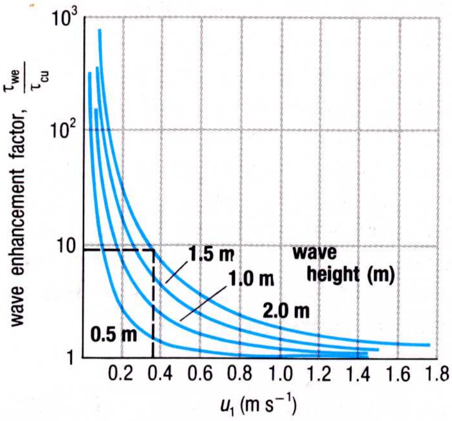

Figure 5.10 The enhancement of currents by waves of various heights, with an 8s period in water 20m deep. τ_{cu} is the shear stress under currents alone and τ_{wc} is the shear stress beneath both waves and currents. τ_{wc}/τ_{cu} is the enhancement factor. u_1 is the current speed measured at 1m above the bed.

discussed in Section 5.2.3, the slight landwards movement of water caused by the wave drift described in Section 1.2.1, and also tidal currents.

The relative importance of sediment movement by waves increases as the influence of current action decreases. Figure 5.10 shows how the wave enhancement varies with the current speed, measured at 1m above the sea-bed. τ_{cu} is the shear stress which would result from the current alone and τ_{wc} is the shear stress due to both waves and currents. The slower the current, the less τ_{cu} will be and so the larger the enhancement factor, τ_{wc}/τ_{cu}, will be. You should note that Figure 5.10 refers specifically to waves with a period of 8s in water of depth 20m.

QUESTION 5.7(a) Examine Figure 5.10 and consider a wave with height 2m. How does the enhancement factor change when the current speed at 1m above the bed is about 0.35ms^{-1}, and when it is about half this speed?

(b) When the current speed at 1m above the bed is about 0.35ms^{-1}, what is the difference in the enhancement factor between a wave with height 2m, and a wave with height 1m?

5.3 BEACH PROFILES

If you visit the coast frequently, you will almost certainly have noticed that beaches made of coarse sand, shingle or pebbles are steeper than those made of fine sand. You may also be aware that in the summer, when fair weather conditions normally prevail, the beach slope may be steeper than in winter when the sea is often stormy. Clearly both sediment grain size and wave type affect the beach profile.

5.3.1 BEACH PROFILE AND GRAIN SIZE

When a wave breaks on the shore, sediment is pushed up the beach face by the swash, and dragged back down by the backwash. Due to percolation of water into the beach face, the backwash tends to be weaker than the swash. Consequently, there is a net onshore movement of sediment up the beach face until eventually the slope reaches a state of dynamic equilibrium and as much sediment is moved landwards as is returned seawards. The rate of percolation is controlled mainly by the grain size. Water percolates much more easily into a shingle or pebble beach than into a fine sandy beach, and so the backwash is greatly reduced in strength and thus the beach slope is much greater.

5.3.2 BEACH PROFILE AND WAVE TYPE

You have already seen that different types of breakers are associated with the angle of beach slope (Section 1.4.6 and Figure 1.16). Small gentle waves and swell tend to build up beaches whereas storm waves tend to tear them down and flatten them. The controlling factor appears to be the wave steepness.

QUESTION 5.8(a) Can you recall how wave steepness is defined?

(b) How does wave steepness vary among the four types of breakers discussed in Chapter 1: spilling breakers; plunging breakers; collapsing breakers; surging breakers?

When a steep wave breaks onto the beach, its energy is dissipated over a relatively narrow area and the swash does not move far up the beach. This means there is less opportunity for percolation to occur and less of the energy is lost in moving sediment up the beach face. Consequently, the backwash is strong and much material can be moved seawards. When a less steep wave, such as a collapsing or surging breaker, breaks on the beach, there is a great deal of movement of water up the beach face as the front of the wave either collapses or surges up the beach. In this case, the swash is strong and so a good deal of sediment is moved up the beach face, too. There is more opportunity for water loss by percolation, and much energy is lost in moving sediment, so the backwash is weak.

