LESSON 5

THE ZEN OF THE BEACH

Musings on a River of Sand

Fig. 5.01. Godwits pay attention to subtle nuances in sand patterns that signal the presence of food.

Few things are more pleasant than walking along the beach barefoot, feeling the sand between the toes.

Millions enjoy these simple delights every year. They come and spread their blankets on the sand and watch the children build sand castles, fated to be washed away by the waves of the rising tide. They watch the shorebirds hunting for worms and crabs hidden within the sand (Fig. 5.01).

But what is sand? What is the nature of the grains that feel gritty between toes and fingers? What stories do they have to tell?

The answer depends on the location, of course. The beaches of southern California generally have mineral grains derived from the weathering of rocks in nearby mountains to the east, mixed with similar grains from the sandy deposits that make up the cliffs rising landward of the beaches. The mountains are largely made of igneous and metamorphic rocks, that is, the minerals they deliver upon weathering were made deep inside the Earth. Material locally derived from cliff erosion is commonly marine sediment, with ground-up shell mixed in. Some beaches hardly have any sand but consist of pebbles. Off Scripps, the beach consists of a layer of well-sorted sand, several feet thick, with pebbles at the base of the sand layer. The beach rests on a terrace cut into the land by waves. The terrace grows as the cliffs keep retreating. In turn, this retreat threatens houses built on the edge of cliffs.

Among the mineral grains making up the beach sand, quartz is the most conspicuous. Quartz is typical for many beaches fed from terrestrial sources, for the simple reason that quartz is resistant to abrasion and to chemical destruction and outlasts most other types of grains. Sand, then, tells stories about its origin and about its travel to the site where we find it. But the sand is usually not just sitting there – it is in transit. Waves wash the sand, move it seaward and landward according to season, and move it along the shore, as well. The general direction of travel is south, because winter waves from the north are the most effective in moving the sand along the shore. Eventually, the sand comes up against an obstacle, such as a promontory. It then has no place to go but down into the deep sea, commonly within a canyon carved into shelf and slope. Exactly how this vanishing act is accomplished was a complete mystery for a long time; some elements of the process still are obscure despite much study. The layers formed at the final resting place of the sand – in a basin offshore or at the foot of the continental slope – tell a story of giant muddy floods invading a usually quiet environment. To survive such events, animals living on the bottom subject to episodic flooding have to be able to escape upward through the layer of mud left by a flood. Those that fail to escape make fossils.

Beaches on the West Coast, if present at all, tend to be rather narrow, and the beaches of San Diego are no exception. As a thin band of bright sand, they separate the vast ocean to the west from the former wetlands and elevated terraces to the east, now largely developed along a wide coastal strip. No longer a lonely marine biology station as it was in its early years at the beginning of the 20th century, Scripps is now situated at the northern rim of a thriving coastal metropolis.

Images

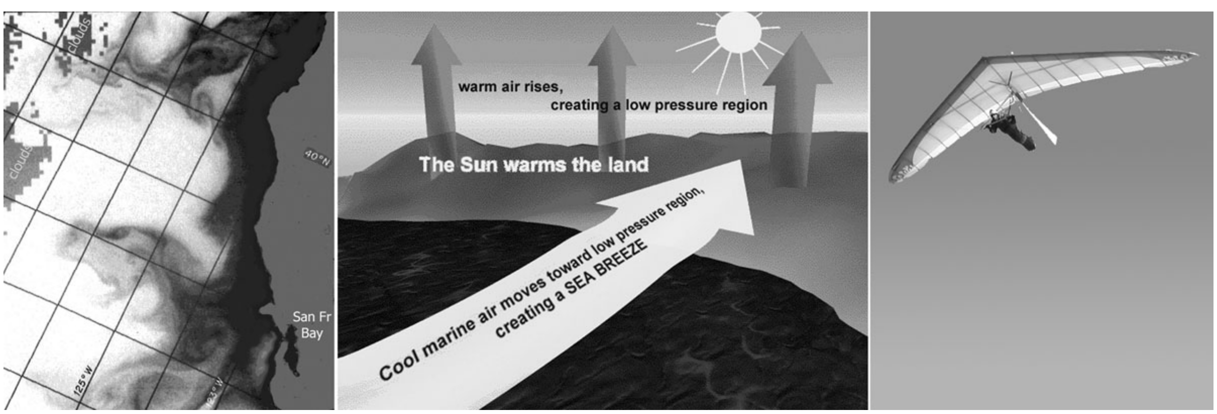

Fig. 5.02. Cool water hugs the coast along much of California, as seen in the satellite image to the left. (Dark: cold; light: warm.) During hot summer days, a cool sea breeze brings relief to the coastal region (Middle). The sea breeze provides an updraft along the cliffs lining the shore, a feature used by pelicans and hang glider pilots (Right).

