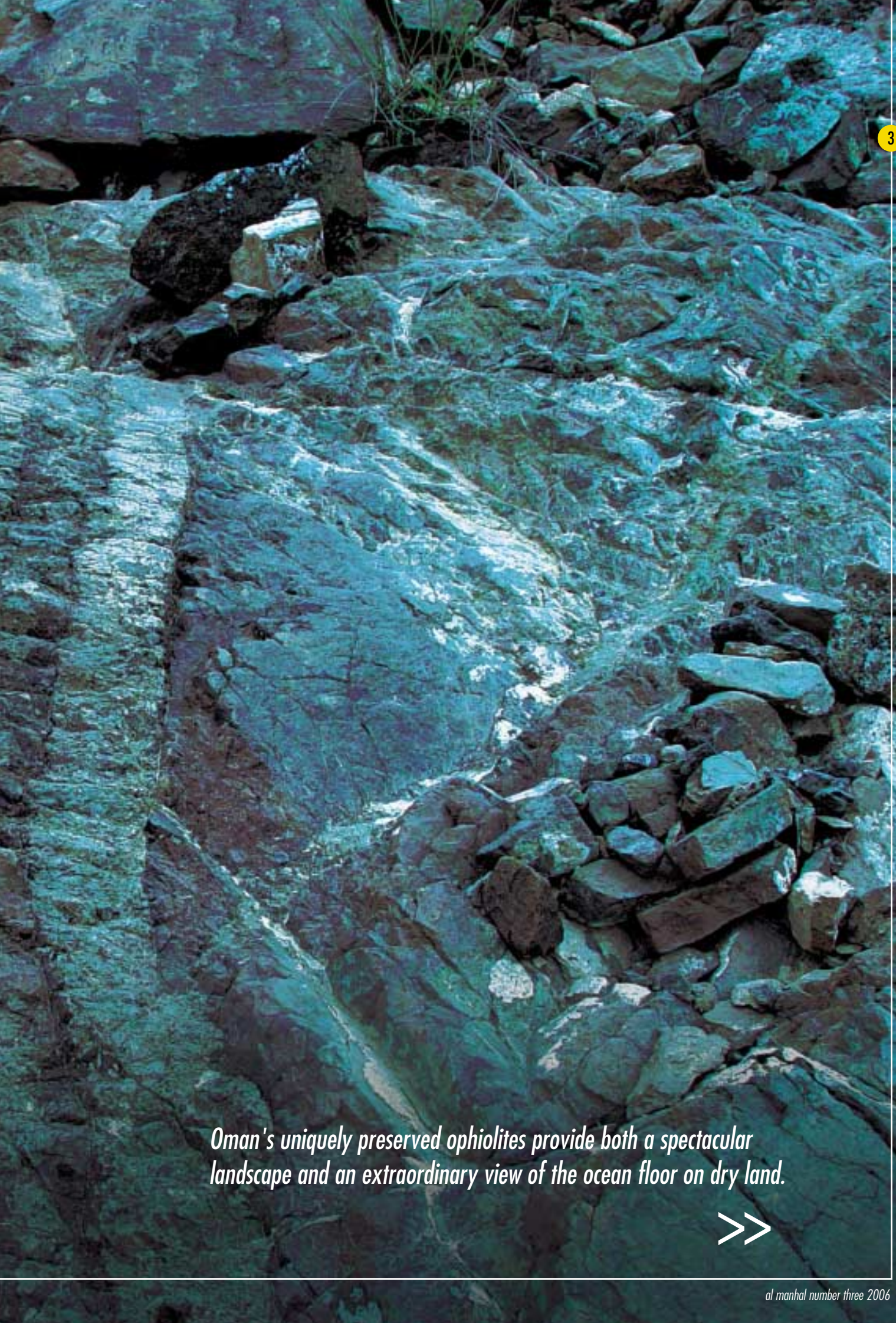
OPHIOLITES

A natural wonder



Oman's uniquely preserved ophiolites provide both a spectacular landscape and an extraordinary view of the ocean floor on dry land.

The Semail Ophiolite which lies exposed on the surface in Oman provides a perfect working laboratory for geologists.

The Earth's oceans and land masses have been in a state of constant motion for millions of years - movement that has created the continents and countries we know today.

The planet's crust is made up of a series of interlocking tectonic plates, like a giant jigsaw puzzle on top of the white-hot molten mantle closer to the core. As these plates move and collide with each other this interaction causes volcanic and seismic activity at the margins where they meet. It has also created some unique and often stunningly beautiful geographical features - among them Oman's al-Hajar's mountain range.

