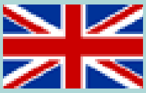
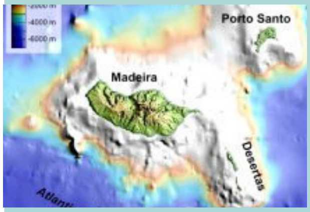
SPECIAL - ENGLISH
EDITION 2025



V10042025

EDITORAL TEAM:
AEMILIA DE KONINGH
GEOPRESSERVICE@GMAIL.COM
ANNEMIEKE VAN ROEKEL
AVROEKEL@XS4ALL.NL

IN THIS EDITION



GeoNewsletter.eu

JAARGANG 3, NR 2 SPRING 2025

Geo-sailing in Atlantic waters

Text & photography: Annemieke van Roekel. Contact: avroekel@xs4all.nl

In March 2025 I had the opportunity to sail as a passenger on the Santa Maria Manuela, a Portuguese tall ship, built in 1937 as a mother ship for cod fishing in Newfoundland and Greenland and part of the historic White Fleet.

Following a complete refit in 2007-2010, the four-masted gaff schooner (hull length ~53 metres) now sails as a training ship in the North Atlantic and Mediterranean, carrying maritime students and passengers. She was present in the Netherlands during Sail Amsterdam in 2010 and 2015. During the 5-day crossing from Lisbon to Madeira, via Porto Santo, I was on the lookout for geographical and geological highlights, including the submarine volcanic landscape.

More than 500 nautical miles from Lisbon to Madeira. Google maps.

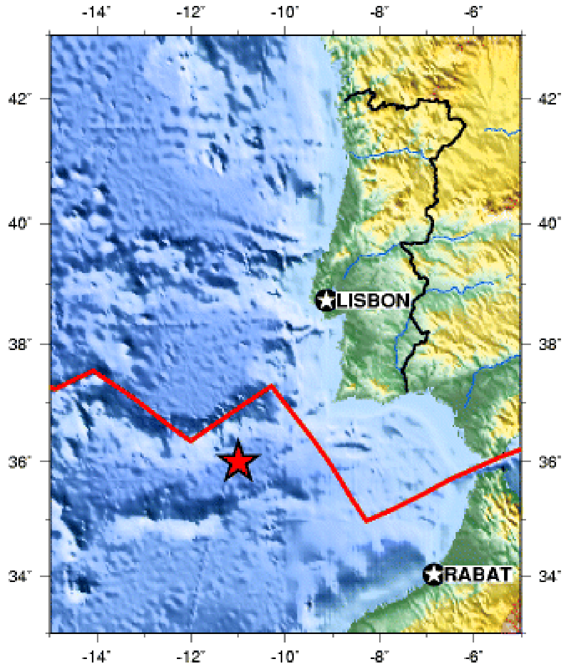
Sailing southwest, from Lisbon to Porto Santo.

Photo A. van Roekel

1755 earthquake simulated

As we had to embark in Lisbon harbour, I visited the QUAKE museum in the Belém area the day before embarkation. A must-see!

