winter.

Access

Most of the area described lies within the Sands of Forvie National Nature Reserve and all notices concerning access must be obeyed, particularly during the nesting season of terns and eider ducks (Apr.–Aug.) when no access is possible to some areas. Newburgh is 21 km (13 miles) north of Aberdeen via the A92 and the A975. Parking for cars is available at the layby by locality 1 at [NK 006 2831], and on the east side of Waterside Bridge for localities 2–8 (Figure 1).

Alternatively the area can be reached by a cliff top path from The Nature Reserve< Centre at Collieston and could be visited in conjunction with Excursion 13. Localities 9–10 can be reached from the beach car park at [NK 002 247] at the end of the turning off the A975 at the Ythan Hotel.

There is a single coach parking space at the parking area at Waterside bridge, but the other parking areas are guarded by narrow entrances to prevent occupation by travellers with caravans.

Walking distance on paths and shore is 9 km for localities 1–8 starting at locality 1 or 6 km starting at Newburgh Bridge. Low tide is essential for examination of the estuarine mudflats and channel. The dunes and beach at localities 9–10 (2 km walking), and locality 11 (7 km walking), can be examined as an excellent alternative when the Nature Reserve is closed. Visitors are strongly advised against venturing onto the mudflats for their own safety and to prevent disturbance of areas under scientific study. Binoculars will be found useful, and wellington boots are advised for the estuary. The area is covered by O.S. 1:50,000 sheet 38.

Introduction

The excursion is designed to illustrate features of sedimentological and ecological interest from the geological viewpoint. Details of fauna and flora have thus been kept to a minimum.

Itinerary

Locality 1. Inner estuary [NK 006 284]

The northerly layby overlooks an area of sand and mudflat on the east side of theriver. The mudflat is crossed by a small tributary stream and backed by an area of saltmarsh. Behind the saltmarsh is an overgrown river cliff indicating that at one time the main channel was close to the western bank.

Saltmarsh. The saltmarsh area is only flooded on rare occasions and is above normal high tide level. The top of the saltmarsh is relatively dry and vegetated with a wide variety of plant species when compared with locality 2. Only a few inlets and pools occur within this marsh area; the pools are normally water filled but have mud floors with polygonal mud cracks indicative of periods of desiccation. Only a sparse fauna is present but some pools contain the amphipod *Corophium* and shore crabs. Strand line material occurs near the edge of the marsh and includes marine elements such as crab shells, seaweed with barnacles and even jellyfish which have been brought up river on the flood tide; also present is vegetation brought down by the river from upstream. The edge of the saltmarsh is broken and degraded and minor erosion appears to be taking place between the layby and the tributary stream. Beyond the tributary stream the character of the saltmarsh top changes due to the presence of a thin covering of blown sand which is best seen 100 m north of the tributary where a small beach is developed and wind blown sand overlies saltmarsh sediments, and bears a different vegetation from the normal saltmarsh top.

Tributary stream. In 1985 the tributary stream had a sand and gravel bed which usually showed well developed linguoid ripples with gravel visible in the troughs and black heavy minerals concentrated on the ripple crests. However in March 2008 (see (Figure 2) below) there was no sand present and the stream was eroding marsh deposits.

The stream bed is soft! At the first bend in the tributary as the stream crosses the mudflat the stream has eroded a small cliff c. 30 cm high in the mudflat sediments which are black and reduced below the surface but retain a brown oxidised zone around burrows which allow water circulation. On the inside of the bend a small point bar of rippled and laminated sand is in the process of deposition. Faster flow in the straight shallow channel downstream of the bend results in the formation of isolated sand ribbons rather than ripples on the channel floor.

Upper beach. At the top of the beach zone a narrow sandy zone is developed which has scattered angular pebbles on its surface in the area near the layby. The surface is usually smooth but small parallel crested ripples are sometimes present. Concentrations of shells of the small gastropod *Hydrobia* frequently occur at the top of the beach in hollows at the marsh edge.