The al-Hajar mountains rise up out of the surrounding desert, reaching a maximum height of over 10,000ft (3000m) on Jebal Akdar, or Green Mountain - so called because its comparatively higher rainfall supports a relatively lush vegetation. The soaring limestone rock peaks, rugged canyons and plentiful wadis support a remarkable variety of life, from fruit trees to birds of prey and mountain gazelles, making them a very popular tourist destination.

But also alongside the al-Hajar range's sharp edged peaks is an impressive more ragged backdrop displaying characteristic golden brown hues in the late afternoon sun. It is this geological gem that has attracted scores of scientists from across the globe and which, perhaps surprisingly, has made a major contribution to our understanding of the rocks that lie beneath our world's oceans.

This is the Semail Ophiolite; a huge slab of ocean crust, (consisting of volcanic rocks and the Earth's mantle) of almost 100,000 square kilometres in area. This crust that was once up to 15 kilometres thick and lay beneath a long vanished deep ocean, is now pushed up on top of the north eastern edge of the Arabian continent (see panel on page 7).

The name ophiolite is derived from the Greek words 'ophis', meaning snake, and 'lithos', meaning rock. The reason for this name is that ophiolite rocks are rich in iron-magnesium silicate minerals that originated deep within the earth. Now lying on the surface of the Earth they are

Exposed ophiolite black-green and brown rocks can be seen around most of the capital area of Muscat.

unstable and convert rapidly into hydrated magnesium silicate minerals, forming serpent-like bands with vivid green/brown colours in the rock.

A better understanding of how ophiolites can be 'beached' on dry land has only come about thanks to the very recent science of plate tectonics (see panel) and advances in deep sea craft that could investigate submerged magmatic rocks and the opening of mid-ocean ridges that cause ophiolites to form. These exposed wide strips of black-green and brown rocks along the mountains can be seen around most of the capital area of Muscat.

Although ophiolites have not been found to contain any oil and gas, they have been found to contain some unusual and often valuable minerals, such as copper. In some areas, rich copper deposits has been found in ophiolites mined many centuries ago, when copper from the land of Magan (the wadi Jizzi area near Sohar) used to be exported across the ancient civilisations of Iran and Iraq.

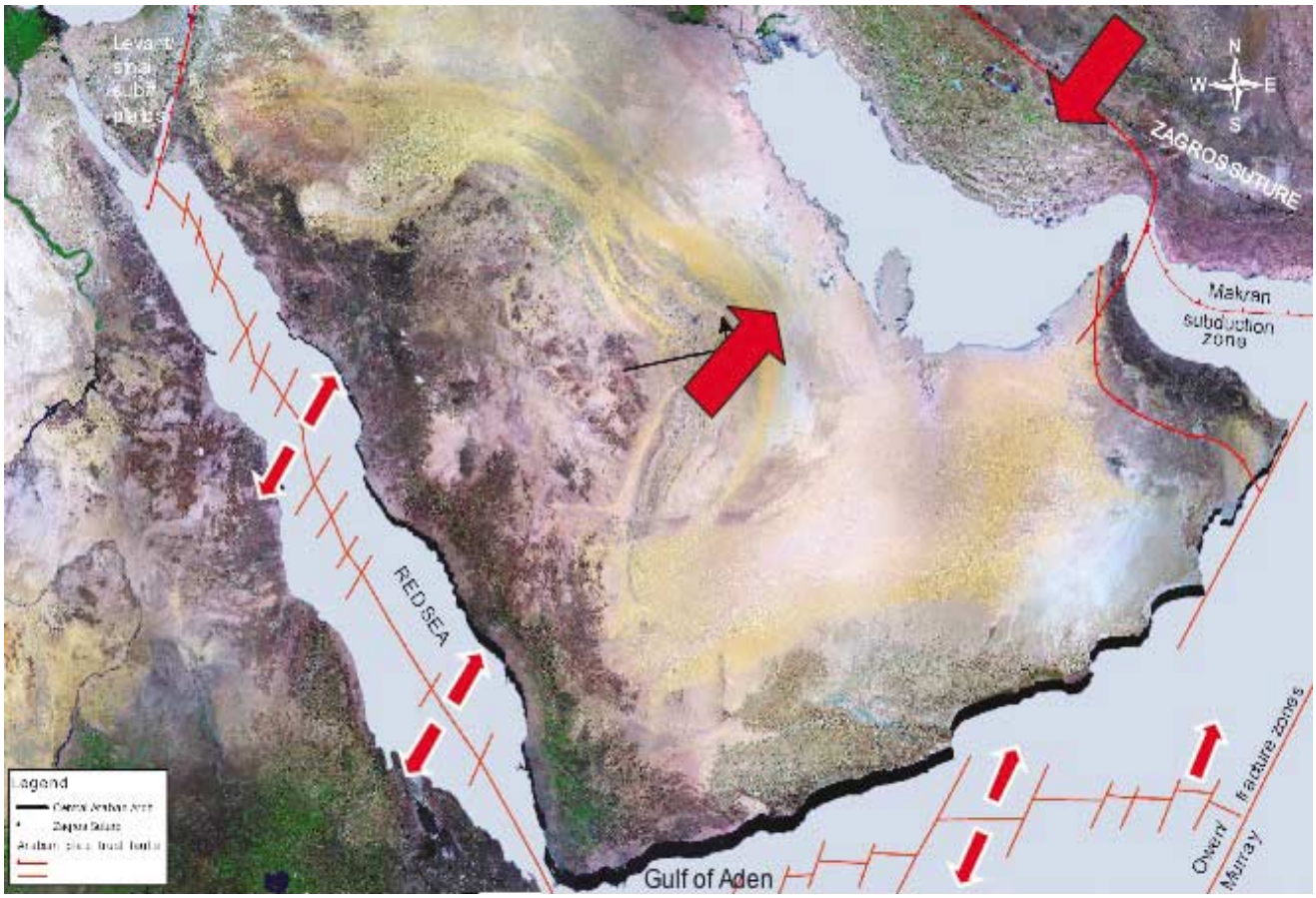
It is estimated that a tectonic plate movement 100 to 80 million years ago, closed an ocean more than 1,500 kilometres wide and a chunk of it was pushed up the edge of the Arabian plate where Oman now sits. About 70 million years later the Arabian plate started pushing into the Eurasian plate and it is believed that the force of this upheaval formed the Hajar Mountains.

