1.1.3 Tour stop 3: the tropical carbonate factory

Our next port of call is the Istrian Peninsula, which juts out from western Croatia into the northern part of the Adriatic Sea. Much of the peninsula consists of various types of Cretaceous limestone, although these are all very different in character from the Chalk in Section 1.1.1. Prominent among these rocks are moderately well-cemented bioclastic limestones that contain abundant shelly fossils of Late Cretaceous age. This rock type makes an excellent building stone, which was much favoured, for example, by the Romans (Figure 1.10).

(a)

(b)

Figure 1.10 (a) Roman arena at Pula, Istria, built using local Cretaceous limestone. (b) Abandoned Roman quarry in similar Cretaceous limestone on Fraškerr Island, south-west Istria, Croatia. *(Peter Skelton, Open University.)*

Much of the bioclastic material in this location was derived from the shells of an extinct group of sessile bivalves known as rudists. In life, these highly gregarious animals were either partially implanted in the sea-floor sediment, or lay prone upon it, forming vast underwater shelly ‘meadows’. Congregations of shells were sometimes buried in life position (Figure 1.11a). The fate of most of the shells, however, was to be toppled or even swept away and broken up by storm currents, so fuelling the supply of bioclastic sand and debris (Figure 1.11b). Local depressions were often filled in by such material, which was swept away from neighbouring shallow areas to accumulate in gently dipping inclined beds (clinoforms) on their flanks (Figure 1.12).

Figure 1.11 Rudist limestones dating from the beginning of the Late Cretaceous (Cenomanian; see Section 1.3) in south-west Istria, Croatia (see Tišljar *et al.*, 1998). (a) Close-up of a congregation of rudist bivalves preserved in life position on the platform top. Scale is 12 cm. (b) Beds of redistributed bioclastic sediment containing abundant transported rudist shells and fragments, shown in the cut face of a quarry. *(Peter Skelton, Open University.)*

(a)

(b)

Figure 1.12 Clinoforms (sloping down to the right) of redistributed bioclastic sediment (as in Figure 1.11b), exposed along the coast of Fraškker Island, south-west Istria, Croatia. *(Peter Skelton, Open University.)*

These and other limestones of shallow marine origin accumulated over large areas in and around the Tethys Ocean and were scattered across the Pacific on shallow volcanic promontories (Figure 1.2), to form massive carbonate platforms, similar to the Bahama Banks of today, although on a far bigger scale (Figure 1.13). Their development through the Cretaceous was episodic, with extended phases of widespread platform growth repeatedly terminated over relatively short time-spans. Whereas the Chalk was the most abundant type of limestone deposited in mid-latitude seas, at least in the Late Cretaceous, carbonate platform deposits dominated at low latitudes. Together, the carbonate platforms and the Chalk constituted such a large geological reservoir for carbon (as carbonate) that their development formed an important part of the global carbon cycle of the Cretaceous — an aspect to which we will return later in this book.

Figure 1.13 Reconstruction of the carbonate platform illustrated in Figures 1.11 and 1.12. On the left, rudist 'meadows' are spread across the top of the platform, while slopes covered by their shelly debris run off to the right. *(John Watson, Open University.)*

1.1.4 Tour stop 4: the susceptible sea

Our next tour stop takes us even further south, to western Central Tunisia. Here, strata dating from the earlier part of the Late Cretaceous crop out in wooded hills near the town of Kasserine. They show a remarkably abrupt change of facies, from thick beds of well-burrowed limestone below, to thinly bedded limestone above a sharp boundary (Figure 1.14a). The latter splits quite readily into thin plates (Figure 1.14b), and, although a pale colour when weathered, is dark grey on freshly broken surfaces. Planktonic microfossils are diverse below the boundary, but impoverished and relatively small above the boundary between the two facies. Moreover, the burrows that testify to bottom-dwelling animals in the lower part disappear above the boundary, where rare ammonites are the only macrofossils encountered (Figure 1.14c).

Figure 1.14 Shelf limestones deposited in the earlier part of the Late Cretaceous (across the Cenomanian/Turonian boundary; see Section 1.3) exposed on Jebel Bireno, Kasserine, Central Tunisia. (a) Due to local tectonic folding, the beds are dipping steeply towards the right. Thick-bedded limestone (on the left) abruptly overlain by platy limestone (on the right). The geologist's right foot is on the boundary between the two facies. (b) Detail of the platy limestone above the boundary. (c) External moulds of ammonites on a bedding surface of the platy limestone. *(Peter Skelton, Open University.)*

(a)

(b)

(c)

- ❍ From the information given above, what is the most likely explanation for the abrupt change in facies?
- ● A change in conditions in the water column extinguished life on the sea-floor, allowing undisturbed accumulation of laminated sediment.

Much of the overlying water column was evidently also affected, as shown by the change in the plankton, although a few pelagic animals such as ammonites survived, presumably by living close to the surface of the sea. The dark grey colour of the laminated limestone would suggest a relatively high content of organic material. The most likely circumstance in which such material would be allowed to accumulate would be in the absence of aerobically respiring bacteria, i.e. in anoxic conditions. So, the most plausible explanation for the change of facies is the onset of anoxia throughout much of the water column.

Such a change of facies in one locality alone need not seem remarkable. After all, today, anoxia occasionally afflicts many restricted marine basins, such as parts of the Gulf of Mexico offshore from the Mississippi Delta, the Black Sea and local areas of the Adriatic (although human pollution also plays a part in all these cases). The case considered here, however, is different, as a similar change can be seen at the same stratigraphical level in marine successions deposited on the continental crust at low latitudes from south-west Mexico to several other sites around the Mediterranean. It has also been documented from sites within all the ocean basins on the basis of cores drilled from the bottom sediments. Not surprisingly, the event was associated with a mass extinction of many marine organisms (especially those dwelling on the carbonate platforms), although the extent to which the extinctions can be attributed directly to the spread of the anoxia remains a matter for debate.

Such drastic events are termed Oceanic Anoxic Events (OAEs) and they occurred on a number of occasions, on varying geographical and temporal scales, during the Cretaceous, although not, it appears, thereafter. They clearly represent major perturbations in the operation of the global carbon cycle, which we will consider in greater detail later in the book.