CHAPTER 2

Reading the rocks

Figure 28. The rock stack exposed along the cliff face of Chapman's Peak Drive provides a record of Cape Town's deep geological history.

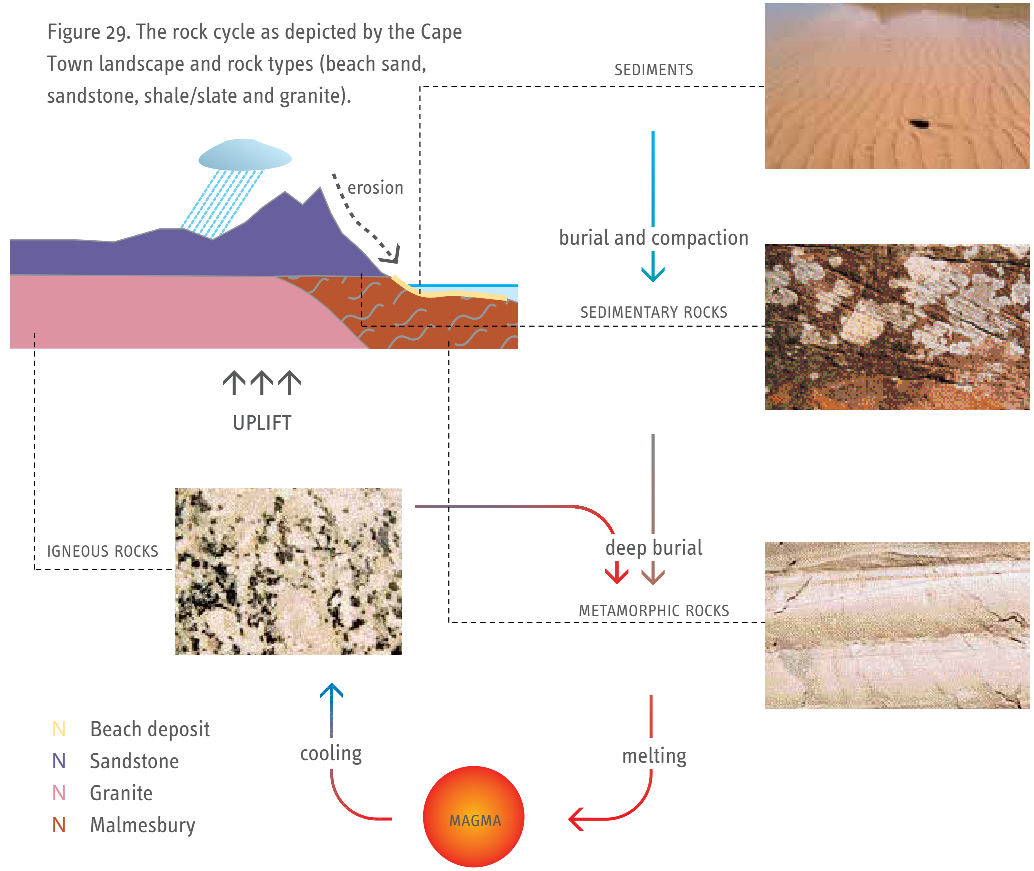
In the previous chapter, we saw that rocks have a large influence on the landscape, soil and vegetation in the Cape Town area. In addition to this relatively recent imprint, the rocks of Cape Town have their own far more ancient origins. What we see today (Fig. 28) is the end product of a long history of geological events and processes that have operated over vast distances and for millions of years. The rocks reveal a wide spectrum of vastly different environments, ranging from subtropical beaches to polar ice caps. These environments have evolved over the long eras of geologic time in the vicinity of what we know today as Cape Town. The story the rocks tell is often difficult to grasp because we are not accustomed to thinking about our world over such enormous spans of time, living as we do from day to day, year to year.

Geologic time is sometimes referred to as deep time, for it reaches back millions – even billions – of years into the past. The raising up of mountains and the opening of ocean basins take millions of years at the rate Earth moves. Most geologic change is imperceptibly slow to us until the ground shakes under our feet during an earthquake. How can we comprehend deep time? A commonly used device is to compress the 4,6 billion years of Earth history into the space of one calendar year. On the first of January our Earth and solar system form; by mid-February the oldest rocks yet discovered form on the surface, and by late March some include simple, unicellular life; it is not until 22 November that abundant multicellular life arrives on the scene; on Christmas Day Earth is struck by a large asteroid and the dinosaurs become extinct; by late morning on New Year's Eve our oldest hominid ancestors break away from the apes; and finally modern humans arrive at around 20 minutes before midnight.