Mudflat. The sandy upper beach grades into the mudflat away from the saltmarsh edge. Increase in mud and water content of the sediment is noticeable! The fauna of the mud surface is dominated by *Hydrobia* (in summer) and the small U-shaped burrows of the amphipod *Corophium*, which in places are found right up to the saltmarsh edge. The only bivalve living in this area is the shallow burrower Macoma balthica. The surface sediment is extensively bioturbated. This area is 4 km from the open sea and the marine fauna consequently reduced in comparison with localities 2 and 3. The bivalves *Cardium* (cockle) and *Mytilus* (mussel) do not live in this area, which is near the upper limit of barnacle and seaweed growth in the estuary. Accumulation of sediment in this area has been taking place (since 1978) on the high area of the sandflat adjacent to the tributary stream. In 1985 this area was in the process of colonisation by grass and algae, with some areas covered in summer with a resistant mat of filamentous green algae and with clumps of grass established on the sand surface. Partial drying of the area occasionally produced incipient polygonal mudcracks at the end of the high area near the tributary stream. Little has changed in the last 30 years, if anything the grass has been reduced to a few smaller patches, and saltmarsh has not become established.

Main river channel. The main channel has a floor of fine gravel with migrating sand bars consisting of small flat dunes with a wavelength of a few meters which are associated with ripple marks. At low tide the tops of the dunes are generally exposed, but not readily accessible. Movement of the sand bars within the channel system causes changes in the channel position from time to time and probably influences deposition on the adjacent mudflat.

Locality 2. Middle estuary [NK 003 271]

Beside the parking area at [NK 004 270] on the east (upstream) side of Waterside

Bridge is an area of saltmarsh connected to the estuary shore by a small tidal creek which comes to within a few metres of the main road. The top of the salt marsh is wetter than at locality 1 and has a less mature flora, with sea plantain and sea pink in evidence. In the creek salinity is sufficient to support a fauna including the lugworm Arenicola whose castings can be seen on the creek floor. The absence of strong currents in the creek allows the castings over the exhalent arm of

the V-shaped burrow to build up as a mound while a depression is created at the inhalent arm of the burrow. A 'pit and mound' structure is thus built up by the activity of the worms on parts of the creek floor. *Corophium* is abundant in the creek together with ragworm (*Nereis*), shore crabs and the small gastropod *Hydrobia*. The marsh top is flooded by the highest tides. Isolated pools on the marsh surface also have a fauna including Nereis, shore crabs and abundant *Corophium*. The burrowing activities of the latter can be watched in the shallow, clear water of the pools. Drying out of the larger pools in summer leaves a mud floor with tracks of birds and crabs and polygonal cracking of the mud takes place. Smaller pools which appear to maintain a permanently damp substrate but do not have standing water, are covered with a green wrinkled algal and bacterial mats.

On the adjacent shore the increase in abundance of barnacles and seaweed attached to pebbles is noticeable, and in summer green fleshy plants of glasswort (*Salicornia*) colonise the upper beach. The numerous articulated Cardium shells lower on the shore are derived from a living population in this intertidal area. Mytilus shells are also present in this area derived from sparse living populations which occur up to 300 m upstream of this locality, particularly on the western bank.

A similar area of marsh, but with more grasses, is present on the downstream side of the bridge in front of the main car parking area.

Locality 3. Lower estuary [NK 004 262]

Beach and mudflat opposite the mill and quay where a fence crosses the beach at the entrance to the Nature Reserve.

Beach. A pebble beach about 20 m wide slopes down to the edge of the mudflat. Abundant broken shell material occurs between the pebbles, with *Cardium* and *Mytilus* are abundant and barnacles and seaweed cover pebbles on the lower part of the beach (contrast with locality 1). Small grass tussocks are attempting to colonise the upper part of the beach. On the beach, and on grassy areas adjacent to the beach, mussel shells opened by gulls and oystercatchers and patches of shell fragments defecated by eider ducks are common. The activities of these birds are discussed in the next section.