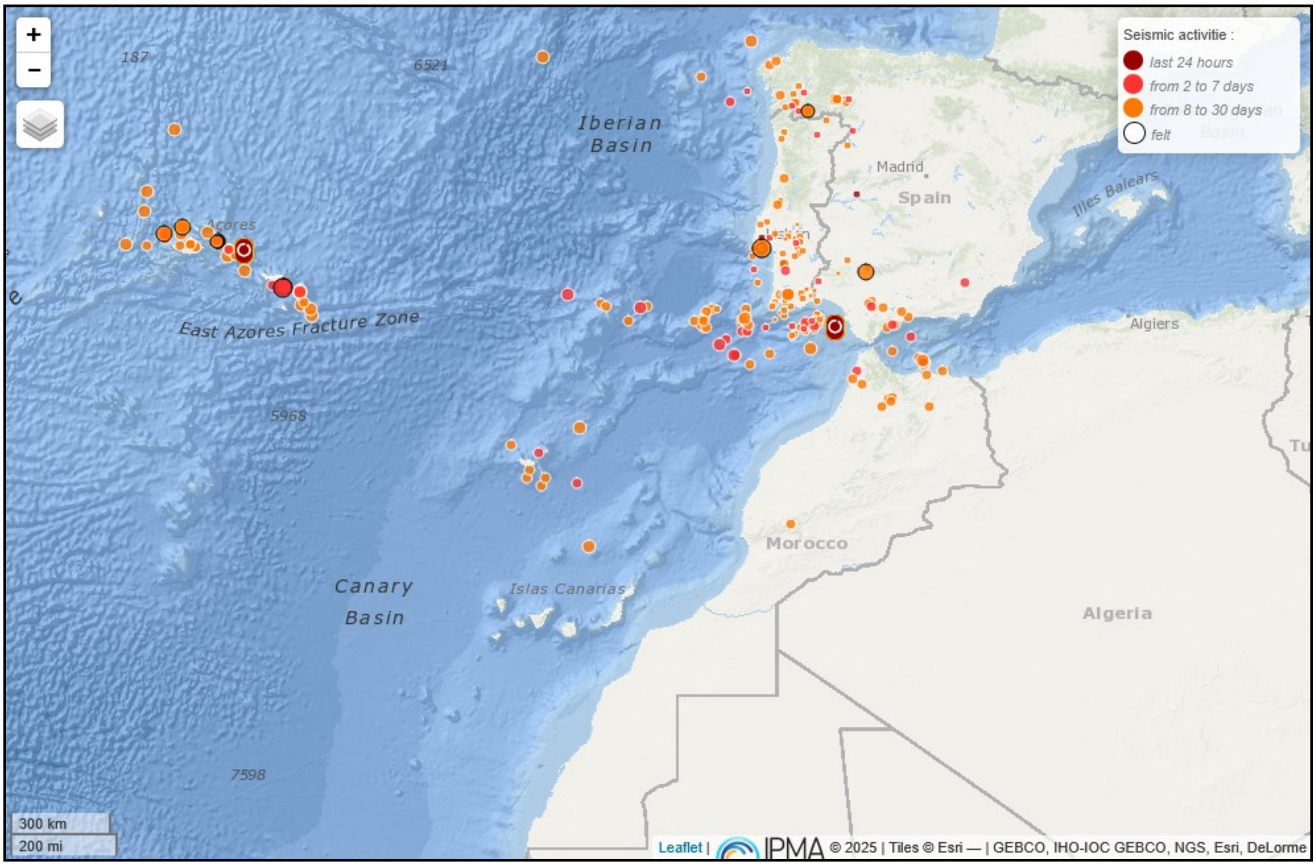
The museum is set up to make the visitors experience the historic earthquake of 1755. It provides a lot of information about the seismic aspects of this earthquake, seismicity in general and strong earthquakes around the world in historic times.
Visitors are guided in small groups through different rooms where many geophysical aspects of earthquakes and seismicity are explained. When you activate your wristband, the information (too much to absorb during the visit) is sent to your email address, so you can read it at home.
The 1755 earthquake, with a magnitude of 8.5-9.0, and subsequent tsunami caused widespread destruction in Lisbon and along the coast of Portugal, Morocco and as far away as Algeria. The epicentre is located ~200 km WSW of Cape St Vincent, as is pointed out on the map below and more in detail on page 4 (top image). The exact location hasn't been assessed yet.



Right: Epicentre of 1755-quake that effected a vast coastal area. Source: USGS.

There must have been a huge displacement of rock in the seafloor in 1755, in the area of the eastern Azores-Gibraltar Fracture Zone (AGFZ). The AGFZ is the boundary between the African (Nubian) and Eurasian plates, showing various types of movement. The triple junction near the Azores shows a complex movement pattern; south of Portugal the two plates collide together (see image on the next page).
The realtime seismic activity of the plate margins around Portugal is shown on the next page.

Right: QUAKE Museum in Belém, Lisbon. Photo A. van Roekel



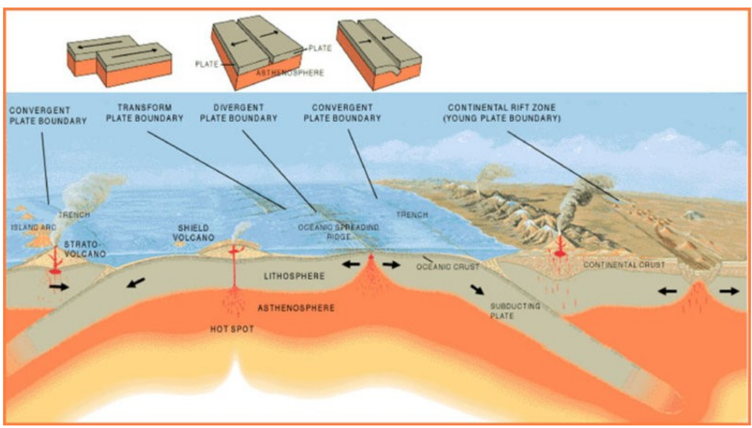
The seismic activity between the African and Eurasian plates is well illustrated in the image above. This is a real-time image (14 March 2025) of seismic activity published online by IPMA, Instituto Português do Mar e da Atmosfera. The active area on the left marks the junction of three tectonic plates in the Azores archipelago. The active area on the right marks the AGFZ, where the 1755 earthquake occurred.

