Limestones

Most of the southern part of the Peak District is underlain by a **sedimentary** rock called limestone. Where this rock is seen in cliffs and **scree** slopes, or in man-made structures such as field walls and buildings, it is characteristically pale grey in colour, giving rise to the descriptive term 'White Peak'. The gently undulating plateau of limestone is deeply dissected by valleys and much of the area is enclosed by a network of drystone walls surrounding pastoral farmland. Numerous field barns, semi-natural woodlands of ash, hazel and elm along the dales, and evidence of disturbed ground where quarrying or mining took place complete the picture.

With such a clear correspondence between rock type and scenery it is useful to understand a little more about how the limestone formed in the first place. During the Early Carboniferous, Britain was located not in its present position, but close to the Equator. Most of the area was covered by a warm shallow sea, similar to the present-day Bahamas.

The sea teemed with life; minute organisms such as plankton and **foraminifera** thrived, along with shark-like fish and free-swimming shellfish, whilst a more diverse group of marine animals colonised the seabed. Most of the seabed dwellers had a protective shell, or at least some hard parts, made of **calcite** (calcium carbonate, $CaCO_3$). When the animals died, their soft parts decayed or were eaten by scavengers, leaving the hard parts vulnerable to breakdown by currents or wave action. Through this process of attrition vast quantities of shell and skeletal fragments accumulated on the seabed, along with lime-rich pellets and oozes produced by living organisms as faecal matter. In those parts of the sea that were particularly shallow the concentration of calcium carbonate was sufficiently high that it precipitated directly onto grains of sand and coated them with concentric layers of calcite.

The process of converting a sludgy, water-laden pile of calcite-rich sediment on the seabed into hard limestone begins as it is progressively buried by subsequent layers of new sediment. This may take a considerable amount of time and it involves some complicated physical and chemical changes, most of which cannot be observed. Once the hard rock has formed it needs to be forced upwards, to the Earth's surface, perhaps many of millions of years later, in order that it can be seen today. What is amazing is that after all this time it is still quite evident that every piece of limestone you look at, particularly if you examine it closely with a hand lens, consists of calcite in various forms. In some cases, distinctive shapes can be recognised as fossil fragments, but more commonly the rock is a densely interlocking mosaic of glistening calcite crystals set within varying amounts of very fine-grained calcite mud.

During the walk it will become apparent that the limestones are far from identical. Not only do their colour, grain size and fossil content vary, but at the larger scale some limestone beds are thin and repetitively developed, whilst others are thick or occasionally almost devoid of any structure apart from a general mounded appearance. To explain these differences, it is helpful to think about how the White Peak area would have looked during Early Carboniferous times.

Imagine a large, rather irregular, elliptical-shaped lagoon, about 30 x 15 km, covered with seawater perhaps just few metres deep. The rim of the lagoon would have been a discontinuous chain of small islands and slightly submerged reef-like structures. Beyond the rim of the lagoon water depths would have increased rapidly to several hundred metres, just as they do in modern tropical reefs. This situation created different environments where various types of limestone formed at the same time.

The thick yellow line traces the extent of limestones that now form the White Peak. In Early Carboniferous times this area was mainly covered by shallow water, with carbonate mud mounds (shown in purple) developing locally, both within the lagoon and around its margin. Reproduced from Tony Waltham's book, *The Peak District: landscape and geology,* Crowood Press, 2021.

Thick or thin, well-bedded limestones characterise the lagoon, commonly occurring in association with shellfish that could tolerate the sometimes highly saline conditions created as the shallow seawater evaporated. In contrast, the lagoon rim would have been a more dynamic setting where water depth, current strength and wave activity changed over short distances. As a result, the limestones that formed here are discontinuous and variable. In the deeper water beyond the lagoon rim, the limestones are rather thin and contain shell fragments that were swept off the floor of the lagoon during periods of storm activity and transported down the sloping seabed by currents.

The lagoon rim itself is typically where coral reefs develop, and there are many modern examples in the Pacific Ocean where that is the case. However, in the White Peak limestones the corresponding reef-like structures are not formed by a rigid framework of corals, but instead comprise carbonate mud that contains relatively few corals or other large fossils. For this reason, we use the descriptive term **carbonate mud mound** for the distinctive features that developed around the lagoon rim and, less commonly, within the lagoon itself or on the submarine slope slightly beyond it.

Carbonate mud mounds commonly have a core that is poorly bedded and mounded, suggesting that once the mound started to form it grew mainly vertically and then spread laterally across the sea floor. Examination of rocks from these features with a microscope shows that the carbonate mud is closely associated with layers of **cyanobacteria** that existed as sticky, rubbery mats on the seafloor. They perhaps protected and stabilised the steep flanks of the mud mound as it grew. Mud mounds are highly variable in size and shape, but if the exposure is sufficiently large it is usual to see that the core of the mound passes laterally into well-bedded limestones. At High Tor (Matlock Bath) and Winnats Pass (Castleton), for example, this configuration is very evident.

The final point to bear in mind about the limestones is that they formed over a period of at least ten million years, during which time there were many subtle changes to the snap-shot described here. The sea level often changed, variously flooding the lagoon with deeper water or allowing it to dry out, and the carbonate mud mounds developed in different places at various times, depending where the conditions for their growth were most favourable. Periodically there was also volcanic activity in the area that produced lavas and layers of volcanic ash that contrast strongly with the limestones.