Mudflat. The mudflat extends out 150 m to the edge of the main channel which is marked by three large posts. The mudflat consists of a sandy mud layer 10–20 cm thick underlain by a shelly layer usually 10–15 cm thick. These two layers form a single graded bed which may rest on sand or on a pebble gravel. The main features of this bed have been described by Trewin and Welsh (1976) and are illustrated in (Figure 3). The mudflat surface is covered, particularly in summer, by filamentous green algae which trap and bind the sediment, aided by the burrowing activity of *Corophium*, and worms such as Arenicola and Nereis. The bivalves *Macoma*, *Cardium* and *Mya* burrow within the sediment and *Mytilus* occurs in groups on the surface attached to each other, seaweed or other suitable objects. *Hydrobia* is common on the mud surface and *Littorina* occurs most frequently in stony areas.

The molluscan fauna forms the main diet of a number of birds, notably the numerous eider ducks living and breeding on the estuary. The ducks' main dietry item is *Mytilus* but they, also take *Littorina*, *Cardium* and crabs. Whole shells are eaten which are broken in the crop and eventually defecated usually at a rest area on the beach. Broken shell material due mainly to the activities of eider ducks (see (Figure 5)) is the main constituent of the shell bed beneath the mudflat, but contributions from oystercatchers (broken mussels) and gulls (mussel fragments regurgitated) are also present. The formation of the graded bed is due to the sorting effect of the burrowing fauna. Despite the major input of mussel fragments at the mudflat surface they do not form the bulk of the shell bed, due to decay of the organic material in the shell structure which leads to distintegration of the shell. Consequently the mud is rich in fine needles of calcite c.1µm wide and up to 30µm long released from mussel shells in this way. Calculations on the numbers of eider ducks present (c. 2,500 in peak months) and their dietary requirements indicate that 38 tonnes of shell fragments are produced annually giving an average deposit of about 40 g/m^2/year over the estuary area below Newburgh Bridge, thus shell fragment input to the sediment due to bird predation is significant in this area. If this shell bed was buried and preserved in a geological context the fine carbonate needles from the mussel shells would probably be redistributed as a carbonate cement. Thus a calcite-cemented shelly bed might result. However mussel shells might be rare as fossils, their carbonate having been converted to cement.

Main channel. Dunes of mobile sand with axes oblique to the main channel may be seen beyond the mudflat and the three marker posts at low spring tides. The dunes, which face downstream and usually have amplitudes up to 30 cm and wave lengths of 10–30 m, are formed by the combination of ebb tide and river currents. The backs of the dunes are covered with linguoid current ripples which have shell fragments concentrated in troughs and heavy minerals on the crests. In windy conditions these ripples may be washed out by wave action during the ebb.

Locality 4. Main channel and mussel beds [NK 007 257]

Downstream from the mudflat at locality 2 the main channel swings close to the eastern shore; the mudflat area, here heavily colonised by mussels, lies to the west of the channel. The sloping area between the shore and river channel is pebbly and apparently stable, particularly near the channel where pebbles have a well developed epifauna of mussels and barnacles as well as seaweed. The edge of the channel is steep and colonised by mussels. Dead shells occur both packed vertically and imbricated between areas of living mussels in the channel. Patches lacking the cover of living mussels and seaweed are under erosion and show mussel shells in muddy sand and also occasional large *Mya* shells preserved in their vertical burrowing position. More than 20 cm of erosion must have occurred following death of the bivalves in their burrows. The hummocky nature of the channel edge is formed by the alternation of accretion areas with living mussels and seaweed forming a sediment trapping framework, and erosion areas lacking the protective living cover.

Downstream from locality 4 the character of the beach changes due to the proximity of the source of wind blown sand. Sand blows from the dunes into the estuary producing a sandy beach; the stronger currents in the lower part of the estuary also prevent mud accumulation. The sandy areas and strand lines usually show concentrations of shell debris from eider duck excreta (see (Figure 5)). The main channel floor and channel sides are colonised by mussels on which the ducks feed., At the edge of the channel dune structures composed of dead, imbricated mussel shells have an amplitude up to 1 m. These structures may be stabilised by living mussels on the steep landward side of the structure.