The simulator in the QUAKE museum recreates the time and place of the 1755 earthquake. Visitors are seated in wooden chairs (without a seatbelt) and a projection of the interior of a church is projected onto the walls of the room. We were part of the early morning service on All Saints' Day, 1 November 1755, where a priest and altar boys were conducting a service. After an initial shock, the priest decided to continue the service, but soon there were more shocks. A chandelier fell and the walls of the church collapsed. After this emotional experience, in the next room you could see that Lisbon was on fire, the result of falling candles, and the impending tsunami was in sight.

According to geoscientists, Lisbon is facing another earthquake, which could happen anytime because of active fault zones under the seabed. It is calculated that such a quake occurs every few centuries, but accurate predictions are impossible.

Lisbon's medieval, destroyed city was rebuilt soon after the disaster and a medieval city gave way to a straight street pattern. Needless to say, these old foundations are not earthquake-proof, and so are the houses built decades ago. Because of the monumental value of Lisbon's buildings, most of them have not been made resistant to new earth quakes.

Roughly three types of tectonic plate boundaries are distinguished: transform, divergent and convergent. Source: NOAA. Click to enlarge.

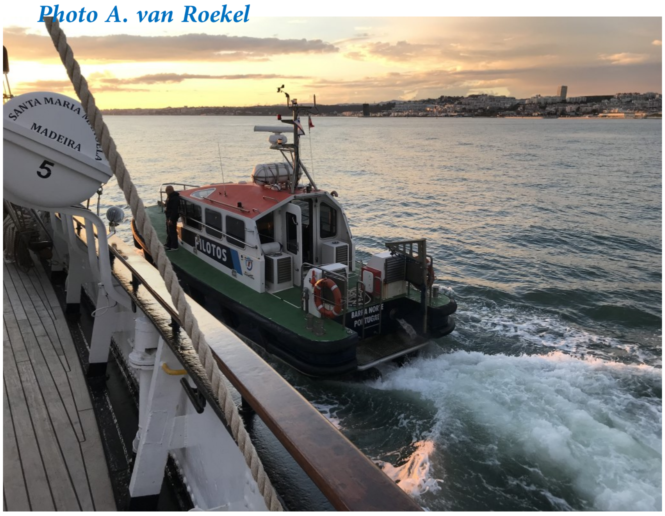


Sailing southwest to Madeira

Photo A. van Roekel

A few hours before sunset on 3 March 2025, we leave Lisbon with a great view of the old city centre to the north. We pass under the famous Ponte 25 de Abril, a suspension bridge over the Tagus River, 1 km long, linking Lisbon to the south bank. The deck of the bridge is 70 metres above the water and the masts of the Santa Maria Manuela are 31 m high... Some more relevant dimensions here: the 28 m high statue of the Santuário de Cristo Rei on a pedestal of 82 m. We move towards the north bank in the river mouth to avoid the shallow waters near the south bank. The pilot boat accompanies us and soon we are on the Atlantic Ocean, no doubt about it, because we can feel the swell, 24/7. A challenge to sleep well, as it turned out!

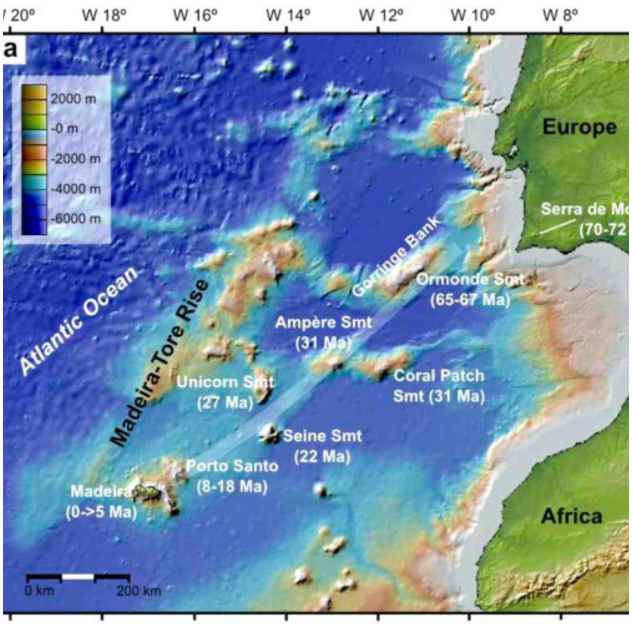
Pilot boat leading us from the Tague mouth to the Atlantic. Photo A. van Roekel



Passing the famous Ponte 25 de Abril. Photo A. van Roekel

A chain of seamounts

On our journey from Lisbon to Madeira, we are actually 'following' a chain of seamounts to the SW. The hotspot, which has been the driving force behind the formation of the Madeira archipelago (now projected SW of Madeira), became active more than 70 million years ago and is responsible for the almost 1000 km long chain of seamounts in a NE/SW direction, up to the Serra de Monchique on the Portuguese mainland. As the tectonic plate above the hotspot moves in a NE direction, the seamounts closest to the mainland are the oldest.

