

THE MEDITERRANEAN SEA

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THE MEDITERRANEAN SEA

Introduction

Looking at a map of the Mediterranean Sea depth contours attentively, one is surprised at the incredibly complex nature of the sea floor: mountain ridges that cut across abyssal plains, isolated landforms rising from the seabed, real submarine mountains, valleys and deep canyons forming a rough and complex scenery, that is quite similar to the landscapes visible on the surface.

There is a great curiosity to know what is hidden under the surface of the sea, to discover how the morphology of the coasts continues underwater and to know the processes that have led to the modelling of the submarine sceneries. Marine geology tries to answer these questions. It is a complex branch of studies because direct observation by humans is difficult in these areas and are necessarily limited to depths of up to few tens of metres only. Therefore, sophisticated equipment is used, that enables the observation of the sea floor with different “eyes”, such as sound waves, sonar equipment and seismic waves that enable the investigation of areas below the seabed, inside the earth’s crust.

With complex and costly equipment it is also possible to sample materials embedded in the sea floor and to drill even further into the layers, taking sample “cores” of the sediments. These are an extremely precious archive of geological and climatic data regarding the evolution of the seabed and the surrounding areas. Together with the study of the specimens collected on dry land, this has enabled the reconstruction of the geological history of the Mediterranean and its present form. Knowledge about the geological processes that are taking place below the sea floor, enables us to comprehend and foresee the possible geological problems, and also in a minor way, to take the necessary measures to keep them under control.

Characteristics of the Mediterranean Sea

Many basins, only one sea

The Mediterranean accounts for 0.7% of the surface of all the seas. It is a closed sea, between emersed land, with only one point of contact and exchange with the Atlantic Ocean, at the Strait of Gibraltar. It has a surface area of 2.5 million km² and extends 4,000 km from Gibraltar to the Bosphorus. Its coasts are never more than 400 km apart. For this reason, since ancient times, the Mediterranean has been one of the most populated and navigated seas, and on its shores, some of the most important civilizations have flourished.

The Mediterranean, seen from the surface, looks like a single sea divided into a number of basins with different characteristics, a different geological history, and also different morphologies of the sea floor. The main division is that of the Western Mediterranean and Eastern Mediterranean: 2 basins separated by an underwater ridge that crosses the sea from Sicily to the coasts of Tunisia. The morphological differences between the two basins also provoke differences in the temperature and in the chemical characteristics of the water. The western basin has a temperature of 12 °C in



winter and 23 °C in summer, its salinity is 36‰, while the eastern basin is warmer and more salty, its temperature is 16 °C in winter and 26-29 °C in summer, its salinity is 39‰. The geological and morphological differences of the two basins also have consequences on the distribution of the living forms.

The two main basins are in turn divided into smaller sub-basins, whose characteristics depend greatly on the geological history that led to their formation. Before examining them in detail, it is therefore important to study the geological history of the Mediterranean.

A long story

The geological history of the Mediterranean area is very old; it began over 180 million years ago, when the fragmentation of Pangaea created an internal sea that progressively widened between what later became the European and the African continents. The real Mediterranean Sea began to take shape much later, 50-60 million years ago, when the collision of the African plate and the European plate separated it from the Atlantic Ocean, which in turn was separating Africa and Europe from North America. During this period the large mountain ranges that surround, and “close” the Mediterranean were formed: from the Atlas Mountain range in Morocco, the Betic Cordillera in Spain, the Alps, the Taurus mountains in Turkey. And at the same time also the straits were formed, more or less in the position of the Strait of Gibraltar today, which isolated and limited communication with the ocean.

But the event that started giving the Mediterranean Sea the appearance it has today, began in the Oligocene Epoch, about 30 million years ago. During this period, an area between the Balearic Islands and Provence, belonging to the Alpine Mountain range, began to fracture and sink.