Rocks provide our window into the deep past. We shall see that in the Cape Town area, as elsewhere, only a very incomplete and partial record of Earth history is on offer: most of time is not represented at all except as large gaps in the rock record. These gaps occur because rocks are continually being recycled as a result of plate tectonics (Fig. 29). Gaps in the rocks represent periods during which the surface in the Cape Town area was undergoing erosion rather than accumulation. Even during those periods when rocks manage to accumulate, only a small fraction of the environment of which they are a part is captured, with most living organisms unlikely to be preserved as fossils and the gases of the atmosphere or water surrounding them even less so. Therefore, the task of reading the rocks becomes paramount to our understanding of the past. Although they are not ideal recorders, they are all we have.

What follows is a reading of the story that rocks exposed in the greater Cape Town area have to tell, so that the next time you see them up close or from a distance you will recognise them as being more than 'just rocks'. The story of the rocks is told from oldest to youngest – not out of respect for age, but because it gives the correct order in which events occurred, from the deep past right on through to the present day.

Figure 29. The rock cycle as depicted by the Cape Town landscape and rock types (beach sand, sandstone, shale/slate and granite).



The rock cycle

Rocks are divided into three types: sedimentary, metamorphic and igneous. All three are represented in the Cape Town area and examples of each are shown here. The rocks that make up Earth are dynamic (Fig. 11) and are continually being transformed, either by deep burial or by uplift and weathering, from one rock type to another (Fig. 29). Sedimentary rocks are first deposited as loose sediment particles derived from the breakdown of pre-existing rocks or from the formation of new particles from salts dissolved in water. A common type of sediment is beach sand, which in the Cape Town area consists of roughly equal proportions of quartz grains (weathered from the rocks of Table Mountain) and shell fragments. Compaction and cementation by deep burial transforms sand into sandstone. Similarly, mud is buried to form mudstone, which upon deeper burial transforms into shale and then slate (sometimes used as roof tiles) in response to increasing pressure and temperature. At sufficiently high temperatures and pressures, minerals transform into new minerals that give a shiny sheen to metamorphic rocks, and at great depths the rock melts to form a liquid magma. Igneous rocks form from magma – coarsely crystalline if the magma cools slowly, and finely crystalline or glassy if the magma cools rapidly in a volcanic eruption. The cycle is completed by the eventual uplift of all three rock types to the surface, where they weather to form new sediment deposits.

Cape Town's oldest rocks

The oldest rocks in the Cape Town area were originally deposited as marine mud and muddy sands, which today make up a suite of rocks known as the Malmesbury Group. These were named, as is often the case, after the area where they were first or most completely described – in this case, near the town of Malmesbury in the Swartland north of Cape Town (Fig. 1). The Malmesbury Group a comprises diverse set of rocks that is dominated in the Cape Town area by shale (metamorphosed mud) and greywacke (muddy sands). Malmesbury rocks are widespread in the Cape Town area, underlying much of the coastal plain (CBD, Cape Flats, Swartland) as well as Signal Hill, Mowbray Ridge and the hills of the Tygerberg. However, unaltered exposures are rare because these fine-grained, highly fractured rocks weather relatively quickly and are covered by soil or wind-blown sand in most areas.

You can see relatively fresh (unaltered), dark-coloured Malmesbury rocks exceptionally well exposed all along the Promenade at Sea Point (Fig. 30). Although they have since been folded and buried into hard rocks, many features acquired when the sediment first accumulated on the sea floor as soft mud are preserved and provide clues to the environment in which Malmesbury rocks were deposited. Many features of these rocks – such as ripples – are similar to those found in sediments today (Fig. 31).

But there are two significant and linked differences between the ancient Malmesbury rocks and modern sediment: Malmesbury rocks lack fossils and have abundant fine depositional layers called laminations (Fig. 32). Laminations are rare in modern sediment because animals (mostly worms) living on the sea floor or in soil are constantly ingesting and burrowing through the sediment. The effect over time is a homogeneous, well-mixed sediment with no fine layers of deposition preserved. The reason Malmesbury rocks are laminated and lack fossil animals is that sea-bed animals

Figure 30. Erosion by powerful surf exposes Malmesbury rocks along the Sea Point Promenade. The rock layers extend offshore to the northwest, steeply dipping to the northeast, with mud-rich shale layers forming gullies and sand-rich layers (greywacke) forming more resistant ridges. These rocks form part of the wave-cut terrace upon which Sea Point is built. The over 300 m high ridge in the background is made up of Malmesbury rocks as well as granite underneath Lion's Head on the right. The Cableway Station is visible on top of Table Mountain on the distant skyline.