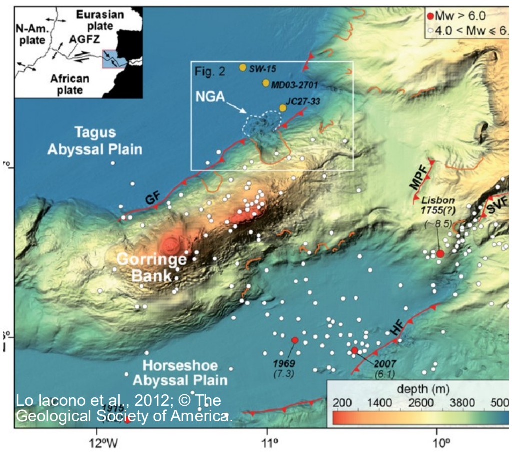


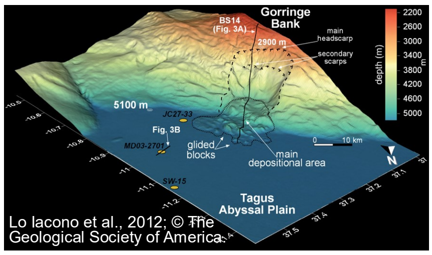
Seamounts NE of Madeira. Source: Ramalho et al., 2015.

On the chartplotter screen on the bridge of the Santa Maria Manuela, we can locate seamount Ormonde to the south. Ormonde was an active volcano 67-65 million years ago, when the Atlantic Ocean opened up. It is one of the two peaks of Gorringe Bank. The second peak is mount Gettysburg.

Taking a closer look at the seamounts on the map (image above, Ramalho 2015), we can see the patchwork of seamounts and their geological ages. To name a few: Coral Patch (31 my), Ampère (31 my) and Seine (22 my). Next in line are Porto Santo and Madeira, which evolved from seamounts to ocean islands.

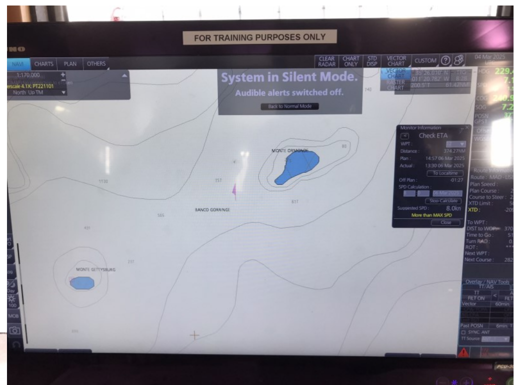
Seamounts are interesting in many ways. They are used by geoscientists to study the transition from seamounts to oceanic islands and are included in geohazard models, as deep-sea landslides are a potential risk for triggering tsunamis. This is the case for the North Gorringe avalanche (NGA), a large mass failure on the northern flank of the Gorringe Bank, 3-5 km deep. Here a landslide of about 80 km^3 occurred in prehistoric times, generating a large tsunami (Lo Iacono, 2012).

