CHAPTER 1



Introduction to Sedimentology and Stratigraphy

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Sedimentology is the study of the processes of formation, transport and deposition of material that accumulates as sediment in continental and marine environments and eventually forms sedimentary rocks. Stratigraphy is the study of rocks to determine the order and timing of events in Earth history: it provides the time frame that allows us to interpret sedimentary rocks in terms of dynamic evolving environments. The stratigraphic record of sedimentary rocks is the fundamental database for understanding the evolution of life, plate tectonics through time and global climate change.

CHAPTER OUTLINE

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Sedimentology and Stratigraphy, Third Edition. Gary Nichols.
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1.1 Overview

Physical, chemical and biological processes act on the surface of the Earth all the time. Some of these surface processes change the nature and composition of the material and make it available for transport and deposition in a variety of different places on land and in the sea. Chemical and biological activity also generate materials that accumulate in some settings. In time these sediments may become sedimentary rocks buried in the subsurface or uplifted by tectonic activity into modern landscapes. The study of these processes and their products is the science of *sedimentology*.

Layers of sediments and sedimentary rocks are known as strata. *Stratigraphy* is a discipline which encompasses the relationships between stratal units, the relative and absolute ages of these strata and the whole framework of geological history. It is one of the oldest disciplines within the geological sciences and includes the use of fossils as indicators of different periods of Earth history. It includes the relationships between igneous bodies and metamorphic rocks as well as sedimentary strata.

The relationships between modern and ancient, sedimentology and stratigraphy, are illustrated in Figs. 1.1 and 1.2. A modern river is a place where a variety of sedimentary processes occur.

- A flow of water confined to a channel has sufficient energy to transport sand which is deposited on bars in the river and, in doing so, creates a sedimentary unit. These are physical processes of transport and deposition.
- When the river floods, water and sediment are carried on to the floodplain adjacent to the channel, where it provides nutrients for a community of plants and animals. Soils form by a mixture of physical, chemical and biological processes.

A sedimentological study of this modern river environment would involve looking at the patterns of sand deposition in the channel and on the bars in relation to the velocity and depth of the water flow. The grain size and extent of the deposits on the floodplain would be related to the magnitude and frequency of flood events. Flooding and the degree of waterlogging also play a role in determining the characteristics of the soils that form on the floodplain along with the climate in the area.



FIGURE 1.1 A modern depositional environment: a sandy river channel and vegetated floodplain.

The rocks exposed in the cutting (Fig. 1.2) can be described in terms of their sedimentological features

- The sandstone body is made up of grains whose size, shape and composition can be related to the river processes that deposited them. The base of the unit marks the surface where the channel cut into the sediment below, and the pattern and orientation of surfaces within the body can inform about depth, velocity and direction of flow in the channel.
- The layering in the beds below and above the sandstone body can be interpreted in terms of flooding events bringing fine sand and mud onto a floodplain. The extent of the layers provides an indication of the magnitude of the flooding events and features within the sand and mud are evidence of soil formation.



FIGURE 1.2 Sedimentary rocks interpreted as the deposits of a river channel (the lens of sandstones in the centre right of the view) scoured into mudstone deposited on a floodplain (the darker, thinly bedded strata below and to the side of the sandstone lens).

These rocks can be related to other rocks occurring in strata above or below, and a local stratigraphy can be established on the basis that the layers below are older than the layers above. Fossils within the beds can provide information of their relative age – although, as will be discussed in later sections, the deposits of rivers and floodplains are generally not rich in the remains of organisms – and the beds placed within a broader, global stratigraphic framework.

1.2 Sedimentology

'Sedimentology' has only existed as a distinct branch of the geological sciences for a few decades. It developed as the observational elements of physical stratigraphy became more quantitative, and the layers of strata were considered in terms of the processes which formed them. However, the concept of interpreting sedimentary rocks in terms of modern process – 'the present is the key to the past' – dates back to the 18th and 19th centuries. Assuming that the laws that govern physical and chemical processes have not changed through time, detailed measurements of sedimentary rocks can be used to make estimates (to varying degrees of accuracy) of the physical, chemical and biological conditions which existed at the time of sedimentation. These conditions may include, for example, the salinity, depth and flow velocity of water in a lake or sea, the strength and direction of the wind in a desert and the tidal range in a shallow marine setting.

A link can be made between modern environments of deposition and sedimentary rocks by interpreting the physical, chemical and biological characteristics of those rocks in terms of processes of formation. This is the basis on which it is possible to develop an understanding of what the Earth looked like at different times in different places during Earth history. The rocks in Fig. 1.3 are from the Cretaceous of the Isle of Wight in southern England: impressions of dinosaur footprints can be seen as bulbous shapes on the base of one bed and weather out of the cliff face as casts. The characteristics of the beds below and above indicate that deposition occurred on a river floodplain, perhaps similar to the setting shown in Fig. 1.1. The sedimentology of the rocks, therefore, informs us about the environment where these dinosaurs lived more than a hundred million years ago.

Every depositional environment has a unique combination of processes, and the



FIGURE 1.3 A cliff on the Isle of Wight in southern England exposes rocks that have been dated as Cretaceous in age. The sandstones and mudstones are interpreted as river channel and overbank deposits and the presence of the casts of Iguanodon footprints (inset) indicate that these dinosaurs lived in this fluvial environment over one hundred million years ago.

products of these processes, the sedimentary rocks, will be a similarly unique assemblage. For the convenience of description and interpretation, depositional environments are classified as, for example, a delta, an estuary or a shoreline, and sub-categories of each are established, such as wave-dominated, tide-dominated and river-dominated deltas. This approach is in general use by sedimentary geologists and is followed in this book.