Locality 5. Dunes [NK 009 247]

If access to the dune area is restricted see localities 9–11. Typically the dune shapes developed are rounded and smooth with only rare slip faces, due to the damp nature of the sand (and climate) which results in only the top few centimetres being dry enough for erosion at any one time. Thus most dune surfaces are gently curved accretion and deflation surfaces. Areas of marram grass exert a strong control on sand erosion and deposition, acting as effective sand traps, but in turn creating deflation areas between grass clumps (see (Figure 4) below).

Some slip faces of the main active dune can usually be seen in this area, depending on recent weather conditions, particularly wind direction (no access during spring and summer). The crest of the dune is usually damp from dew in early morning, and dune faces become oversteepened. As the sand dries, runnels of dry sand (grain flows, see Locality10 picture) form on the dune face together with small sand slides containing coherent blocks of damp sand. Under some conditions, particularly after easterly gales. the slip face or rounded dune surface plunges directly into the river channel and the sand is returned to the sea by the river and ebb currents. Thus the sand is continuously recycled through the beach-dune-estuary system. Under extreme winter conditions interesting structures occur due to freezing of the surface and interlamination of snow and sand.

Locality 6. Sea beach

The sea beach forms an even sweep of coastline backed by sand dunes for 16 km south to the River Don at Aberdeen. There is considerable variation in the character of the beach, and depth of accumulated sand. At the time of writing (March 2008) the old wartime concrete defence post at the river mouth had sand covering part of the roof, and marram grass becoming established on the surface. However, only a few years ago the whole of the concrete structure was exposed and rested on gravel with boulders. At present sand level is high on the beach all the way from the Ythan mouth to Rockend.

The dunes are colonised by marram grass on the seaward side and by increasingly varied flora away from the sea. At the Sands of Forvie the dune system reaches its maximum development with a series of four major dunes which become increasingly stabilised by vegetation to the north away from the river mouth. Fresh sand enters the dune system from the beach under southerly to easterly winds. Dune shapes are irregular due to effects of marram grass colonisation, but low angle cross stratification can usually be seen where parts of old dunes are being eroded by the sea. In between the major dunes are deflation hollows which sometimes expose a pebble pavement which is apparently very old since the pebbles are frequently beautifully wind facetted on their top surfaces. It is possible that the dune system was established immediately following stabilisation of sea level following the last glaciation at about 10,000 years B.P. In places the dune system appears to overlie boulder clay. Stone hut circles and

Mesolithic worked flint flakes occur beneath the dunes in places. The flint being from water-worn pebbles. The medieval Forvie Church (Figure 1) was buried by blown sand in a great storm traditionally recorded as taking place in 1413. It is clear from historical records that the parish of Forvie, including the church and agricultural land was covered by blown sand prior to 1680. The dunes advanced as far as Collieston, but are now largely stabilised by vegetation.

Features of the beach zone vary according to tides and weather conditions, but normally the upper, supratidal part of the beach is dominated by structures formed by windblown sand which may be depositional (ripples and sand dunes), or erosional (sand ridges left behind shells and other objects).

Below the strand line, which usually contains the typically marine bivalve genera *Mactra*, *Spisula*, *Ensis*, *Arctica*, *Tellina* and *Venus* which do not occur in the estuary, the beach slopes at 1–5° to near low tide level and the surface is usually smooth with swash marks. Near low tide mark and beyond are a series of sand bars with long axes parallel to the shore which are driven onshore by wave action. Erosion of sand dunes backing the beach on this coast frequently occurs opposite a temporary gap in the offshore bars which allows the full force of the waves to remove sand from the upper beach and lower beach level so enabling waves to reach the dunes at high tide and erode a sand cliff.

The situation in March 2008 is one of sand deposition and seaward growth of the dune system in this area, however, rapid local changes can result in dune erosion as seen south of the river mouth at localities 10–11 (see below).

