THE GEOLOGY OF THE CLIFFS OF MOHER

Summary points:

1. The limestones were formed in a shallow tropical sea when Ireland was located about 10 degrees south of the Equator.
2. Fossils in the limestones are almost always fragmented, which tells us that the sea floor was affected by waves and currents.
3. The shallow sea deepened, probably due to a rise in sea level caused by melting of polar ice caps during an ice age, and limestone deposition stopped.
4. Shales were laid down in this deep sea until a large delta system advanced from a landmass to the southwest.
5. This delta system deposited sediment across an area that spreads from the Cliffs of Moher to North Cork, i.e. at least 800 km^2; the thickness of sediment laid down is approx. 2.5 km.
6. The sandstones and siltstones exposed at the Cliffs were laid down during successive flood events about 317-318 million years ago.
7. In between flood events, the action of currents and waves caused ripples to form on the sediment surface.
8. Every so often, about every 65,000 years, there were changes in sea level caused by the ongoing ice age. When sea level rose, shales (e.g. the Moher Shales) were laid down on top of the delta sediments. The deltas gradually re-advanced over the area, laying down more sandstones and siltstones on top of the shales. There are five of these cycles in total exposed in the delta sediments; two are exposed at the Cliffs of Moher.
9. The deltaic sediments contained lots of nutrients and supported a rich ecosystem, evidence of which is seen in the abundant trace fossils.
10. The most common, sinuous, trace fossils were made by a woodlouse-like animal or by a snail (gastropod).

A bit more detail….

What rocks do we find in North Clare?

We have two basic types of rock in North Clare: **limestones** (that are exposed in the Burren), and **siltstones, sandstones, and shales (**exposed at the Cliffs of Moher). All are **sedimentary** rocks (i.e. laid down at the Earth's surface as a result of weathering, erosion, and the buildup of the remains of animals).

How old are the rocks?

The rocks of North Clare were formed between **341 and 317** million years ago. The limestones were deposited between 341 and 326 million years ago, then followed by shales between 326 and 318 million years ago, and the rocks exposed at the Cliffs of Moher were deposited about **318-317** million years ago.

To put this age into context…

In terms of the evolution of life on Earth, the rocks at the Cliffs were formed before the evolution of humans, dinosaurs, mammals, flowering plants, and reptiles. Invertebrates, fish, shellfish, and land plants had already evolved; insects were just evolving at this time.

Why do the limestones occur in the north of the region, and the sandstones/siltstones /shales in the south?

The limestones are older than the sandstones/siltstones/shales and were therefore originally laid down underneath them. Due to tectonic forces that affected the rocks when they were buried in the Earth's crust, the rocks are all now tilted gently to the south. So as you travel from north to south you are crossing progressively younger rocks.

What's the basic story of the rocks?

The limestones were laid down in a shallow sea over about 15 million years. This sea suddenly deepened, and limestone formation stopped. Nothing but shales were laid down for 8 million years. Then suddenly a huge delta system moved into the area, and laid down thick deposits of sandstones and siltstones, in a very short period of time – less than a million years.

How did the limestones form?

The limestones were formed in a shallow tropical sea when Ireland was located approx. 10°S of the Equator. These rocks contain abundant fossils (see below) in a grey background. This grey background consists of microscopic particles of calcium carbonate (calcite). Some of these particles formed directly in the water column in the tropical sea; others are the remnants of shells (and skeletons of other marine animals) that were ground very finely into a lime mud.

What are the fossils we see in the limestones?

The most common fossils are corals, crinoids (sea lilies), brachiopods (lamp shells), and gastropods (snails).

Corals: both solitary and colonial corals are found in the limestones. In cross section, individual “branches” of the corals have lots of lines arranged in a radial pattern. These fossils are evidence of the sea being **shallow** (as most corals need sunlight to make their food, via symbiotic photosynthetic algae) and **warm** (corals have a skeleton made of calcite, which is easier to lay down in warm, as opposed to cold, water).

Crinoids: These animals are related to modern starfish and sea urchins and are still alive today. They are attached to the seafloor, and have lots of feathery arms that gather plankton and other microscopic food particles floating through the water. The arms pass the food into a central mouth with sharp teeth that sits on top of a long hollow vertical stem. In the rocks, the fossil remains of these animals usually appear as white circles with a hole in the middle: these circles are pieces of their stem. These fossils would have been a few feet high, but there were also giant forms up to several metres high. See for footage of crinoids crawling.