It is, however, important to recognise that these environments of deposition are convenient categories or 'pigeonholes' and that the description of them tends to be of 'typical' examples. The reality is that every delta, for example, is different from its neighbour in space or time, that every deltaic deposit will also be unique, and although we categorise deltas into a number of types, our deposit is likely to fall somewhere in between these 'pigeonholes'. Sometimes it may not even be possible to conclusively distinguish between the deposits of different environments, especially if the data set is incomplete – which it inevitably is when dealing with events of the past. However, by objectively considering each bed in terms of physical, chemical and biological processes, it is always possible to provide an indication of how a sedimentary rock was formed.

1.3 Stratigraphy

Use of the term 'stratigraphy' dates back to d'Orbingy in 1852, but the concept of layers of rocks, or strata, representing a sequence of events in the past is much older. In 1667 Steno developed the principle of superposition: 'in a sequence of layered rocks, any layer is older than the layer next above it'. Stratigraphy can be considered as the relationship between rocks and time, and the stratigrapher is concerned with the observation, description and interpretation of direct and tangible evidence in rocks to determine the history of the Earth. We recognise that our planet is a dynamic place, where plate tectonics creates mountains and oceans and where changes in the atmosphere affect the climate, perhaps even on a human time scale. To understand how these global systems work, we need a record of their past behaviour to analyse, and this is provided by the study of stratigraphy.

Stratigraphy provides the temporal framework for geological sciences. The relative ages of rocks, and hence the events which are recorded in those rocks, can be determined by simple stratigraphic relationships (younger rocks generally lie on top of older, as Steno recognised), the fossils that are preserved in strata and by measurements of processes such as the radioactive decay of elements which allow us to date some rock units. At one level, stratigraphy is about establishing a nomenclature for rock units of all ages and correlating them all over the world, but at another level, it is about finding evidence for climate change in the past or the movements of tectonic plates. One of the powerful tools we have for predicting future climate change is the record in the rock strata of local and global changes over periods of thousands to millions of years. Furthermore, our understanding of evolutionary processes is in part derived from the study of fossils found in rocks of different ages that tell us about how forms of life have changed through time. Other aspects of stratigraphy provide tools for applied geosciences: for example, 'sequence stratigraphy' is a predictive technique, widely used for the exploration of the subsurface for energy and mineral resources.

1.4 Sedimentology and Stratigraphy

The relationship between these two closely related geoscience disciplines is illustrated in Fig. 1.4. The interpretation of both sediments in modern environments and sedimentary rocks in terms of processes and the associations of them that characterise environments of deposition provides the basis for further studies. These studies may include the consideration of successions in sedimentary basins and the transition from a sedimentological to a stratigraphic analysis as a temporal framework of geologic time is introduced.

The combination of sedimentology and stratigraphy allows us to build up pictures of the Earth's surface at different times in different places and relate them to each other. The character of the sedimentary rocks deposited might, for example, indicate that at one time, a certain area was an arid landscape, with desert dunes, with washes of gravel coming from a nearby mountain range. In that same place, but at a later time, conditions allowed the formation

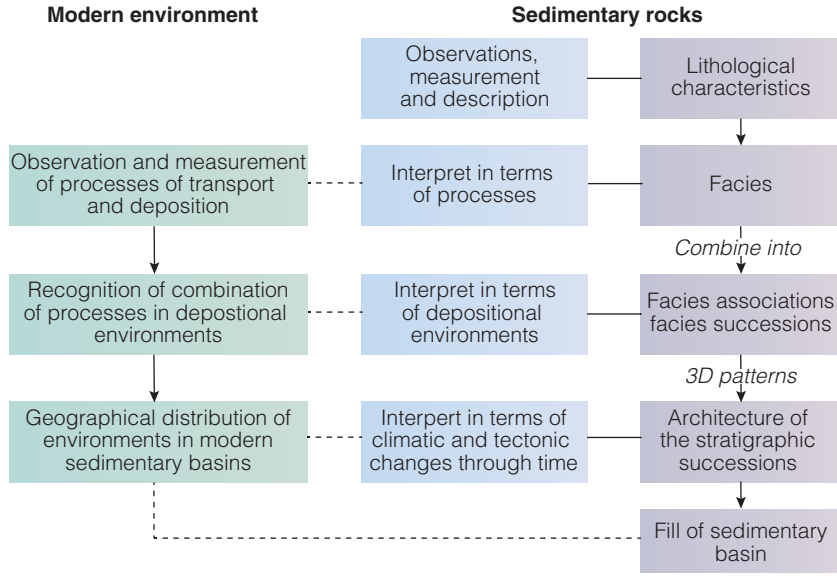

FIGURE 1.4 The relationships between observations and interpretations in modern environments and successions of sedimentary rocks. The procedures for defining facies and facies associations are covered in Chapter 5 and the context of sedimentary basins in Chapter 25.

of coral reefs in a shallow sea far away from any landmass, and we can find the record of this change by interpreting the rocks in terms of their processes and environments of deposition. Furthermore, we might establish that at the same time as there were shallow tropical seas in one place, there lay a deep ocean a few tens of kilometres away where fine sediment was deposited by ocean currents. We can thus build up pictures of the *palaeogeography*, the appearance of a region during some time in the past and establish changes in palaeogeography through Earth history. To complete the picture, the distribution of different environments and their changes through time can be related to plate tectonics, because mountain building provides the source for much of the sediment, and plate movements also create the sedimentary basins where sediment accumulates.

Sedimentology and stratigraphy cannot be considered in isolation of other aspects of geology, and in particular, plate tectonics, petrology, palaeontology and geomorphology are complementary topics. Reference is made to these subjects in the text, but only a basic knowledge of these topics is assumed.

Further Reading

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