Let us try to understand what happened

A fragment of the European continent became detached from the rest of Europe and began to move away towards the East, and rotating anti-clock wise, a new sea was opened. This fragment, that geologists call the Sardinian-Corsican block, was made up of Corsica and Sardinia and a small part of the Calabria region. The movement of this fragment of Europe led to the formation of the western Mediterranean basins: the Alborà Sea, the Algeria-Provence basin, and a part of the Tyrrhenian Sea. Therefore these are relatively young basins, approximately 30 million years old. This movement stopped about 16-18 million years ago, in the Early Miocene Epoch. The movement of Corsica and Sardinia towards the East had a very relevant consequence for the geological history of the Mediterranean area: the beginning of the formation of the Apennines. The range of Apennine mountains began to form as a result of the folding of the earth's crust due to the subduction of the plate called Adria below the Sardinian-Corsican block. During this phase, however, the Apennines still did not have the characteristics of a real mountain range and emerged only slightly from the sea.

Approximately 8 million years ago, during the Late Miocene Epoch, the event that determined the present configuration of the Apennine mountains and the western Mediterranean Sea took place: the opening of the Tyrrhenian Sea. This geological event was caused by a shifting towards the East,

of the Adria plate, that opened large systems of fractures and faults. Gradually a series of deep basins formed, which then evolved into the Tyrrhenian Sea as we know it today. On the opposite side of the Adria plate, this event provoked a compression that made the newly born Apennine range rise further and pushed the European plate in a wedge under Adria. At the same time as this phase in which the Tyrrhenian Sea was opened (a phase that the geologists call rifting) along the eastern margins of the Apennine Mountain range that was forming, a great magmatic and volcanic activity began in a vast area extending from Tuscany to Latium and later to the Campania region. In the South, instead, the opening of the Tyrrhenian Sea provoked the beginning of the subduction of the African plate under the so-called Calabrian Arc: the volcanic phenomena in the Aeolian islands, and the frequent and very intense seismic activity in this region, which is one of the most geologically active areas in the Mediterranean, are due to this process.

Some more history

Beginning 10-12 million years ago, the series of straits that permitted communication with the Atlantic began to close, under the thrust of Africa against Europe. Since at the time, the climate was quite arid, evaporation was greater than the amount of water fed by the rivers, and the Mediterranean survived only because of the exchange with the Atlantic. The progressive decrease in this exchange led to a gradual lowering in the sea level. About 6 million years ago (during the Messinian period), communication with the ocean closed definitively and the lowering in the level of the Mediterranean ended in the so called "salinity crisis". The Mediterranean almost evaporated completely, transforming into an arid landscape of deep desert canyons and small hyper-salty basins where 6% of the salt in all the oceans collected. Layers of evaporates deposited, often over 2,000 m thick, a proof of the different phases of the drying process. The existing rivers flowed 1,000 m above sea level and therefore dug deep canyons that ended with gigantic cones built from the large quantities of sediments transported from the continents. The river Nile, as all the principal affluents of the Mediterranean (as for example the Rhone), dug deep canyons (buried under thousands of metres of more recent sediments) that continued, submerged for many kilometres toward the open sea, a geological and morphological proof of the Messinian salinity crisis. About 5.5 million years ago, all of a sudden, the threshold of Gibraltar crumbled, thus enabling a real waterfall of water to flow back into the Mediterranean basin. Notwithstanding the rapid and sudden phenomenon, it took thousands of years to reach the present level of water, whose return to the Mediterranean basin provoked a lowering of 20 m in the average level of the oceans.

The drying of the Mediterranean and, in particular the modelling of the rivers and their deposits, greatly contributed to the construction of the Mediterranean landscape. Of this ancient scenery and the processes that modelled it, it is still possible to find traces buried under thousands of metres of sediments – the use of particular geophysical testing techniques, that use seismic waves, enables the reconstruction of the geology that lies buried in the subsoil below the seafloors.