Brachiopods: These animals are still alive today and appear similar to bivalved molluscs such as mussels (but they have a different internal anatomy). In cross section, the fossil remains of these animals look like curved white lines in the rock or as white circles, depending on the plane of sectioning.

Gastropods: These fossils appear as white spirals in the rock.

Why did limestone formation stop?

During deposition of the rocks of North Clare, the Earth was experiencing an ice age, similar to the one which ended 10,000 years ago. During an ice age, there are times when the ice advances from the poles to form large ice caps, and there are times when the ice retreats slightly, and the ice caps shrink. The ice caps lock up large amounts of water, and when they melt, this water is released back into the Earth's oceans, causing a global rise in sea level. One of these phases of ice retreat may have contributed to the rise in sea level that switched off limestone formation.

Where did the deltas come from?

The rise in sea level meant that the sea was now much deeper. Into this deep sea a large complex delta system advanced from a landmass somewhere to the SW of Ireland. This delta system was carrying sediment from a large series of braided rivers flowing across an ancient continent. The deltas deposited massive amounts of sediment across an area that extends from the Cliffs of Moher today down through Co. Limerick, Kerry, and parts of North Co. Cork. The delta sediments are estimated to be about 2.5 km thick. This ancient delta system is considered to be similar to the Mississippi delta today, which carries several million cubic metres of sediment to the sea floor every second.

Why did this delta system appear so suddenly?

Modern deltas are constantly changing their position, both laterally along the coast, and prograding out to sea. This ancient delta would have behaved in the same way, but it is impossible to say exactly why the delta appeared at that particular time. Just chance!

Why do these deltaic rocks consist of alternating sandstones and siltstones?

The deltas deposited most of their sediment during flood events. The sandstone beds were laid down during strong floods, whereas the siltstone beds were laid down during weaker floods (stronger currents can carry larger particles of sediment). Alternatively, the sandstones could indicate times when the delta channels were closer, and the siltstones, times when the delta channels were further away.

What features do we see in the rocks at the Cliffs?

The upright slabs that form the "wall" at the seaward margin of the site contain excellent examples of ripples and trace fossils (the trails or marks left by animals in sediments). In cross-section, the ripples can be symmetrical (where both sides of the ripple have the same curvature), asymmetrical, or irregular. Symmetrical ripples are typically formed by an oscillating current, i.e. a tide; they show that the area was in between delta "arms" at the time. Asymmetrical ripples are typically formed by a current travelling in only one direction, and show that the area was close to one of the delta arms. Irregular ripples that are neither symmetrical nor asymmetrical indicate the area was influenced by a mixture of currents.

By far the most common trace fossils in the upright slabs are sinuous, meandering trails about 5-15 mm wide. In some slabs, you can see that the trails have a distinctive internal structure formed by closely spaced, curved, transverse lines. These lines show that the animal that produced the trace was either a multi-legged animal similar to a woodlouse, or else a gastropod (snail). Many of these trails also have a distinct raised ridge running down along their length. These sinuous trails are characteristic of estuaries and delta environments. Other types of trace fossil also occur in the rocks at the Cliffs, but are rare. The fact that a single type of trace fossil is dominant here shows that the environment was hostile or stressful (recurring flooding would certainly count as an environmental stress!), and was suitable for colonisation by only opportunistic animals.

Why do we sometimes get marine mudstones ("The Moher Shales") in the sequence of delta sediments?

The Earth was still in the grip of an ice age, and every so often, when the ice caps retreated, water was released back into the world's oceans and sea level rose. When this happened, the sea deepened and the shallow delta shelf was flooded. As before, only shales were laid down in this deep sea. The deltas, however, were still carrying sediment out to sea and over time they "caught up" and moved over the area again, depositing siltstones and sandstones on top of the marine mudstones. We know that the rise in sea level was not just a local phenomenon because the mudstones contain a specific species of a fossil animal called a goniatite (related to modern squid and octopus). The exact same species occurs in rocks of the same age throughout Europe and in other continents, showing that the rise in sea level was occurring around the world at the same time.