Fig. 5.03. Cliff erosion along the coast of San Diego, south of Mission Bay. The beaches are pocket beaches and derive their material from the cliffs. Boulders were put at the foot of the cliff in places to retard erosion.

Fig. 5.04. The beaches of southern California have pebbles and sand largely derived from crystalline rocks. Sand from the Scripps beach (right) is rich in quartz grains.

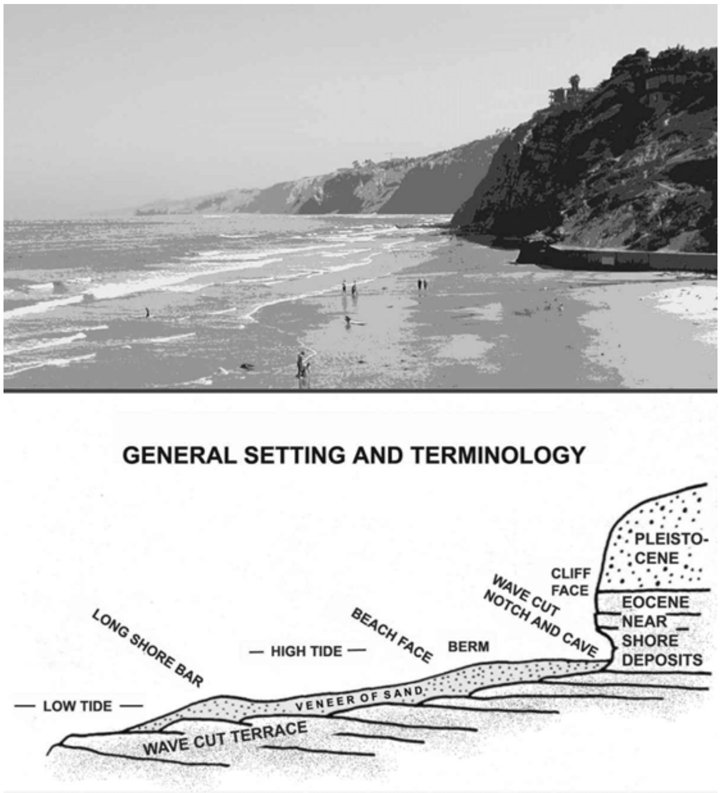

Fig. 5.05. What the beach looks like to a tourist (upper panel) and to a geologist (lower panel). The profile implies the cutting of a terrace by the waves.

Fig. 5.06. What the beach looks like after storm waves remove the sand. Left: enrichment of hard-to-move pebbles. (Note protective board in front of view window). Right: exposed layers of rock of the marine terrace normally bearing a beach.

Fig. 5.07. Waves that break at the end of the Scripps Pier are about 10 feet high. They are generated by winter storms offshore, to the north. They readily move sand.

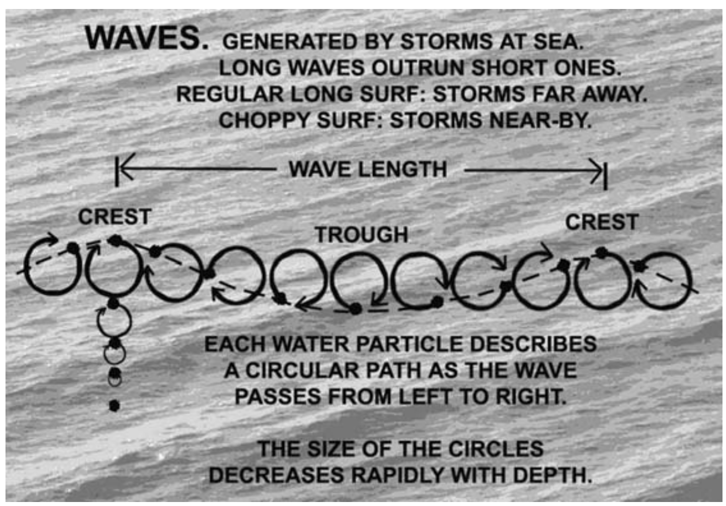

Fig. 5.08. Waves in the open ocean move energy, with water particles traveling in circles.