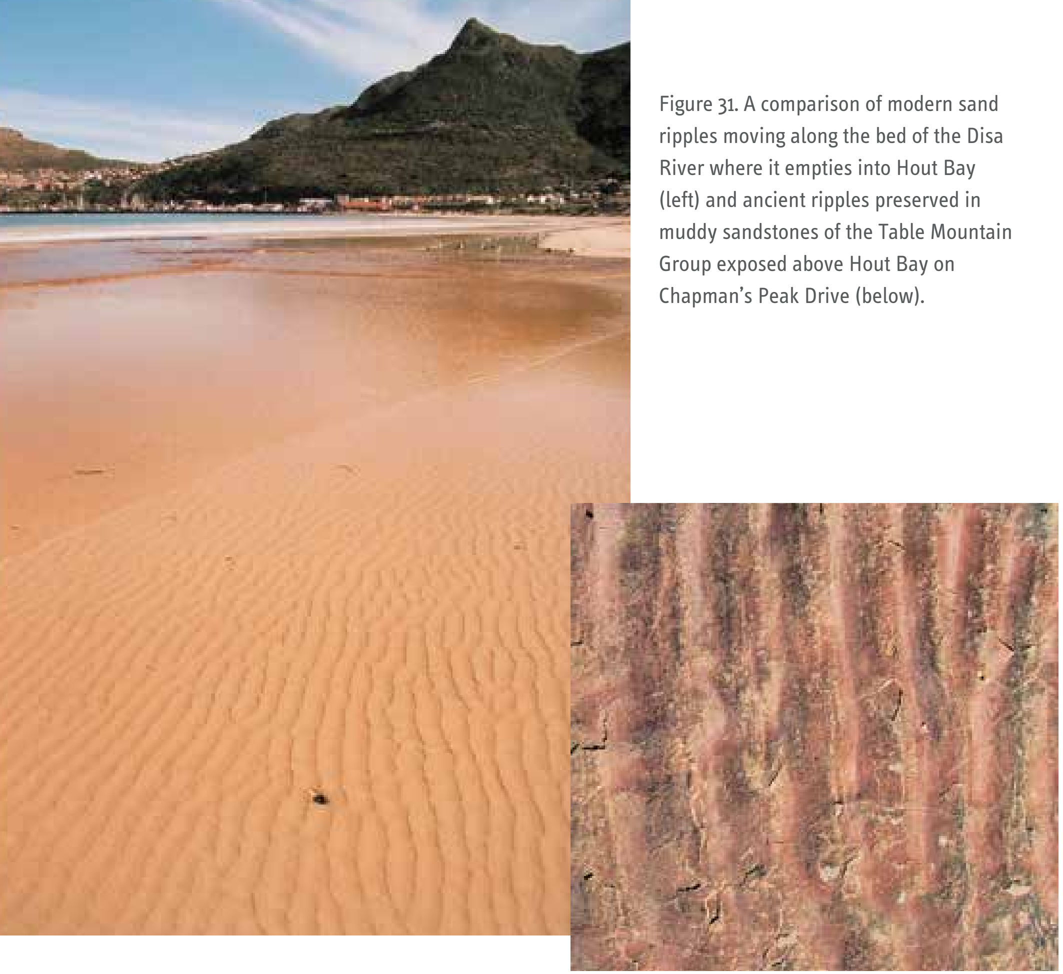


Figure 31. A comparison of modern sand ripples moving along the bed of the Disa River where it empties into Hout Bay (left) and ancient ripples preserved in muddy sandstones of the Table Mountain Group exposed above Hout Bay on Chapman's Peak Drive (below).

THE PRESENT IS THE KEY TO THE PAST

One of the most powerful approaches to deciphering the story of ancient rocks is to find modern examples where similar rocks are actively forming today. The principle of uniformitarianism, championed by one of the founding fathers of geology, Charles Lyell, is summed up by the statement: 'The present is the key to the past.' The idea is that what we observe today also happened in the past and that the cumulative, long-term effect can be seen in the rock record: for example, how ripples are formed in sand by flowing water (Fig. 31). One limitation of uniformitarianism is that conditions on Earth have not always been the same as today. The climate as well as the composition of the atmosphere and seawater have changed over time; and for much of Earth history, life on the planet consisted of single-celled organisms (until November on our compressed calendar). We have witnessed only a wink of the eye of Earth history, and many past events and environments are not represented on Earth today. Although uniformitarianism is an extremely powerful tool to interpret the rock record, one should always bear in mind that many aspects of the past were significantly different from the present.