Small seas

The continental shelf

The various minor basins into which the Mediterranean Sea can be subdivided are the result of different geological processes, that affect the morphology of the sea bottom.

The continental shelf is a submerged “rim” that outlines the continents separating them from the dominion of the sea, strictly speaking, with a slope at a depth of 150-200 m. We can imagine this area as an extension of the continents under the sea level.

The continental shelf is not a typical characteristic in the Mediterranean area. In fact, it extends only in the northern part of the Adriatic Sea, near the coasts of Tunisia, between Sicily and Malta, around Corsica and Sardinia, and in the Aegean Sea.

Thus there is no “connection” between the continents and the sea bottom, with a passage from one to the other that is often rapid and sudden and characterized by a brusque drop in the bathymetry.

The Alboran Sea

It extends from the Strait of Gibraltar to the Balearic Basin. Its maximum depth is 1,500 m, that drops to 1,800 m in the Alboran rift, that separates it from the Algerian basin. In the centre there is a small volcanic island, 10 m above s.l., that rises from the sea bottom that is 1,500 m below. This part of the Mediterranean receives the direct influence of the Atlantic, because it is where the sea water mixes with the ocean water. The water here is generally colder and less salty and rich with organisms coming from the Atlantic.

The Algerian- Provence basin

This is the vastest basin of the western Mediterranean area. Leaving the Alboran Sea to the west, it extends with a triangular shape from the Gulf of Valencia to the Ligurian Sea. Its maximum depth is 2,800 m, near the western coasts of Sardinia. It is characterized in its most western part, by the large deep-sea cone of the Ebro River, where the continental shelf reaches a width of 60 km. Along the northern coasts, up to Genoa, the continental shelf is practically absent, it is no wider than 3-9 km. Here the sea bottom descends rapidly to depths over 2,000 m and is characterized by a number of submarine canyons that cut across it. These canyons carry large quantities of material from the erosion of the emerged land toward the abyssal depths. Transportation of this material generally takes place in the form of underwater landslides. And in this part of the sea, in particular, off the coast of Nice, in 1979 the telephone cables were damaged during a landslide movement. On this occasion the speed of the landslide movement was calculated to have been from 17 to 40 km/h, caused by sliding sediments transported by the river Var, that also provoked an anomalous wave, several metres high.

Towards the South, the continental shelf extends to the islands of Majorca and Minorca, while between these islands and Ibiza the sea bottom is cut by a furrow that is 800 m deep. Between these islands and Corsica and Sardinia, there is the large Balearic abyssal plain, which is 2,600-2,800 m

deep, and has a relatively monotonous morphology. Towards the North, the abyssal plain is covered by the large cone of the river Rhone, whose sediments spread for various kilometres towards the deeper parts, through a large submarine canyon.

The Tyrrhenian Sea

The Tyrrhenian Sea is an almost triangular shaped depression, between Sardinia and peninsular Italy, and is the youngest of the deep Mediterranean basins. It has a depth of 3,800 m and is the deepest of the western basins. From a geological point of view, it is a little ocean (the youngest in the planet) as on its bottom there are two small abyssal plains formed by the ocean crust. Morphologically, it is a deep basin surrounded by sharp and deep slopes, cut by deep submerged valleys. It communicates with the other basins through 4 passages : a 300-400 m deep channel puts it in communication with the Ligurian Sea; a wide, 2,000 m deep channel between Sicily and Sardinia connects it to the Algerian basin; the Boniface Strait (that is max. 50 m deep) connects it to the Provence basin; and finally, the Strait of Messina is the connection (100 m deep) with the Ionian Sea.

Large volcanic structures, which, for the time being are quiescent, rise from the sea bottom here. . Fig.10-11 To the North of the Aeolian islands is the Marsili Seamount, the largest volcanic structure in the Mediterranean, that formed during the course of the last 700,000 years. Its diameter is over 50 km and it is 3,265 m high. Its peak rises 540 m above sea level. Around this giant, there are other "satellite" volcanoes of a remarkable size, such as Alcione and Lametini, that are as big as the island of Vulcano. Between Sardinia and Latium there are other large sized submerged volcanoes such as Magnaghi and Vavilov.