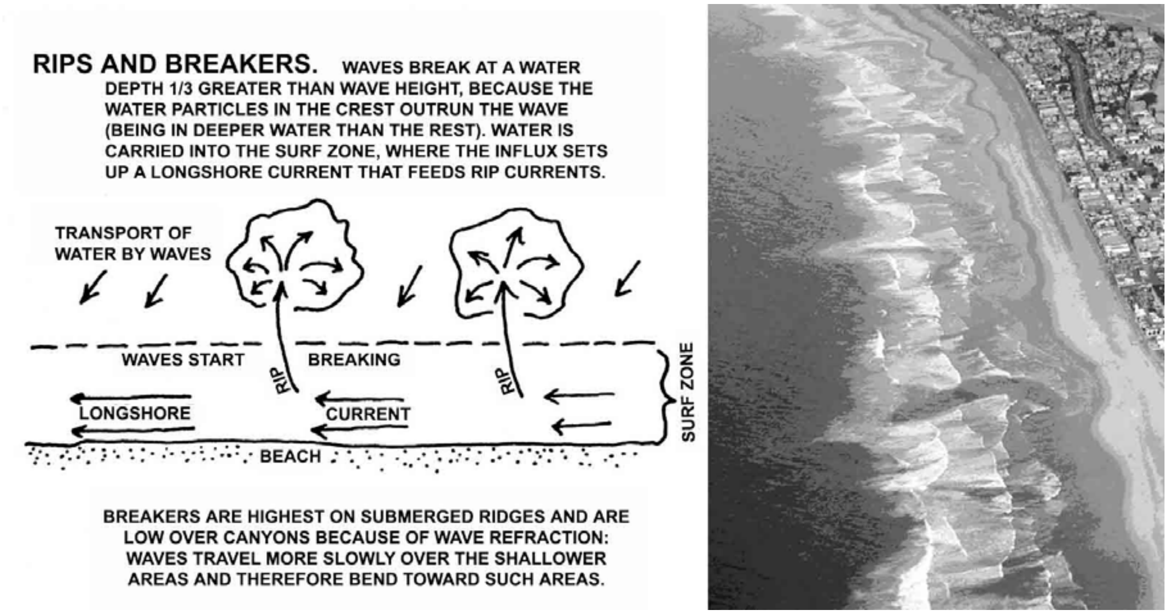

Fig. 5.09. Rip currents take water piled up on the beach back out to sea. Left, illustration of the principle (after F.P. Shepard). Right, a view of rip currents from the air, Mission Beach, San Diego.

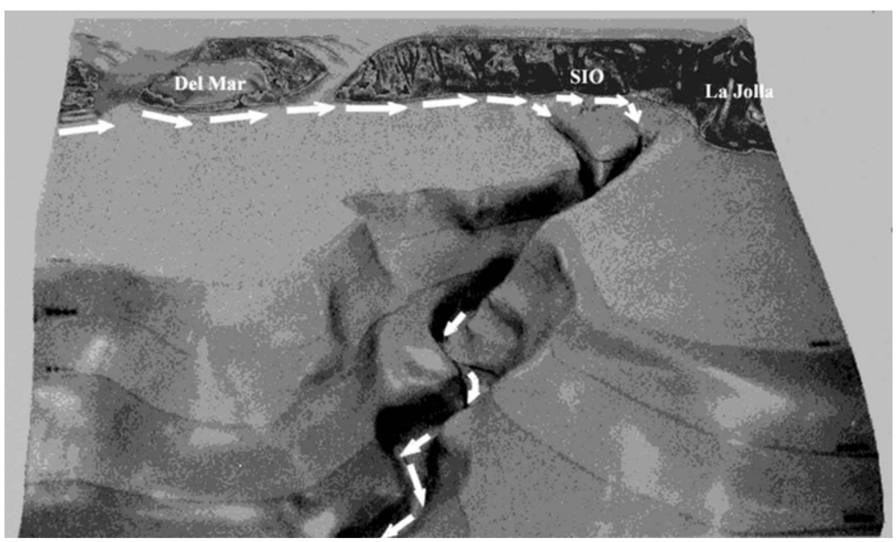

Fig. 5.10. The sand on the beach moves south until it disappears into a canyon.