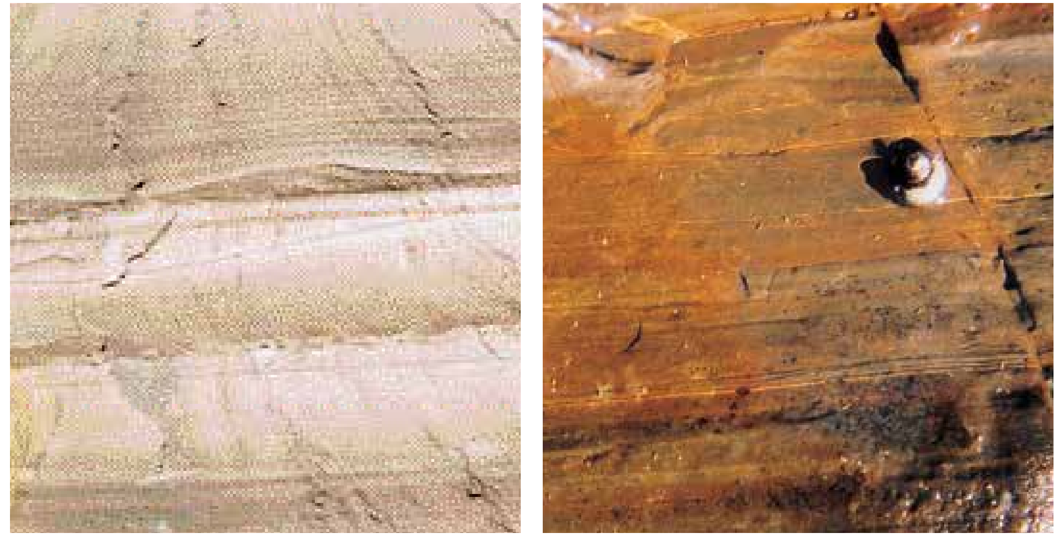


Figure 32. Close inspection of Malmesbury rocks at Van Riebeeck's Quarry on Robben Island and in a Sea Point tidal pool reveals the presence of fine (less than 1 cm thick) sediment layers called laminations.

with hard skeletons had not yet evolved on Earth in significant numbers at the time when these rocks were forming. The dark colours of Malmesbury rocks indicate that there is organic matter in the sediment, but it takes the form of the remains of single-celled bacteria and algae. Unlike animals, these small organisms were incapable of disrupting fine sediment layers and more likely carpeted the seafloor in mats of algae that helped to preserve the laminated sediment.

Graded bedding can also commonly be seen in Malmesbury rocks. Graded beds contain what are referred to as turbidite deposits. These form from the settling out of sediment that has been suspended by large-scale slumping events, often triggered by an earthquake. As the sediment grains settle out of the turbid water, the larger grains reach the bottom first, followed by finer grains. Ripples and graded bedding provide important indicators as to the 'right way up' in sedimentary rocks like these, which have been intensely folded.

In addition to sedimentary rocks, the Malmesbury Group contains volcanic rocks, which tell us volcanoes were active at least episodically during their deposition. You can see these reddish-brown volcanic rocks along the rocky shores at Bloubergstrand. The presence of volcanic rocks is revealing for, unlike the modern offshore sediments, these

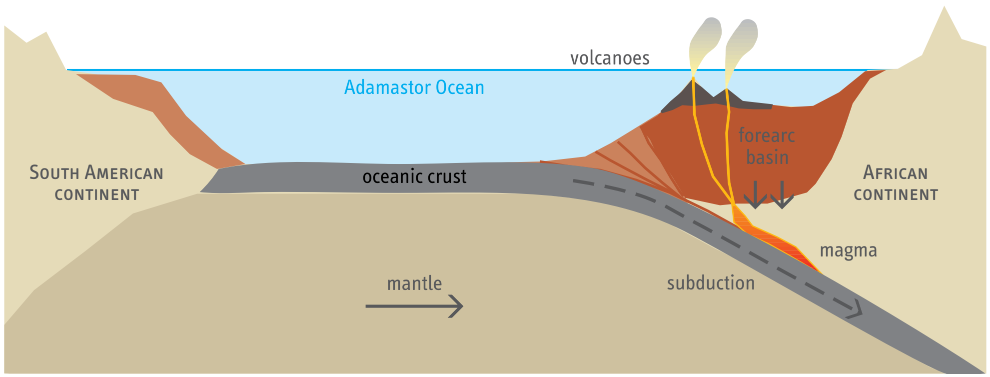


Figure 33. Possible tectonic setting during deposition of the Malmesbury Group.

earlier sediments most likely accumulated on a tectonically active margin with volcanoes being generated as oceanic crust was subducted below the continent (Fig. 33).