Locality 7. Heavy mineral concentrations [NK 018 261]

Towards the end of the sandy beach some 500 m from Rockend concentrations of heavy minerals, notably black magnetite and pink garnet occur near high water mark particularly between the old tank traps (not exposed in March 2008) and the dunes. The heavier grains are initially concentrated by wave action near high tide mark, and the concentration is enhanced by the selective removal of lighter grains by the wind into the dune system. When the sand level on the beach is low (tank traps fully exposed) the beach surface may be black near high water mark due to heavy mineral concentration.

It is usually necessary to excavate a small pit to observe the heavy mineral bands which can be up to 10 cm thick and display low angle truncations of laminae due to changes in upper beach slope, and to deflation of the upper beach by wind action. When traced down the beach the bands become more diffuse and eventually die out. If only the tops of the tank traps are visible the thick bands of heavy minerals are too deeply buried to be seen. At present these heavy mineral sands are buried by over 2m of beach and dune sands.

Locality 8. Stabilised dunes [NK 015 267]

From locality 7 take the path (at small stream just before the start of the rocky shore) back to Waterside Bridge. The track passes the ruin of the old Forvie Church where there is a signed trail that can be followed. The church and settlement of Forvie was covered with sand during a storm in 1413. The track then passes over mature heather-covered stabilised dunes which contrast with the active dunes near the mouth of the Ythan. On the left of the path at locality 8 the overgrown face of a dune is seen with marram grass on the dune top. At the foot of the dune face rosebay willowherb and thistles are common (in summer) and on the marshy slack in front of the dune a low willow scrub with grass tussocks and crowberry is developed. Dryer areas are covered in heather. This dune was active in 1985 with deflation gaps on the

dune crest through which sand was blown to form a slip face, in severe gales sand was blown as far as the track from the dune crest.

Locality 9. Beach and estuary mouth [NK 004 245]

Locality 9 is reached by the turning to the beach at the Ythan Hotel at the southern end of Newburgh. From the car park (narrow restricted entrance) proceed to the old lifeboat station on the west bank of the estuary from where the partially stabilised dune at the end of the Sands of Forvie can be seen across the river (see (Figure 6) below).

It is on this dune that the main tern colony is situated. The large active unstabilised dune of locality 5 can be seen, and large scale features observed through binoculars. The position of this dune changes with varying wind directions; at times its steep but rounded lee slope descends directly into the river channel, but the most active slip face is usually to the north.

At low tide the beach generally shows a good variety of sedimentary structures, particularly current ripples and small dunes with mud drapes (see (Figure 6) above).

Traces made by birds, worms and gastropods are usually present. The sand mason worm *Lanice* occurs in patches, trapping sand, and lugworm (*Arenicola*) castings are common (see picture below).

There is a wide area of pebbly surface between the sandy beach and the channel; mussels and barnacles colonise this surface near low tide mark (see (Figure 8) below).

Proceed along the beach past the small wreck towards the mouth of the estuary noting the greater extent of sandy and pebbly shore on this more exposed beach than at locality 3. A line of tank traps are seen (March '08) emerging from under a dune and crossing the shore to the river channel, recent erosion of the dunes has caused collapse of the dune face. The concrete defence post may be visible on the beach at the point across the river (see Locality 6). At the river mouth the offshore bars protecting the estuary are exposed at low tide or usually marked by a line of breakers at higher states of the tide. The beach now becomes sand-dominated and is more influenced by waves and tides than the river flow. Shallow offshore bars protect the river mouth and are usually marked by lines of breaking waves.

At this point the reader may wish to walk about 2.5 km south on the beach to the northern end of Menie Links (Locality 11), or take a short route back to the carpark through Foveran Links (Locality 10).

Locality 10. Dunes of Foveran Links [NK 005 240] Stabilised dunes with marram grass extend from the river mouth south to the mouth of the River Don at Aberdeen. This is an active dune system that was established thousands of years ago, and continues to be active. There is a nearly continuous rampart of dunes, partly stabilised by marram grass above high tide level. Gaps in these dunes allow sand to be blown inland to form active dunes such as those of Foveran, Menie and Balmedie links where the active dune surfaces can be examined. The dunes are gradually moving north as can be seen from slip faces and vegetation changes. Examples of advancing dune faces show marram grass being covered with sand and slip faces with grain flow tongues (see (Figure 9) below).