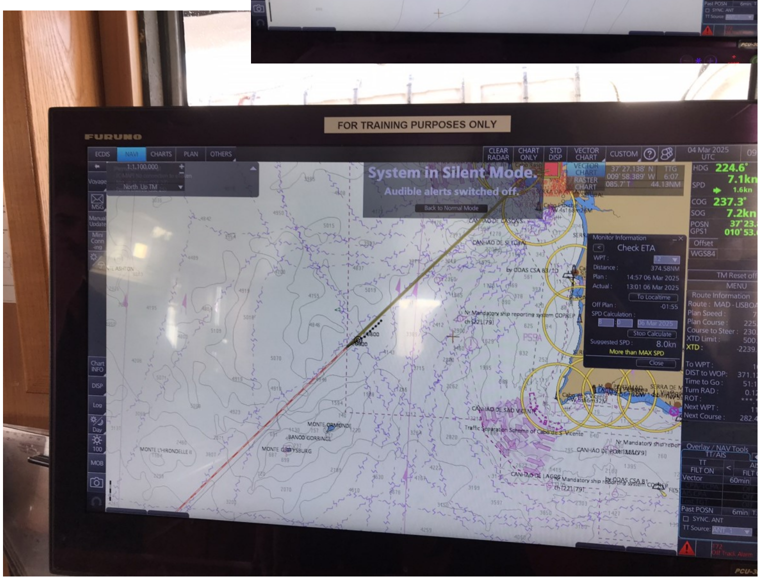


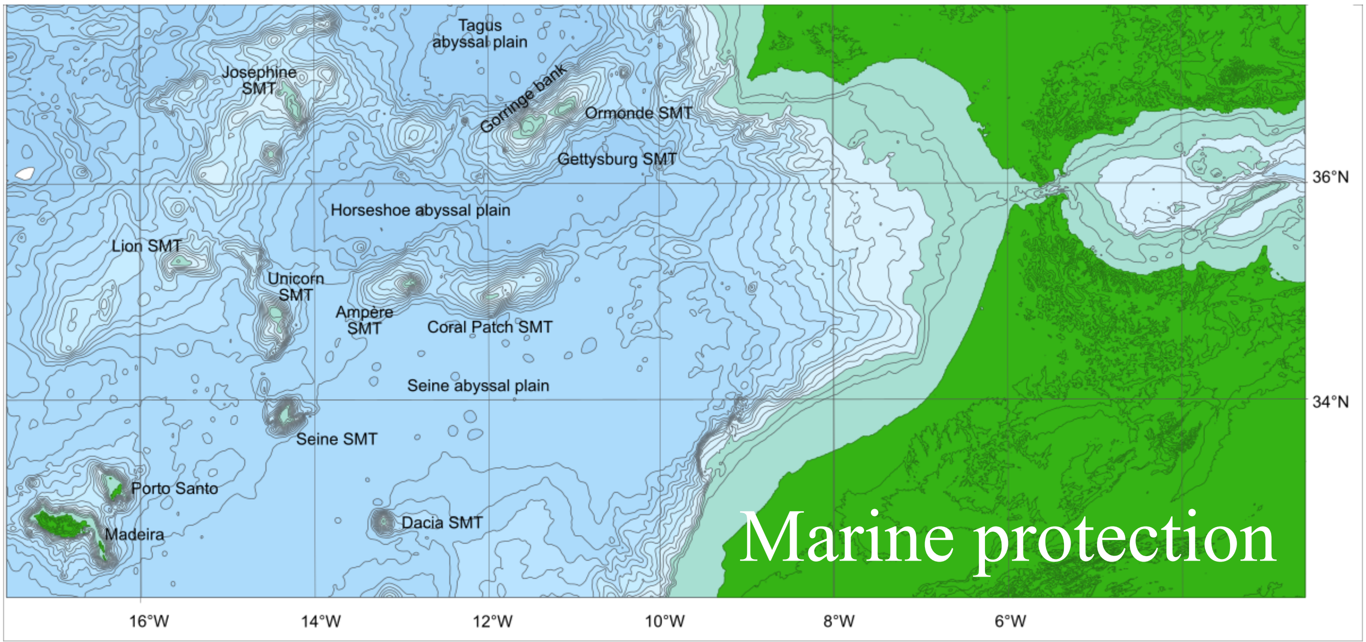


Left: Images showing the Gorringe Bank avalance (NGA). Above: the location of the NGA; note the epicentre of the 1755 quake. Middle: detail of sea floor morphology. Lo Iacono et al., 2012; © The Geological Society of America. With kind permission.

On the chartplotter screen (below) you can see that we are steering clear of the shallow peaks of Gorringe Bank (only ~27m below sea-level; SMM's draft: 6m). Course of the ship = red dotted line. Right: detail of chartplotter screen with the two peaks of Gorringe Bank.







Marine protection

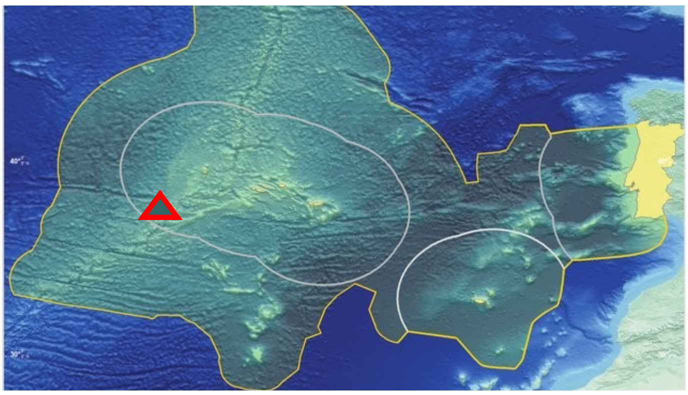
Another important aspect of seamounts is their biodiversity, as they are shallow areas in the deep sea attracting a variety of wildlife. Sailing close to Gorringe Bank, captain João Ciríaco tells us that the SMM was involved in the Oceano Azul Expedition, a research expedition in September 2024. The aim of this project is to study the biodiversity on and around Gorringe Bank and its peaks, rising 5 km from the seafloor: mount Ormonde (27 m below sea level) and mount Gettysburg (20-23 below sea level). "Due to upwelling of nutrients as a result of currents around the seamounts, the area is rich in fish, attracting large scale fishing activities," according to Ciríaco.

Gorringe Bank is located within the Exclusive Economic Zone (EEZ, within 200 nautical miles from the coastline), near the Azores–Gibraltar Fault Zone. Portugal has the third largest EEZ in the EU because of the presence of many islands: Madeira, the Azores and Ilhas Selvagens (between Madeira and the Canary Islands).