The deep erosion of the uplifted and folded pile of rocks resulted in a neat cut through the ophiolites as well as deep into the underlying rocks forming the mountains and wadis as we know them today.

Despite the absence of hydrocarbons, PDO geologists still regularly visit the Oman mountains, as some of the exposed and eroded limestone rocks provide an excellent reference point to deep sub-surface formations in the oil fields of the interior.

One of the area's other remarkable features - visible on satellite images - are cones of debris, some 200 km wide, that were carried down from the mountains by rainwater. These are known as alluvial

Tectonic plate movements millions of years ago resulted in the opening of the Red Sea & Gulf of Aden, pushing Arabia against Asia and creating the Oman Mountains, the Zagros Mountain Belt and the wadis that exist today.



fans and they were created when Oman's climate was a lot wetter than it is today.

Satellite images of the fans show a whiter area. This is ophiolite material that has been altered and cemented to form dolomite rock, containing calcium magnesium carbonate minerals (known as Barzemanite after one of the villages that proudly resides in the middle of it).

Other visible signs of the ophiolites' oceanic past come from large blocks of limestone rocks (known as the Oman Exotics), surrounding reefs and islands that were also carried along with the oceanic crust during the tectonic movement. These blocks of limestones can clearly be seen as huge white blocks sitting on darker rocks at the edges of the al-Hajar Mountains, like land-locked islands. Often used as the base for watchtowers around settlements, the largest of these is Jebal Khawr, while Sohar peak was an important landmark for ancient seafarers.

The more the ophiolite areas are explored, the more rewards they offer to geologists. But some of these unique rocks are in danger of being lost forever; victims of road building and other construction that comes with Oman's economic progress.

The Geological Society of Oman has already achieved preservation listings for some sites; the hope is that more of the unique ophiolite rocks can be protected for the benefit of future scientists.

How the Semail Ophiolite was formed

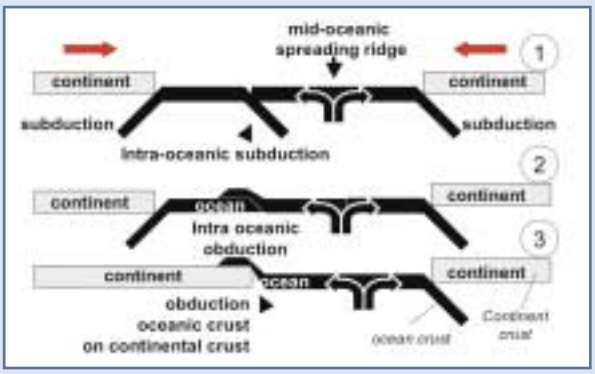
Example of the "pillow lavas"

The earth's tectonic plates are made up of both light continental crust and heavy oceanic crust.