Erosion of the dunes leaves isolated sand pillars capped by marram grass indicating the former level of the vegetated surface, and displaying the internal cross-bedding structures within the dune. (see (Figure 10) below)

World War 2 installations and telegraph poles in the Foveran dunes give a graphic illustration of the effects of both erosion and sedimentation in the past 65 or so years in this area. When the first edition of this guide was prepared in 1985 gun slits in defence posts were blocked by marram grass tussocks several metres high and telegraph poles protruded only 2 metres above the dune sand. Since that time a fallen rusty scaffolding tower has appeared from beneath the sand, and rust fragments now form an artificial armoured deflation surface that slows sand movement. The telegraph poles are not visible at present. At the northern end of the sand dune beside the path back to the car park a typical marshy interdune area with willow scrub is seen in the process of invasion by sand dunes from the south.

Locality 11. Foveran to Menie [South to [NJ 993 213]

Many more features of the beach and dune system can be seen by walking south as far as the northern end of the Menie dune system. At present (March '08) there is clear evidence of erosion of the seaward dune face. A line of tank traps has been revealed by the erosion (see (Figure 11) below), showing that dune sands well over 10 m thick had accumulated since about 1940.

The erosion took place coincident with high tides and waves that swept sand from the beach, lowering the level of the upper beach by over 2 m. This is local erosion due to weather, waves and tide; nothing to do with climate change! At the same time a high sand level on the beach was maintained to the north of the Ythan estuary. Behind the seaward dune rampart there are deflation areas with pebble pavements and ventifacts (pebbles shaped by sand blasting during high winds) Worked flint flakes are present at Foveran and Menie on these surfaces showing them to have a history dating back thousands of years. The dunes generally have rounded forms with surfaces dominated by wind ripples. Two small streams emerge through the dunes, one of these [NJ 997 220] channels sand from an active dune face back to the beach, but the stream mouth is being forced northwards by the migrating dune.

Reference

Trewin. N.H. and Welsh, W. 1976. Formation and composition of a graded estuarine shell bed. Palaeogeog. Palaeoclimatol. Palaeoecol. 19, 219–30.

Figures

(Figure 1) Locality map of the Ythan Estuary. Intertidal sediments are indicated in yellow, and the extent of sand dunes in pale brown. In the north of the Forvie reserve the dunes are all vegetated.

(Figure 2) Stream emerging from saltmarsh and crossing mudflat towards channel at Locality 1.

(Figure 3) Diagrammatic section through the graded surface bed of the estuarine mud flats. The bed overlies pebbles (left-hand side) or waterlaid sand (right-hand side). Broken shell material and occasional pebbles with finer non-biogenic detritus constitute the lower part of the bed which is overlain by muddy sand and sandy mud. Living organisms and burrows are indicated by letters as follows: A, *Mytilus edulis*; B, *Littorina*; C, *Hydrobia*; D, *Cardium edule*; E, *Macoma balthica*; F, *Mya arenaria* (juv.); G, *Corophium* burrow; H, *Nereis* burrow; I, *Arenicola* burrow. Modified from Trewin and Welsh (1976).

(Figure 4) General view of dune surface with areas stabilised by marram grass. Locality 5.

(Figure 5) Mussel fragments resulting from eider duck predation on mussels concentrated at strandline. Estuary beach near Locality 5.

(Figure 6) View across estuary from Locality 9. Small dunes and ripples with mud drapes in foreground. Pebble pavement near low tide level extends to river channel. Large active dune of Locality 5 in the distance.