Gorringe Bank is a Natura 2000 site (an ecological network of protected areas) and might get the status of a Marine Protected Area (MPA) in the future, enabling to enforce stricter environmental rules.

To gain sovereign rights over a larger ocean area, Portugal has submitted a request for the "Extension of the Continental Shelf". This only applies to the seafloor and subsoil. In the SEAMAP 2030 programme advanced techniques of multibeam echosounders are used to map the seafloor in high resolution. A first result of the request was the recognition, in 2006, of the Rainbow hydrothermal vent field as the first Marine Protected Area beyond 200 nautical miles, and more MPA's were soon to follow.

Portugal's EEZ and potential extension of the continental shelf (in legal terms). Red triangle: Rainbow hydrothermal vent field.



The Dutch organisation NIOZ explored the Rainbow hydrothermal vent field in 2019. Near the Mid-Atlantic Ridge, black smokers are a common phenomenon. Photo: NIOZ. With kind permission.

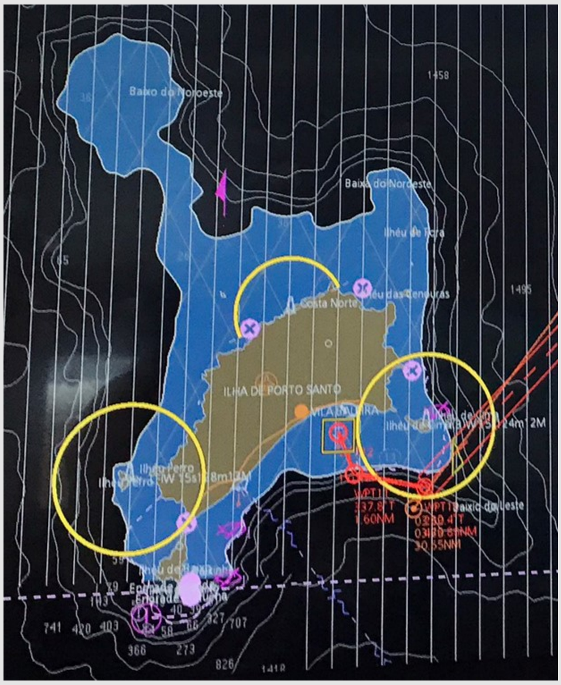
Porto Santo: volcano eroded down to the bone

Top photo: approaching Porto Santo from the northeast on the Santa Maria Manuela, in the early morning of 6 March 2025.

After a few days on the open sea, early in the morning of 6 March, we see an island on the horizon. Porto Santo! I approached it twice from the south with the ferry from Madeira, when travelling in 2020. So this is a completely new angle and silhouette!

Porto Santo was discovered in the year 1419, Madeira one year later. The main island is vaguely visible on the horizon. The subaerial part of the island is dated at 14 million years, geologically much older than Madeira (5.6 my) and is considered to be an individual volcanic complex.

The island is best known for its long sandy beach (even sand therapy is possible here…), stretching along the south coast. The formation of the beach dates back to the Ice Ages, when the sea level was about 130 metres lower than today. During glaciations, the surface of the island was five times larger than today. Large scale erosion from the NW-part of the extended island (now below sea level) due to dominating northern winds, led to a southern transport of vast amounts of sediment that make up today's southern beach. A large part of Porto Santo, now above sea level, was formed under submarine conditions.



Above: 50 m depth line on the chartplotter screen in the wheelhouse, showing the theoretical shape of the island when the sea level would be 50 m lower. To the NW the extension of a plateau is visible which provided the sediments for the southern beach during the Ice Ages, when the sea level was even 130 m (!) below the present level. Below: the 9 km long beach, in the background the peak of the Ana Ferreira. The top is a dike of columnar basalt, that used to be quarried.

Below: Profile of Porto Santo during glaciations. Dotted line=present day sea level, showing that the part above sea level is just a "tip of the iceberg". Carracedo & Troll, 2021.