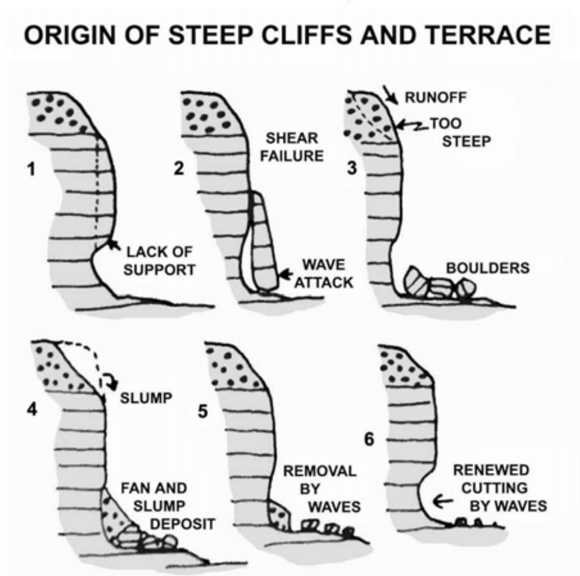

Fig. 5.11. Erosion at the foot of the cliffs keeps them steep.

Fig. 5.12. Uplift is at the heart of the Californian coastal landscape. A wave-cut terrace a few feet above the sea level suggests a recent episode of uplift north of Santa Barbara. (The layers of sediment, originally horizontal, were tilted by mountain-building forces).

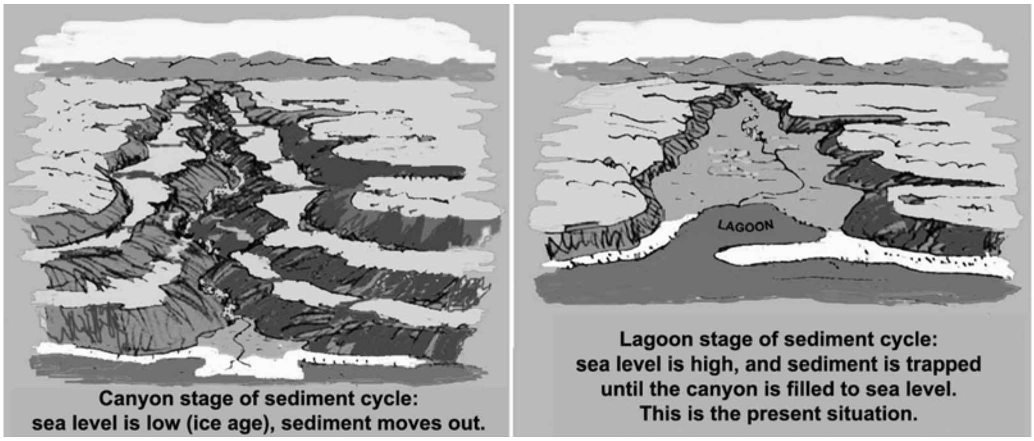

Fig. 5.13. When sea level stood low, rivers cut deeply into the canyons between the mesas. When sea level rose at the end of the last ice age, bays formed, trapping sediment. They filled up to make wetlands.

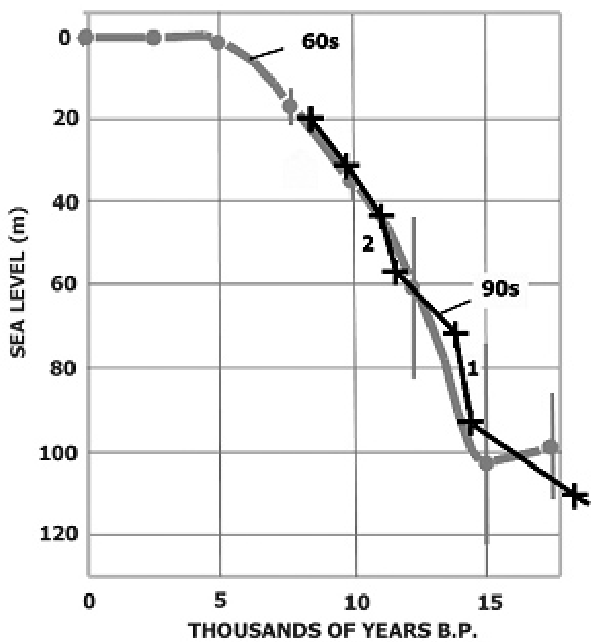

Fig. 5.14. Sea level rose between 16,000 and 7,000 years ago. Note the large range bars for the 1960s. In the 1990s it was confirmed that there were two major steps of deglaciation