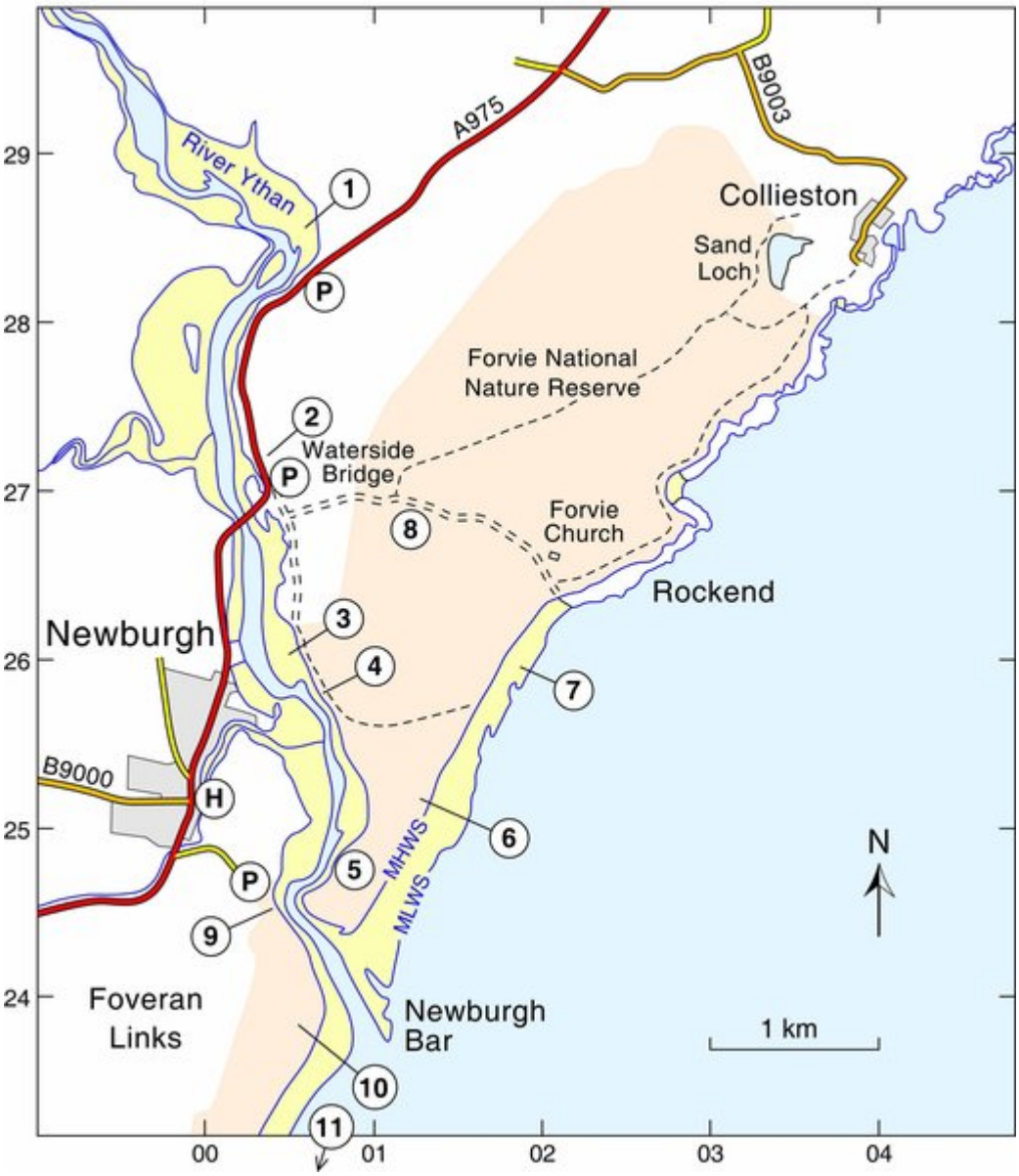
(Figure 7) Intertidal sand surface at Locality 9 with ripples, mud drapes, tubes of the sand-mason worm *Lanice* and casting of lugworm *Arenicola*.

(Figure 8) Pebble pavement at Locality 9 with mussels (*Mytilus*) and barnacles attached to pebbles.

(Figure 9) Small dune face with grain flow lobes advancing over, and burying, marram grass. Foveran links Locality 10.