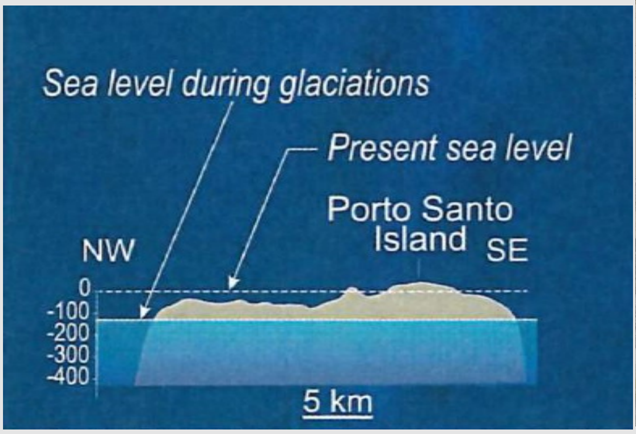


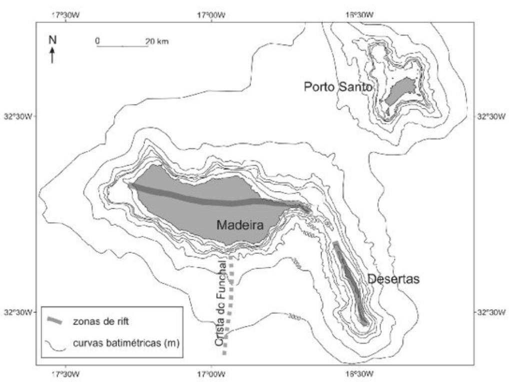
Photo A. van Roekel

Madeira & Ilhas Desertas: one volcanic complex

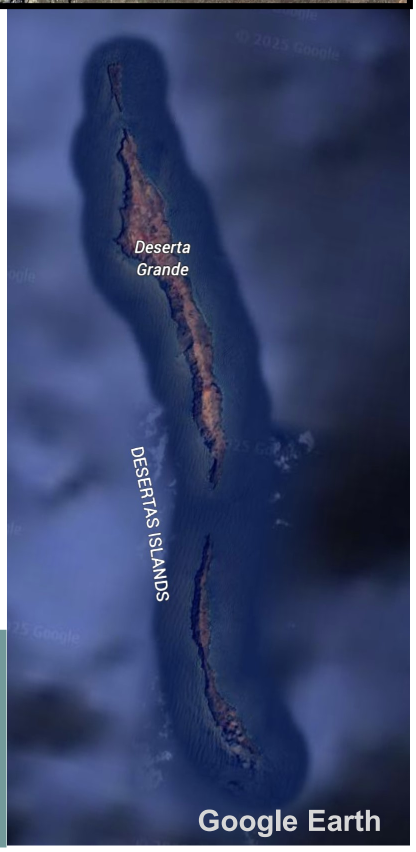
Aerial photo North Desertas by A. van Roekel, adapted by Art-Aruba.com

The Desertas Archipelago is a submarine ridge formed by an alignment of eruptive centres and parallel dyke swarms. The Desertas rift zone is a NNW-SSE continuation of the WE-Madeira rift zone (image below). The subaerial parts of Madeira and Desertas are considered to be one volcanic complex, the subaerial part is younger than 5.6 million years.

The northern island of the Desertas, Ilhéu Chão (photo above), is remarkably flat. The platform shape can be explained as "a larger, thicker lava flow that is more resistant to weathering, perhaps because of a low vesicle content, and therefore eroded to a plateau" (by email March 2025 from Valentin Troll).



Left: Rift zones and seabed topography of the Madeira-Desertas-Porto Santo Group, Mata et al., 2010. Inset: red arrow pointing to the lighthouse on Ilhéu Chão. Right: Ilhas Desertas. Both images from Google Earth.



The incredible uplift

These basalt columns below pyroclastic deposits can be interpreted as a central intrusion that spread laterally, inside a cinder cone. Location: Bay of Funchal, just west of Ponta do Garajau (Cristo Rei Viewpoint). Photo A. van Roekel.