The Adriatic Sea

The Adriatic basin has geological and morphological characteristics that are quite particular. Over one third of the area of the sea bottom is no more than 50-60 m deep, unlike the Ionian basins where there are the greatest depths of the Mediterranean. The Adriatic basin lies between the Apennine Mountain range and the area of the Balkans. It is a zone of great compression with the margin of the European plate dipping below the Adria plate. It is not a very deep sea, it filled rapidly with the sediments from the erosion of the two mountain ranges facing each other, and in a near geological future it is destined to disappear. It is subdivided into three different basins. The northern part, or Upper Adriatic Sea, is entirely covered with the alluvial deposits of the large rivers of the Northeast, specially of the Po River, and is characterized by a sea-bottom that degrades gently to a maximum depth of 75 m. The central part is a closed and more variable depression, the so-called Middle Adriatic trench, which is 266 m deep. The southernmost part is known as the Lower Adriatic and is characterized by a plain, that is 1,000 m deep on average. The basin reaches a maximum depth of 1,230 m near the coast of the Puglia region. Toward the south, the sea bottom rises to a depth of 800 m near the Strait of Otranto, which separates the Adriatic Sea from the Ionian Sea.

The Ionian

The Ionian Sea occupies the central part of the southern Mediterranean. Here the maximum depth of the Mediterranean is reached (5,093 m in the Hellenic trench). It is characterised by deep trenches (Hellenic trench, Herodotus trench near the Libyan coast, Malta trench and Pantelleria trench), vast deep abyssal plains to the East, and less deep plains towards the West, as in the area near Sicily and the Sirte plain, near the Libyan coast. The Ionian Sea is characterized by the subduction of the African plate under the Calabrian Arc, making it one of the most geologically active areas in our country. Even though, geologically speaking the Calabrian Arc, belongs geographically to the Apennine range of mountains, it is a small portion of the Alpine range of mountains, like Corsica and Sardinia. The superficial expression of the subduction is the volcanic arc of the Aeolian islands. Towards the West the Ionian Sea is bordered by the deep Malta Slope, this 3,000 m drop separates the Ionian Sea from the Western Mediterranean. Between the two basins is the so-called Pelagian Block, an offshoot of the African coast that extends between Tunisia and Sicily, forming a submerged ridge, of which Malta and the Pelagian Islands (Lampedusa and Lampione) are the highest tops, so high that they emerge from the sea.

The Aegean Sea

Analogously to the Ionian Sea, the Aegean Sea finds its origin and morphological characteristics in the subduction of the African plate, in this case underneath Greece. This too is an area of intense volcanic and seismic phenomena (the caldera in the Island of Santorini is famous). It is characterized by the presence of over 200 islands and is subdivided into various minor basins, such as the Crete sub-basin, surrounded by a trench that is 2,500 m deep.

The Levantine Basin

It is the easternmost part of the Mediterranean. It is characterised by an average depth of 2,000 m, with a maximum depth of 4,834 m in the Plinius trench and 3,720 m in the Stenone trench in the North. To the South it is characterized by the gigantic cone of the Nile, that brings the continental sediments that cover the abyssal plain of the Levantine Basin.

Submerged volcanoes

Where can we find them

The main volcanic provinces in Italy are in the Campania region around Vesuvio-Campi Flegrei and the island of Ischia in the Aeolian archipelago, in the area of Mount Etna and in the Sicilian Channel. The three "giants", Marsili, Vavilov and Magnaghi, are only three of the numerous volcanoes that are present on the sea-bottom in the Tyrrhenian Sea. The volcanic islands of the Mediterranean are only the visible part, on the surface, of volcanoes that are much larger and volcanic elements are also present on the sea bottom surrounding them.