Where there is a seasonal difference between fair weather, swell-dominated waves in summer, and steep storm waves in winter, sediment is moved up the beach face during the summer to build berms, while during the winter the berms may be destroyed, and the beach slope flattened. The sediment that is removed from the beach face during winter is transported seawards to build the longshore bar. During the following summer, when swell waves prevail again, the sediment of the bar is moved landwards, up the beach face to reconstruct the berms. Clearly, on any particular beach both the predominant grain size and the prevailing wave steepness will play a part in determining the beach slope. The relationship between these three variables is shown in Figure 5.11.

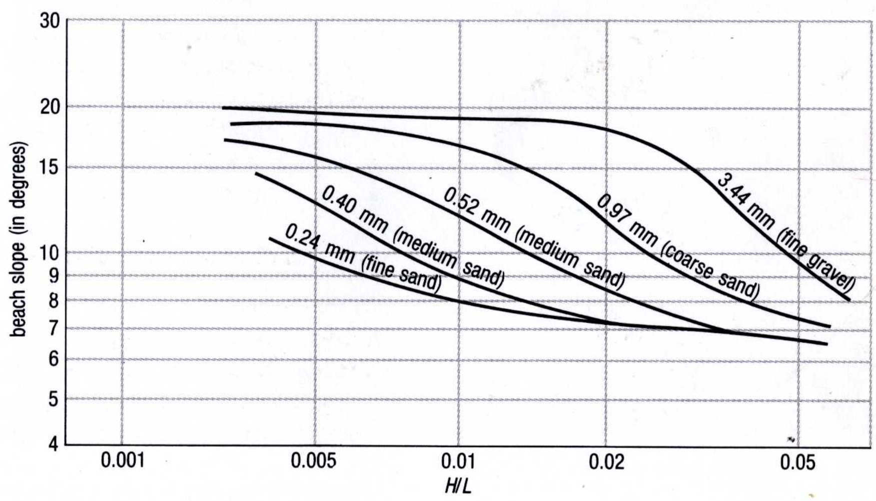

Figure 5.11 The relationship between beach slope (measured in degrees), wave steepness (*H*/*L*) and average grain size. Note that the scales for both beach slope and wave steepness are logarithmic.

QUESTION 5.9 The curves in Figure 5.11 show the relationships between beach slope and wave steepness for sediments of different grain sizes. Describe how the influence of wave steepness on beach slope varies as the sediment grain size decreases.

5.4 BEACH MATERIALS AND SEDIMENTARY STRUCTURES

Before leaving this discussion of the littoral zone, it is appropriate to say something about the different types of sediments found there, as well as saying something about the more common depositional features seen in the intertidal zone.

5.4.1 BEACH MATERIALS

Beaches bordering continental areas in temperate climatic zones tend to be formed of pale yellow to brown quartz-rich sands, the most common solid products of weathering and erosion. Pebble or shingle beaches also occur in which the pebbles are usually derived from some fairly local source such as an adjacent line of cliffs. However, quartz beach sands and pebbles are not the only types of sediment found on beaches.

Around volcanic islands, beaches often consist entirely of basaltic or andesitic lavas and may be black in appearance. The green sands round parts of Hawaii contain a high percentage of olivine crystals derived from the surrounding volcanic rocks. In tropical regions, where biological productivity may be high and land-derived sediment scarce, beaches are often comprised of brilliant white sand and gravel-sized fragments of coral and shells, and even carbonate grains which have been precipitated inorganically from seawater. Very occasionally, some beach sediments are artificially derived. For example, beaches near coal-mining districts often contain a high proportion of sand-sized coal fragments, and the pebble beach at Lynmouth in Devon contains pieces of wave-rounded bricks and tiles, debris resulting from a flood disaster in 1952 during which entire houses were washed down the Lyn valley into the sea.

