CHAPTER 4

Carbonate facies models

Carbonate rocks often overwhelm the untrained eye by a bewildering variety of textures, structures and grain types. Patchy diagenesis adds to the impression of almost chaotic diversity and irregularity. Upon closer inspection, the situation is not nearly as bad. If carbonate sediments are characterized by sedimentary structure, texture and grain kind, a recurring succession of facies belts can be recognized in shore-to-basin transects. These facies appear throughout the Phanerozoic and with only slight modification also in the late Precambrian. This surprising persistence indicates that the evolution of organisms in this time interval had only a modifying effect on the basic carbonate facies. The standard carbonate facies seem to capture trends dictated by other parameters such as the carbonate growth function, i.e. the distribution of growth rates as a function of depth and distance from shore, the degree of protection from waves and tidal currents, and the degree of restriction in the water exchange with the open sea. On the slopes, the declivity and the the balance between sedimentation and erosion are crucial controls. These principles are discussed in the next section, followed by a presentation of facies on ramps and rimmed platforms.

UNDA, CLINO AND FONDO ENVIRONMENTS

One of the most fundamental classifications of depositional environments and facies is the subdivision by Rich (1951) into unda (shallow, wave-swept), clino (slopes shaped by gravity transport), and fondo (basin-floor) environments. Rich (1951) proposed the suffix “-form” for the morphologies associated with these environments and the suffix “-them” for the respective deposits. In practice, the distinction between morphology and sediment body has rarely been made. I will use the terms undaform, clinoform and fondoform for the deposits and the morphology inferred from these deposits. Rich’s (1951) classification is broader (but analogous) to the subdivision of deltas in topset, foreset and bottomset beds (Barrell, 1912). The definitions of Rich (1951) apply to all depositional systems where transport of particulate sediment is important. In carbonate rocks, the expression of the unda, clino and fondo domains varies somewhat among the three factories.

The T factory produces nearly all its sediment in a narrow depth range that normally extends only tens of meters down from sea level. The seaward perimeter of this highly productive zone is often protected by an elevated, wave-resistant rim. This production system generates a platform geometry with a particularly flat unda environment swept by waves and tidal currents, and a rapid transition, across the rim, into the clino environment. The clinoforms can be much steeper than in siliciclastics (Fig. 3.11). The clino environment passes basinward into the fondo environment of the flat basin floors. Both clinoforms and fondoforms may contain abundant slumps and debrites, often with meter-size clasts. Where the M factory replaces the T factory, for instance after major extinctions, it builds platforms with the same unda, clino and fondo differentiation as the T factory. In its typical development, the M factory lacks the unda facies. The mud-mounds are upward-convex constructions that are not planed by waves and form in the clino environment, even though the slope declivity may be very low (ramp setting).

In the C factory, the ability to build rims is weak and the facies pattern resembles that of siliciclastic sediments. The unda environment is a seaward sloping shelf that gradually bends down into the clino domain. Sediments reflect these gradual changes. Slumps and debrites are scarce, as are large clasts. Deep-sea accumulations of the C factory lie in the path of contour currents and are streamlined by these currents.

In the unda environment of carbonate platforms, two parameters control the further subdivision of depositional environment and facies – the degree of protection from waves and currents, and the degree of restriction in the exchange of water with the open sea. Both parameters are related to a third characteristic of the system – the elevation and continuity of the platform rim. The rim index (p.42) provides a measure of the fraction of wave energy that passes through the rim. Sediments deposited behind the rim obviously “feel” this energy flux.

In the clinoforms, the most important control on both geometry and facies is the balance between sediment input from above and sediment output onto the basin floor. Variations in the material balance lead to the subdivision into accretionary, bypass and erosional slopes described in chapter 3.