FGS field trip to Burton Bradstock – Sunday 1 July 2007

The theme for this trip was the **Flandrian Marine Transgression** and its many and varied effects on the West Dorset coast. We looked at sea level rise from a geological point of view, particularly the many geological processes which are the consequence of a major, rapid marine transgression - landform modifications which include weathering, erosion and sediment deposition. Study of the actions and consequences of sea level rise provides critical information to help geologists interpret ancient sedimentary sequences.

Before the Ice Age, the Pliocene sea level was about 200m higher than to-day. In Britain, the Ice Age (Pleistocene) has lasted 2½ million years so far, with many cold stages (glacials) and warm stages (inter-glacials). Glaciers reached as far south as the Thames. On occasion, sea level was as much as 200m lower than to-day and permafrost gripped the land, including a dry English Channel. During some of the inter-glacials, Britain was as warm as to-day's Mediterranean, and sea level was much higher than at present.

The last glacial stage, the **Devensian**, ended about 10,000 years ago, when sea level was some 35m below present. During the succeeding inter-glacial, the **Flandrian** or Holocene period, continuous ice melt led to, and will continue to cause, global sea level rise. As the glaciers melted, sea level rose "in a rush" until about 5,000 years ago, since when it has risen slowly; the rate has been approximately:

9,000 - 8,000 BP	12 mm / annum	
8,000 - 7,000 BP	9 mm / annum	(7,500 BP - sea level at about -20m)
7,000 - 5,000 BP	5 mm / annum	
5,000 - present	1 mm / annum	

In Britain, global eustatic sea level rise is being modified by glacio-isostatic recovery; the weight of the glaciers caused northern Britain to sink, and the south to rise (reflecting the movement of viscous rock in the underlying mantle). Now the glaciers have gone, equilibrium is being restored; northern Britain is rising and the south is sinking. Thus the effect of global sea level rise is exacerbated along the Dorset coast. The rate of eustatic sea level rise slowed around 7,500 BP, to be overtaken by glacio-isostatic subsidence.

1. What geological processes modify a coastline?

Weathering - by precipitation, heat and cold; these chemical, mechanical and biological processes include:-

- ***Salt weathering*** - when sea spray drenches the cliffs, it evaporates and salt crystallises in confined spaces; expanding salt crystals weaken the rock structure.

- ***Corrosion*** - salt on the cliff face corrodes certain minerals, eg iron, weakening the rock.

- ***Frost weathering*** - water entering cracks and pores in the rock expands on freezing and increases its volume by nearly 10%.

- ***Biological weathering*** – eg: by algae, plants, bunnies, birds.

Erosion - the removal of rock by gravity, wind, water (rain, rivers, sea) and ice.

- ***Wind erosion*** removes fine loose material; wind borne sand erodes rock faces.

- ***Hydraulic erosion*** - when waves break at the foot of a cliff, trapped air exerts a tremendous pressure which fractures the rock, particularly during storms, hurricanes or tsunami. Wave undercutting forms a notch at the cliff base, destabilising the cliff.

- ***Corrasion*** occurs when waves throw beach material at the cliff face, eroding the rock face and removing loose material.

- ***Gullying*** - particularly after a rainstorm, when water flows over a slope of 20^o or more; rivulets rapidly remove loose material to form an outwash fan at the base of the gully. This is a major cliff erosion process.

- ***Earthquakes*** cause cliff falls; vertical cliffs with fractures and “gulls” are particularly susceptible.

- ***Landslips*** - rain water passes readily through porous and permeable rocks, but may be obstructed by clay layers; these lubricated surfaces form slip planes along which slumping and landslips occur.

Transport and deposition - material removed from the cliffs is transported along the coast by wind and sea. The prevailing winds are SW, consequently there is eastward movement of beach material. East winds are lighter, but can transport fine material westwards; this is significant along lee coasts protected from SW winds eg Bournemouth is protected by the Isle of Purbeck, Weymouth Bay is protected by Portland.