5.4.2 SEDIMENTARY STRUCTURES

One of the most common features seen on the beach is the wave-generated ripple. These ripples are symmetrical and have long, straight crests which occasionally bifurcate. These features distinguish them from the asymmetrical ripples produced by unidirectional currents. They are symmetrical because sediment is moved towards the crest on both sides of the ripple: on the seawards-facing side as the crest of a wave passes when there is maximum horizontal movement of water particles in a landwards direction, and, conversely, on the landwards side as the wave trough passes when the water particles move seawards.

Wave-generated ripples begin to form as soon as the threshold velocity for grain movement is reached. As orbital velocities increase, the height of the ripples decreases until the sediment moves as a suspended 'sheet flow', backwards and forwards over the sea-bed.

Occasionally, the ripple marks found in runnels (Section 5.1.3) are a fascinating combination of straight-crested wave-generated ripples interspersed with asymmetrical current-formed ripples, trending roughly at right angles to the wave ripples (Figure 5.12). The resulting patterns are known as **ladder-back ripples**. Sometimes, the current ripples give an indication of the longshore current direction, but in the case of Figure 5.12 they are probably formed by water draining from the runnel on the ebb tide.

Another common feature you have probably seen on sandy beaches is the rhomboid pattern formed by fast-flowing backwash (Figure 5.13). The origin of these patterns is not fully understood but it may be that minor irregularities in the surface texture of the beach sediment are sufficient to split the backwash into diverging minor currents which cross each other to leave the characteristic rhomboid marks.

Figure 5.12 Ladder-back ripples: wave-formed ripples with linear, bifurcating crests, in between which are smaller, current-formed ripples running at right angles to the wave-formed ripples. The scale is given by the camera lens cap.

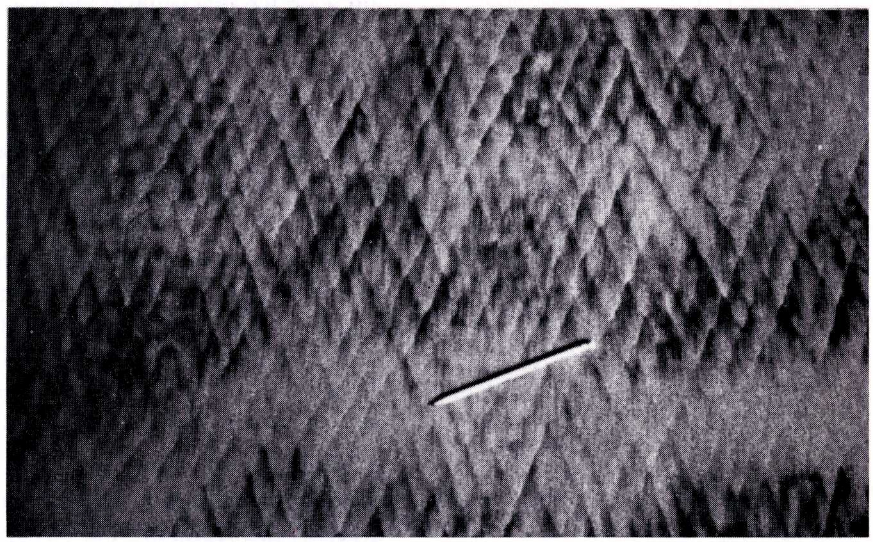

Figure 5.13 Rhomboid marks in beach sands. The scale is given by the pencil.

5.5 SUMMARY OF CHAPTER 5

1 The littoral zone is divided into various component zones according to the influence of tides or waves, or according to the sediment profile. The tidal zones are the backshore, foreshore and shoreface; the wave zones are the swash zone, the surf zone and the breaker zone. The beach profile includes the berm, the beach face with swash bars and runnels, and longshore bars.

2 Water particles in shallow-water waves follow orbital paths which become progressively flattened towards the sea-bed. In shallow water, the maximum orbital velocity u_m and shear stress at the bed increase as the wave height increases and as water depth decreases.