(Figure 10) Eroding dune with a cap of marram grass, the roots exposed due to erosion. The dune sands show aeolian cross-bedding. Foveran Dunes Locality 10

(Figure 11) Erosion in March 2008 revealing tank traps in front of blockhouse near Menie links. Locality 11.



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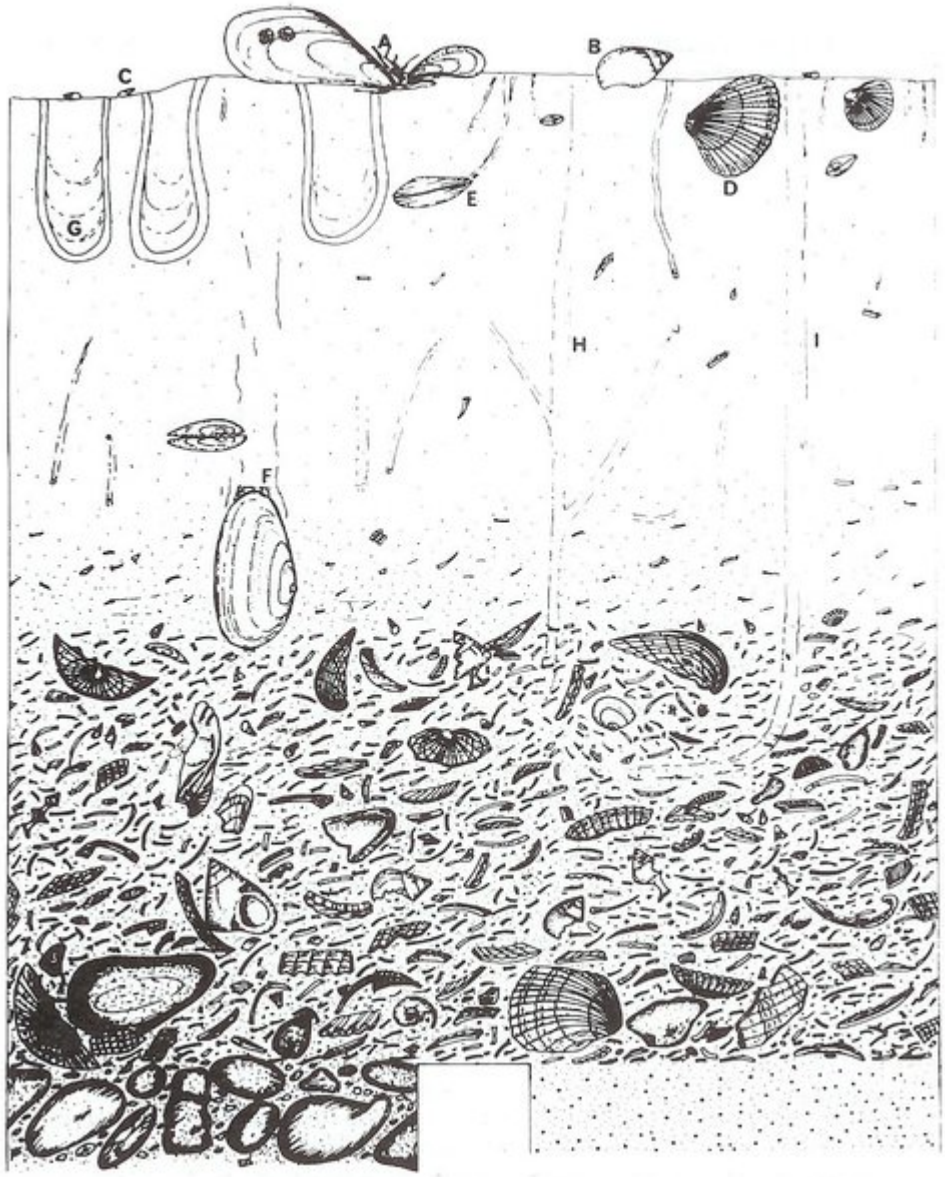

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