The geological origin of the different active magmatic provinces is not the same, and there are different chemical characteristics of the materials that form them, just like there are different characteristics in the volcanic events. The volcanic activity in the Vesuvian area is tied to the subduction of the Adriatic lithosphere under the Apennine, while that of the Aeolian islands is connected to the subduction of the African plate, under the Calabrian arc. In this case, the magma produced is viscous and rich in silica, and this gives origin to the explosive, spectacular type of vulcanism (as in the case of Stromboli), which however is also dangerous (as in the case of an awakening of Vesuvius). The magmatic activity of Etna, of the volcanoes present in the Sicilian Channel (Linosa and Pantelleria) and the volcanoes in the Tyrrhenean Sea, instead, is due to the fracturing in the earth's crust, with an uprising of magma that originates from deep below. This magma has a higher basalt content and is characterized by great fluidity: volcanic events are therefore more "peaceful" with lava effusions that are characterised by very fluid flows and minor explosive activity.

The Aeolian Islands

In the Aeolian group of islands, at present the volcanoes that are considered to be active are Stromboli, Vulcano and Lipari. The most ancient island is Filicudi (which was formed 1 million years ago) while the others date back to 10,000 to 400,000 years ago. Alicudi and Filicudi stopped being active tens of thousands of years ago while Salina and Panarea were active up to less than 13,000 years ago. The island of Stromboli consists in a volcano cone that reaches 924 m above sea level. Actually, it is only the peak of a volcano that is much larger, and whose base is on the sea floor 1,500-2,000 m below. The Strombolicchio rock is a part of what remains of the central conduit of the much larger and much more ancient volcano structure. Stromboli is well known, since ancient times, as the "lighthouse of the Mediterranean" due to its practically continuous activity. It has a characteristic explosive activity and gives its name to a category of volcano activities that are of the "Strombolian" type, characterized by a continuous spitting of volcanic rocks and scoriae up to almost a hundred metres high. The geological danger of a volcanic island such as Stromboli is tied not only to its explosive activity but mainly to the landslides and collapses that may take place on its steep sides; the landfall of large volumes of material into the sea can provoke small seaquakes and the formation of tsunami waves. Also the island of Vulcano is only the tip of a large volcano whose base is at a depth of about 1,000 m. It formed 120-100,000 years ago and was subjected to a collapse that formed a large caldera, which was subsequently filled by lava flows. The last eruption dates back to 1888-1890 and at present the activity is limited to the emission of fumaroles. Lipari is characterized by very explosive eruptive cycles that produce large quantities of pumice, with intervals of long periods of quiescence. The sea around these islands is characterized by high-temperature gaseous emissions.

Etna

Etna's activity began 600,000 years ago, and it is the largest active volcano in Europe. It formed from the sea bottom of a large gulf. The proof of these initial underwater phases is the finding of

particular lava formations, the so-called lava pillows. The progressive accumulation of outflowing material, together with the general rise in the area has led to the surfacing of this volcano. In the future, perhaps, also the large formations of Marsili, Magnaghi, Vavilov and other volcanic structures may surface from the waters of the Tyrrhenean Sea, thus forming a series of islands, analogous to Etna.