We know that Malmesbury rocks are the oldest in the Cape Town area because they always occur at the lowest levels and all other rocks either rest on top of or cross-cut Malmesbury rocks. But how long ago were Malmesbury rocks deposited? This is not an easy question to answer, in large part because these rocks lack fossils. The youngest of a number of individually dated (Fig. 34) grains of zircon (a hard-wearing and hence common trace mineral found in sedimentary rocks) reveals that Malmesbury rocks sampled at Sea Point are no older than 560 million years. This may not appear to be very helpful except that, as we shall see, the granite that intrudes Malmesbury rocks is about 540 million years old. Therefore, Malmesbury sediments were deposited some time between 560 and 540 million years ago.

In summary, Malmesbury rocks are the oldest in the Cape Town area, having originally accumulated some time between 560 and 540 million years ago as muddy sediment on the edge of a tectonically active continent. The fine laminations and absence of fossils indicate that these sediments accumulated before there were abundant animals on Earth. It is not known how deeply the Malmesbury rocks extend because no one has ever drilled to the older rocks beneath them. However, they are believed to represent a thick pile of sediment similar to the wedge of sediment up to 18 km thick that sits on the present-day edge of the continent deposited since Africa split away from South America 135 million years ago. The history of plate tectonics tells us that Malmesbury sediment did not accumulate on the edge of the present-day South Atlantic Ocean basin, but in an earlier ocean basin called Adamastor.

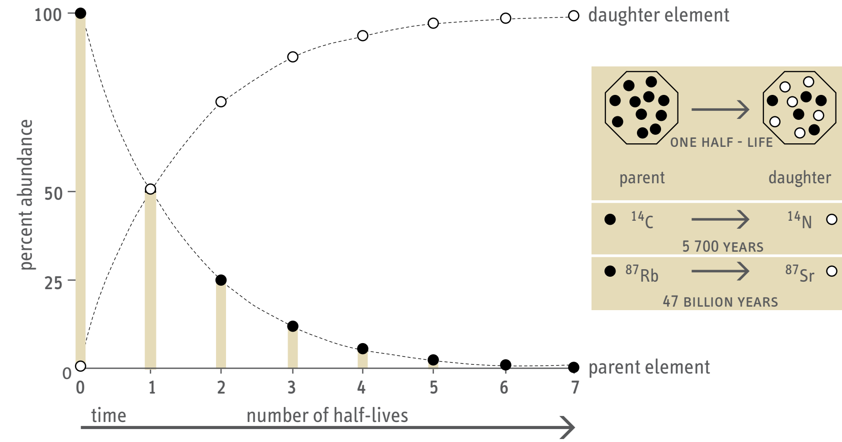


Figure 34. A determination of the absolute age of rocks relies on the fact that some elements (the parent) spontaneously decay to stable (daughter) elements. If certain conditions are met, then the relative abundance of parent and daughter elements can be used to determine how many years ago the mineral formed.
The rate of decay varies among radioactive elements. For example, carbon atoms with an atomic mass of 14 are radioactive, as are rubidium atoms of atomic mass 87, but the time required for half of the carbon 14 atoms to decay (half-life) is approximately 5 700 years and 47 billion years for rubidium 87. For this reason, carbon 14 is used to date relatively recent material (<50 000 years old) and rubidium 87 is used to date older rocks (>500 million years).

Dating rocks, relatively and absolutely

Determining the relative age of rocks is fairly straightforward. For example, because sediment is deposited as nearly flat layers (the principle of original horizontality), the rocks at the top of a stack of sediment layers must be younger than the rocks below (the principle of superposition). Where sediment layers have been tilted or turned upside down by folding, features of the sediment – such as ripples, graded bedding or cross-bedding – can be used to determine the original way up. But stacks of sediment vary from place to place and reflect the wide variety of different types of sediment that accumulate on the surface at any given time. This variation makes it difficult to correlate rocks unless they contain fossils. Rocks containing the same fossils were deposited within the interval of time when those organisms lived. Because extinction is forever and the evolutionary turnover of new species is quite rapid on geological timescales (the average species exists for 4 million years), fossils are useful in correlating similarly aged rocks.
Although relative ages are useful, they give only a crude history of the rocks. Geologists want to know exactly how many years ago a particular rock formed. Radioactivity, the spontaneous decay of one element into another, is commonly used to assign an absolute or numerical age to a rock. Igneous rocks are typically the best candidates for absolute dating because many of the radioactive clocks start when minerals first crystallise from the magma. For this reason the age of the Cape Granite is much better known than that of the sedimentary Malmesbury rocks (no one has yet dated the Malmesbury volcanic rocks at Bloubergstrand).