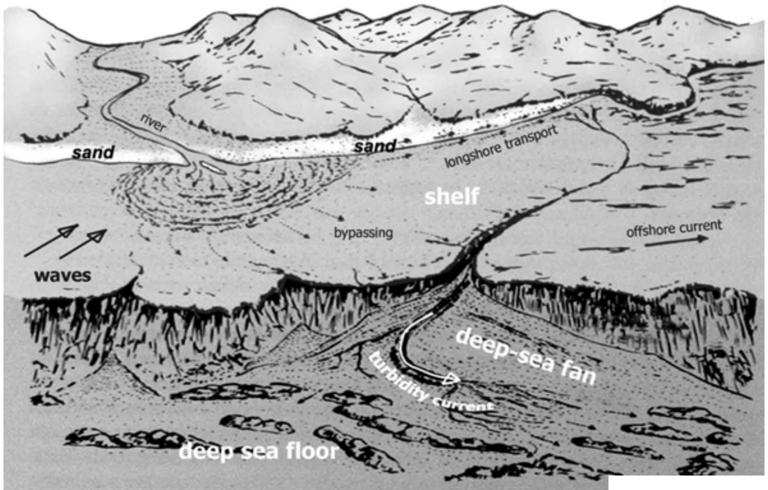

Fig. 5.15. Geologic setting of the beach (after D.G. Moore): Waves make beach sand from river mud, and the sand travels south till it finds a canyon that funnels it down into a deep-sea fan.

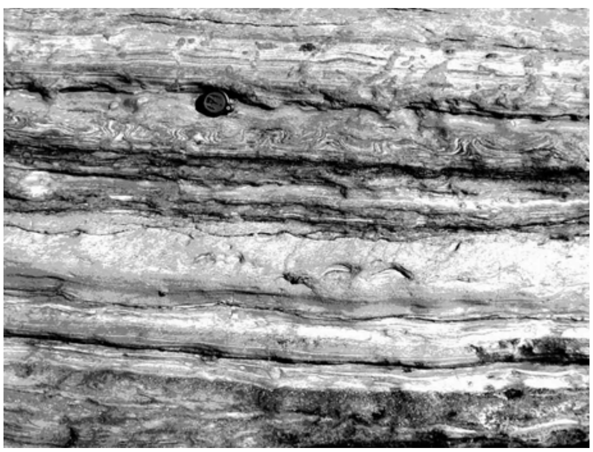

Fig. 5.16. Turbidite layers in deep-basin sediments of Cretaceous age, La Jolla sea cliffs. Hand lens ca. 1 inch.

Figure sources (where based on sources in the literature, on the web or in museum exhibits: figures are considerably modified and adapted for present purposes, using Adobe Photoshop; drawings and photographs by the author are marked "orig."):
1, orig.; 2, R. Stewart 1985 (NASA), NASA, and orig.; 3, orig.; 4, orig.; 5, orig.; 6, orig.; 7, orig.; 8, W. Berger 1976 (see Ch. 3 for reference) and orig.; 9, W. Berger 1976 and orig.; 10, SIO Aquarium (orig.); 11, W. Berger 1976 and orig.; 12, orig.; 13, orig.; 14, Shepard and Curray 1967 (note large uncertainty), and Fairbanks 1989; 15, Moore 1969; 16, orig.

References: R.H. Stewart, 1985. *Methods of Satellite Oceanography.* University of California Press, Berkeley, 360pp.; F.P. Shepard and J.R. Curray, 1967. *Carbon-14 determination of sea level changes in stable areas*. Progress in Oceanography, 4, 283-291; R. G. Fairbanks, 1989. *A 17,000-year long glacio-eustatic sea level record: Influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation.* Nature 342, 637-643; D.G. Moore 1969, cited in E. Seibold and W.H. Berger, 1993 (see Ch. 4 for reference).