- ***Waves*** - a circular motion of surface water generated by wind blowing in one direction across an expanse of water, the “fetch“. When a wave is blown onto a beach, sea bed drag forces it to break; water driven up the beach is “swash”, the return flow is “backwash”.

- ***Longshore drift*** - the movement of beach material along the coast. In Dorset winds arrive from between the south and west for 60-70% of the year. These winds and waves hit the coast at an angle; the swash moves material along the shore; the backwash is at right angles to the shore and returns material to the wave zone where the next swash will move it obliquely along the shore. Migration of beach material depends on the strength of the wind, the supply of material, the beach slope, and the nature of the beach deposits. A change in any of these factors can dramatically change the shape of the coastline very rapidly. Where the pattern is obstructed, eg by a headland or shallowing sea floor, the decrease in wave velocity will lead to **deposition** to form offshore sand bars and spits.

- ***Coastal deposition*** occurs when wave energy is dissipated. A gentle beach profile will cause the base of the wave to break and produce large amounts of swash which will travel a long distance across the gentle gradient of the beach, depositing material in its path; as water dissipates into a wide beach, there is little water available for backwash, and little beach material is returned to the wave zone; therefore, these are "constructive waves". If the offshore is deep, and/or the beach is steep, the backwash can be very strong and able to remove beach material, resulting in erosive "destructive waves". In the lee of a promontory, the wind becomes offshore, reducing the ability of the waves to erode or to carry sediments. The nature of beach material affects accretion or erosion by the waves. Ironically, flat sandy beaches allow the sea to flow over and attack a cliff base ie "constructive waves" can **erode** cliff bases; steep shingle beaches can offer good protection, the energy of "destructive waves" is absorbed and the cliff base is protected.

- ***Beaches*** - where swash is greater than backwash, waves build up the beach, transporting sediment from offshore; where backwash is greater, waves can remove sediment.

2. Effects of a marine transgression on a hard rock coast - The Bridport Sand of Burton Bradstock and West Bay:

- The **River Brit** exits at West Bay. The valley side (bevel) is steep (Fig 1), but suddenly flattens across the valley floor (Fig 2). Clearly the valley was once much deeper, but has become silted up.

Figure 1

Figure 2

- During the last glacial, at a lower sea level, the River Brit eroded a deep valley through hard Bridport Sand into soft Lias clay beneath. The weight of the Bridport Sand caused the Lias Clay to flow out from under the valley sides into the heart of the valley (a process is known as **"Valley Bulge"**) whence it was removed by the River Brit. Consequently, the valley sides began to collapse; at East Cliff, once horizontal Bridport Sand strata dip towards the valley, via a series of small extensional faults (Fig 3).

- Flandrian sea level rise raised the base level of erosion; the Brit has stopped cutting into its bed, and the whole valley has silted up. The "Valley Bulge" process has effectively ceased.

Figure 3

Figure 4

- In the Pleistocene a little stream cut a **small gentle valley** into the Bridport Sand of the East Cliff. This stream has a gentle seaward gradient, which would take it to a sea level a long way south in the English Channel. The valley floor is filled with river and terrace deposits. The sea has risen quickly and eroded the lower reaches of the stream valley faster than the stream has been able to erode its bed down to base level (base level is effectively sea level, above which there is erosion and below which there is deposition). Consequently, we now see a **"hanging valley"** preserved in East Cliff (Fig 4).

- The occurrence of the hanging valley shows that this beach cannot protect the coast. To-day, a gentle beach gradient of sand and fine gravel allows storm waves to flow across the surface without energy dissipation to attack the base of the cliff. (If the beach had been pebbles and boulders, much of the energy would have been dissipated before the wave hit the cliff, reducing erosion).