The oceanic crust is heavier and contains solidified mantle materials rich in heavy metal ions such as iron and magnesium. It is created when two crustal plates under the sea move apart and the underlying molten mantle wells up as lava and solidifies in the gap as it cools. The different minerals crystallise in a sequence that produces a distinct layering in the final, solid oceanic crust. Where lavas break through the crust they erupt on to the sea bed, quickly cooling to congeal into characteristic sausage-like forms with smooth outer surfaces, known as 'pillow lavas'.

Normally when two plates with different crusts converge, the light crust is pushed up, forcing the heavy oceanic crust down into the hot mantle to be re-melted.

However, on rare occasions, including in Oman, the heavy oceanic crust can be pushed up and over a piece of continental crust, leaving it exposed and accessible instead of buried kilometres below the ocean bed.



How the Oman Mountains formed

The pushing-up of the Oman Mountains in relatively recent geological time wasn't caused by a single tectonic movement - the openings of the earth's crust that created the Gulf of Suez and the Red Sea both contributed, pushing the Arabian continental plate into the Asian plate, forming mountains not just in Oman but also across Turkey and Iran. This clash of the continents is also what gives Iran and Turkey continuous problems with earthquakes, and it is causing Mussandam to sink by several centimetres each year.

Erosion and Oman's desert climate has also planed away the slab of oceanic crust to reveal the ophiolite's internal parts, creating the largest and best-exposed fragment of oceanic crust anywhere in the world.

This acts as a perfect working laboratory for geologists, who have been able to discover the different mineral layers that make up ophiolite rock without the enormous trouble and expense of deep sub-sea exploration.

Copper: Oman's oldest 'industry'

Thousands of years before oil and gas brought prosperity to Oman, a very different natural resource found in ophiolite areas provided wealth and trade within the region: copper.

Copper suplhides are commonly found in ophiolite rock, and there is clear evidence of copper mining on a vast scale in the al-Hajar Mountains; for example the large black heaps of molten rock that are remnants from the smelting process. In ancient times the characteristic blues and greens of weathered copper (known as gossans) often led miners to new copper sites. The copper industry has been on such a big scale, with extensive smelting of copper ore, that we have to assume that it may have resulted in the deforestation of the Oman Mountains for wood to burn and smelt the copper.

The copper itself was transported by ships either via Sohar or by land to the Emirates coast.

Today there is very little copper mining, but companies employing much more modern technology than their ancient forbears are looking for low grade deposits of precious and semi-precious metals such as gold, platinum or chromium. These modern day mineral explorers have not enjoyed any bonanza finds so far though.

A brief history of plate tectonics

The father of modern plate tectonics was Alfred Wegener, who in 1912 proposed that the continents were once joined in a single protocontinent, which he called Pangaea (meaning 'all lands'). Wegener claimed that around 300 million years ago Pangaea broke apart and the continents began drifting into their current distribution.

However, Wegener's hypothesis lacked a geological mechanism to explain how the continents could drift across the Earth's surface as he proposed, and his scientific theories were dismissed by the experts of the day.

Around the same time another scientist, Arthur Holmes, elaborated on one of Wegener's many hypotheses; the idea that the repeated heating and cooling of the Earth's mantle as it rose to the surface and sank again, a process he called thermal convection, could provide the power for continents to move.

This idea received very little attention until the 1960s when greater understanding of the ocean floor and the discoveries of features like mid-oceanic ridges suggested that Holmes' thermal convection might indeed be at work. Thus, some 50 years after it was first espoused as a theory, plate tectonics came of age.

How to find out more about Oman's unique geology

The Geological Society of Oman (GSO) is playing an active role in helping Omanis discover their country's rich and varied terrain. It is also at the forefront of efforts to protect and preserve that geological heritage for the enjoyment of future generations.

The GSO runs regular field trips in the cooler seasons as well as hosting talks and presentations by experts in the field, including PDO geologists.

See the website www.gso.org.om for more details.

If you're also interested in the archaeological/ anthropological aspects of Oman's past, the Historical Association of Oman has an array of field trips and lectures throughout the year and welcomes new members.

See the website www.hao.org.om for further information.

Glossary

Earth's crust: The rigid layer of the earth consisting of continental and oceanic plates that move over the earth's surface. Continental plates can range from 30 to 50 kilometres in thickness. Oceanic plates are denser and thinner, being only about six or seven kilometres thick.

Igneous rock: Solidified molten rock, or magma. Igneous rocks can be categorized according to the depth of their magma source and the quickness with which the magma solidifies.

Mid-oceanic ridge: Subsea mountain range associated with separating oceanic plates.

Subduction: The process by which an oceanic plate is pushed below a lighter continental plate (or possibly below another oceanic plate) as a result of the movements of plates.

Obduction: The unusual process by which an oceanic plate is pushed on top of a continental plate, as happened, for example, in Oman.

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