Volcanoes in the Sicilian Channel

In the Sicilian Channel, we find some islands of volcanic origin that still show signs of volcanic activity. Pantelleria has a large caldera, the Montagna Grande that rises to 836 m. Its most ancient rocks are 325,000 years old and since at least 3,000 years volcanic activity is quiescent. Linosa is formed from basaltic flows that erupted 1 to 0.5 million years ago, however no volcanic activity has been recorded here since at least 10,000 years. A quite singular geological feature of the Sicilian Channel is the Ferdinanda island, whose geological history is as interesting as the diplomatic case that its birth triggered in 1831. At present it is not visible, it is now a rock 40 kilometres from the coast of Sicily, at a depth of 5 metres. In July 1831 the naturalist Salvatore Rosa described the birth of the island. The activity of an underground volcano was forming the island, that gradually emerged from the water. On the 17th of July the cone was 9 m high, after 5 days the island had grown to 25 m. In the month of August, the diameter of the island reached 5 km and its height was 70 m. The Sicilians named it Isola Ferdinanda after the Bourbon King Ferdinand II, and claimed its ownership, but the island was first seen by an English Admiral, who called it Graham Island and declared it belonged to the British Empire. The French, however, were faster and baptized the island Julie, as it was born in the month of July. The small island therefore was contested by three countries! On the first days of December, the same year, however, the diplomatic case was solved by nature, because the island sank into the sea again, and disappeared.

Submarine eruptions

The word “eruption” immediately brings to mind images of fountains of incandescent lava and columns of ashes and vapour shooting towards the sky. But how does an underwater eruption take place? The pressure of the water limits the explosive force of the activity, while the rapid cooling due to the contact with the cold water determines the morphological characteristics of the flow. The incandescent lava that is produced, feels the influence, in fact, of a very rapid cooling on the surface. In this way a kind of large “drop” of lava is formed, whose surface hardens immediately forming a vitreous “crust”. This is what the geologists call a pillow of lava. The continuous production of lava provokes a break in the crust of the first pillow that opens letting new lava flow out, which in turn forms a second pillow. Thus, pillows of lava accumulate, slowly forming the volcano’s structure. At times, specially if the magma contains large amounts of gas, and is very viscous, bubbles of gas form and these transport pieces of lava material to the surface. This cools rapidly on contact with the water and gets fragmented into a myriad of chips of volcanic glass when pushed by the bubble of gas that expands as it rises. These fragments fall back onto the sea-bottom and accumulate forming rocks called hyaloclasts (from hyalo that means glass and clast that means

fragment). The progressive accumulation of the fragments contributes to the growth of submarine volcano structures.

Dangerous sea floors?

Great apprehension accompanied the communication of the discovery of large potentially active volcanoes on the Mediterranean Sea bottom. Actually, a submarine eruption, unless it occurs in shallow waters, rarely has any effects on the surface, and usually occurs in a “peaceful”, silent manner. The direct danger for man is relatively low, unless he is passing exactly above the point of the eruption, if this takes place in shallow waters. Direct damages may be made to the submerged anthropic structures such as cables or pipelines, but the possibility that these could have been positioned near a submerged erupting volcano are quite unlikely. Severe damages are incurred by the marine fauna near the eruption, due to the increase in the temperature and due to possible gas emissions that are toxic for the living marine creatures. In this case besides the environmental damage there may also be severe repercussions in the fishing industry. The possible damages provoked by a submarine eruption in the Mediterranean seem to be quite limited. However, other geological phenomena may be tied to the volcanic eruptions, such as earthquakes and underwater landslides. Both these phenomena provoke sudden movements of large volumes of water and can therefore trigger the propagation of anomalous waves. In a basin that is as small as the Mediterranean, it is quite difficult for the anomalous waves to reach the horrifying heights recorded in larger oceans. However, their nearness to the coasts makes them very dangerous. The time the wave takes to reach the coast will be very short, thus leaving a very short margin of time to warn the populations living on the shores. Furthermore, there may also be reflection phenomena, in which the waves may bounce a number of times from one coast to another, causing damages and destruction every time they pass.

A detailed analysis of the morphology of the bottom of our sea and the materials that compose it enable, in any case, the identification of the elements that may be a potential danger (such as active volcanoes or potentially active ones, areas with a particularly high level of seismic risk, areas that could possibly be subjected to underwater landslides, following other geological events) and to keep the areas of greatest risk under control. Marine geology is therefore a precious instrument in order to control geological risk, and in order to reconstruct the history and the geological evolution of the Mediterranean and of country.

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