    - To the south (in the English Channel) a major river system cut down into the Lias, and valley bulge effects probably influenced the Bridport Sand; there are many fissures almost sub-parallel with the cliff face, easily eroded by seeping rain water into open **"gulls"**(Fig 5); these zones of weakness lead to cliff falls, particularly if there is also a wave cut notch at the base of the cliff, as at Burton Bradstock (Fig 6).

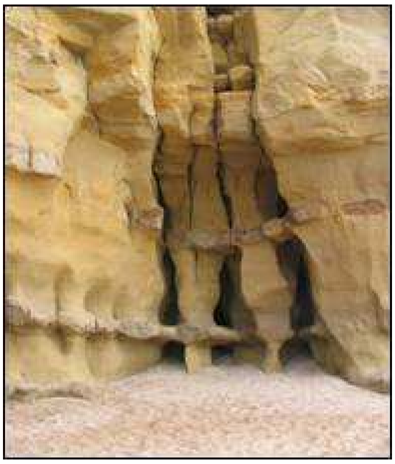
Figure 5


Figure 6

3. Effects of a marine transgression on a soft rock coast - The Frome Clay at Burton Bradstock and Abbotsbury.

- The Frome Clay is a thick sequence of soft grey clay above the Bridport Sand. It weathers and erodes naturally to a low angle of rest (probably less than 20^o), before becoming vegetated and stabilised (Fig 7). This stable condition can be maintained, firstly where there is no change in the base level of erosion ie there is no sea level rise or fall, or secondly where the slope base is protected.

- At Abbotsbury, the Frome Clay slope is stable (Fig 7), protected from the sea by a large pebble beach ridge. This ridge is gradually advancing up the stable slope as sea level rises.

- There is a flat sandy beach at Burton Bradstock. Storm waves can race across this beach to attack the Frome Clay. Consequently, there has been rapid erosion to form a cliff (Fig 8), which itself destabilises the foot of a slope which was once stable (in the Devensian).

Figure 7

Figure 8

4. The formation and influences of beaches

Beaches are nature's coast protection. Material is derived from cliff erosion. Where prevailing winds are oblique to the coast, this material can be transported down wind - longshore drift. Once a beach system has stabilised, the cliff line can erode back to a natural slope where vegetation can become established and stabilise that slope. The beach protects the foot of the slope. This stability can be disturbed by sea level change, or by interference in the pattern of longshore drift, ie sediment supply.

During the Devensian (last) glacial interval, sea level was much lower, and the coast was out in what is now the English Channel. The beaches were driven landwards as Flandrian sea level rose. Thus, the present beaches are less than 5000 years old. The beach material derives from two sources, the transport / migration of the old Pleistocene beaches, plus recent cliff erosion caused by sea level rise.

There is a continuous beach between West Bay and Portland - Chesil Beach (Fig 9). It grades from sand in the NW to large cobbles in the SE. The material is predominantly flint and chert derived either directly from erosion of Upper Greensand and Chalk (respectively) or indirectly via Eocene river gravels. There is a fair proportion of crystalline material (igneous and metamorphic rocks), largely derived from SW England, and even from Brittany; some of this material came via the Triassic Budleigh Salterton Pebble Bed. At the SE end, there is a large proportion of chert and limestone from recent erosion of Portland.

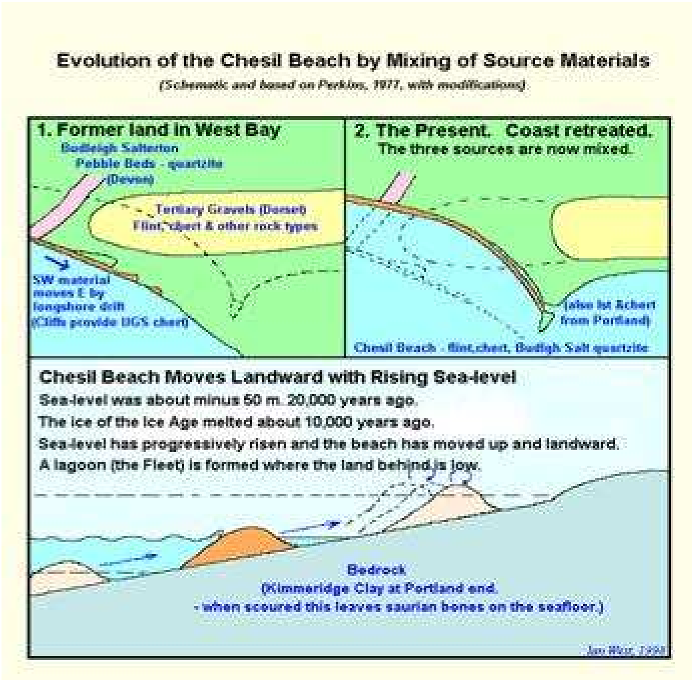

Figure 9

West of Chesil Beach, parts of the coast are characterised by wide rock platforms; there is negligible transport of beach material across these platforms, they act as transport barriers. There are also sea defence works such as groynes and sea walls. Consequently, the crystalline material in Chesil Beach can no longer be derived directly from coast erosion; it comes from the old Pleistocene beaches formed in the Channel when sea level was lower.

Chesil Beach is backed by cliffs from West Bay to Abbotsbury, and then by a lagoon down to Portland. Mud, silt and peat are being deposited in the lagoon. After major storms, peat has been found thrown up on the beach at Abbotsbury. There are lagoonal muds on the sea bed off Chiswell. In the lee of Chesil Beach there are large wash-over fans consisting of beach material thrown over the beach by storms. These features show that Chesil Beach is migrating landwards, over the lagoonal deposits. Between 1850-1960, the beach migrated 50' at Portland Harbour.

In 1824 there was a hurricane and storm surge in the English Channel; a massive wave crested the beach and crossed the lagoon, rather like a tsunami; at East Fleet village it flowed up a narrow valley and destroyed the entire village; the water was 30' deep; only the chancel of a little church remains. Generally, the pebble beach absorbs the power of the waves, as the water passes through the "porosity" into the lagoon behind.

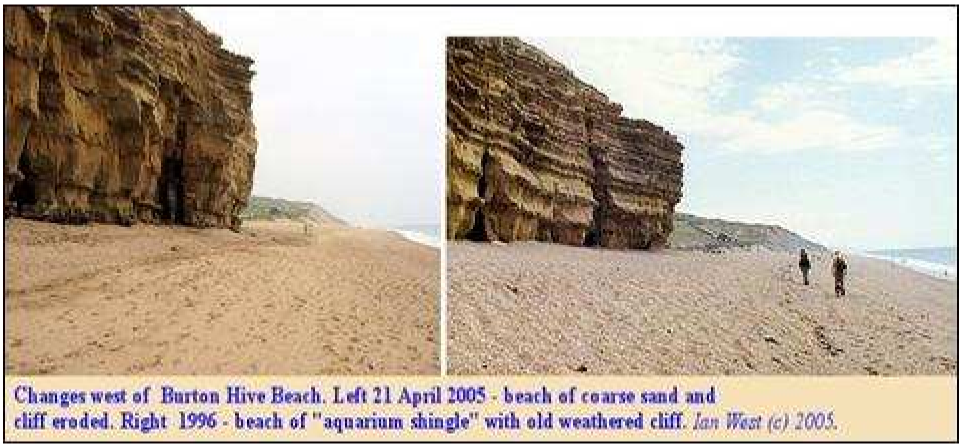

Figure 10

Over the last ten years, there has been a significant major in the character of the beach at Burton Bradstock from shingle to coarse sand (Fig 10), and cliff erosion has increased markedly. The power of storm waves is dissipated in highly porous shingle, but easily races across a level sand surface to attack the cliff. This change coincides with the construction of major sea defences to the west, and it is an ominous sign for the future of this coast and Chesil Beach.

Dr G M Williams

Back to past trips   Back to top of page