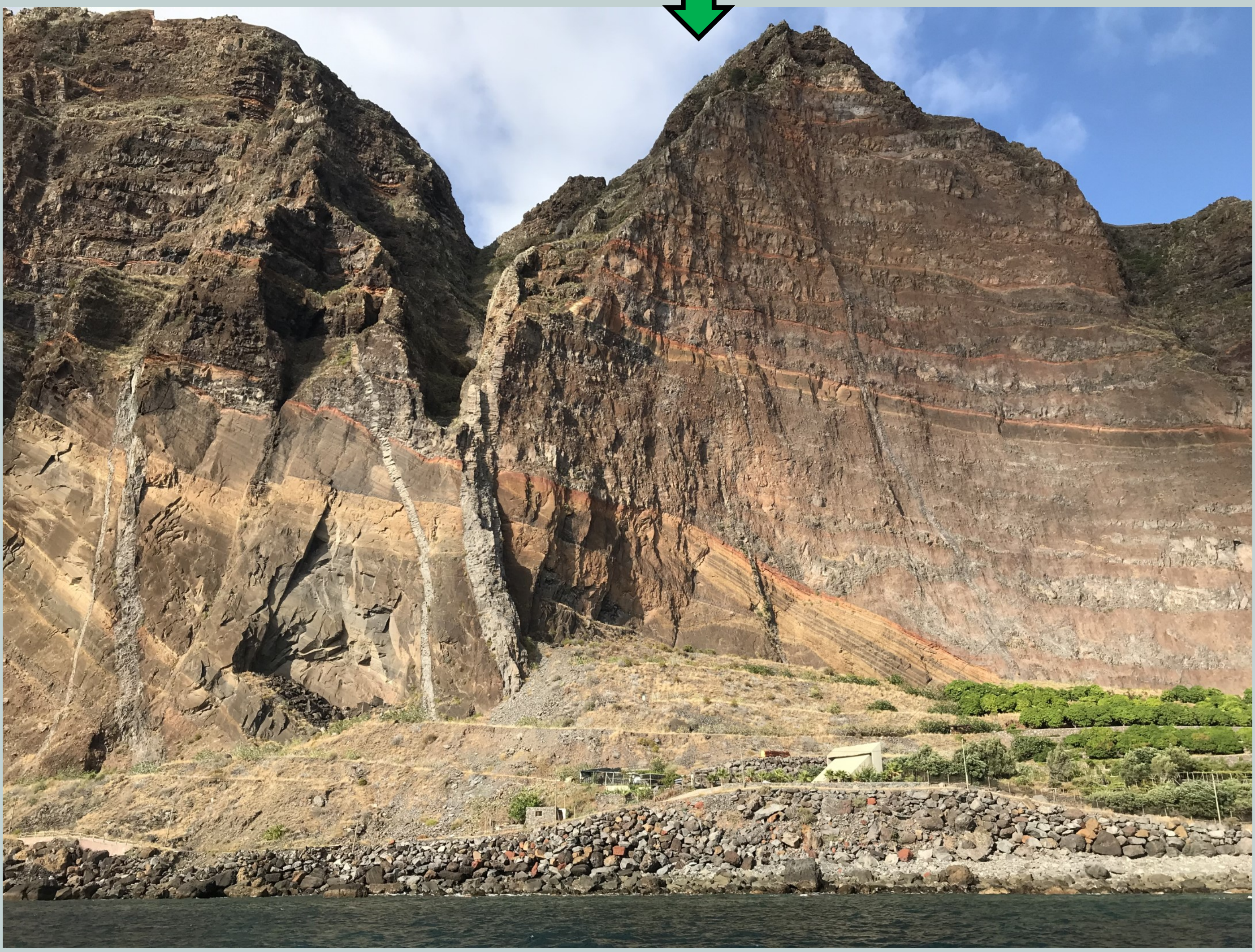
Madeira marks the end of a NE-SW trending alignment of seamounts. During its initial stage the island emerged by uplift (Carracedo & Troll, 2021). If you're not an earth scientist (like me), these processes are really difficult to image. It might give some comfort that the great geologists of the 19th century were also filled with disbelief when they observed geological phenomena in the field, which had but one explanation: massive uplift of ocean islands. Ilhéu de Baixo was visited by the Victorian geologists Lyell and Hartung, and they were amazed by the limestone reef on top of the tuff: *"At the beginning of January 1854, Lyell and Hartung spent three days on the island of Porto Santo, thirty miles NE of Madeira, to which they sailed in the British warship HMS St Jean d'Acre through the kindness of its captain. Porto Santo was a volcanic island, formed much like Madeira by volcanic eruptions on land. On the small island of Baixo off the west end of Porto Santo, they found a fossil coral reef, resting on volcanic tuff. Baixo provided clear evidence of the elevation of formerly submarine volcanic rocks." In: Wyse Jackson, 2007.*

Dykes intruding pillow lava is a clear proof of uplift of oceanic islands. Location: Caldera de Taburiente, La Palma. Photo A. van Roekel (2022).

Right: View of Ilhéu de Baixo from SW Porto Santo. This island is made up of fossil corals on top of tuff layers, which is evidence of the immense uplift of oceanic islands. Photo A. van Roekel (2025).

Cabo Girão (1), revealing Madeira's inner structure

The inner rocky structure of Madeira as a shield volcano is visible in the cliffs, for example at the spectacular Cabo Girão, 10 km west of Funchal. The cape is about 2 km long (EW). The photo below the Google Earth panorama was taken from the sea and shows the layered structure in the eastern part (green arrow). Madeira sits on 140 Ma old crust (i.e. the crust formed at the Mid-Atlantic Ridge ~140 million years ago and was slowly transported eastwards) and rises 4 km from the seafloor due to a hotspot (Carracedo & Troll, 2020). During the early seamount stage, Madeira was uplifted by underplating of magma and intrusions. Madeira emerged by rapid uplift at 7.0–5.6 Ma before the phase of shield volcanism (Ramalho, 2015). The subaerial edifice lies unconformably (i.e. with a time gap due to eroded sediments) on the eroded seamount; 99% of the island currently above sea level was actually formed under subaerial conditions. The photo below shows dark layers of basalt alternating with brown-orange layers of tuff: basaltic pyroclastic deposits transformed into rock by pressure and heat. The central and western parts of Cabo Girão are highlighted on the following pages.



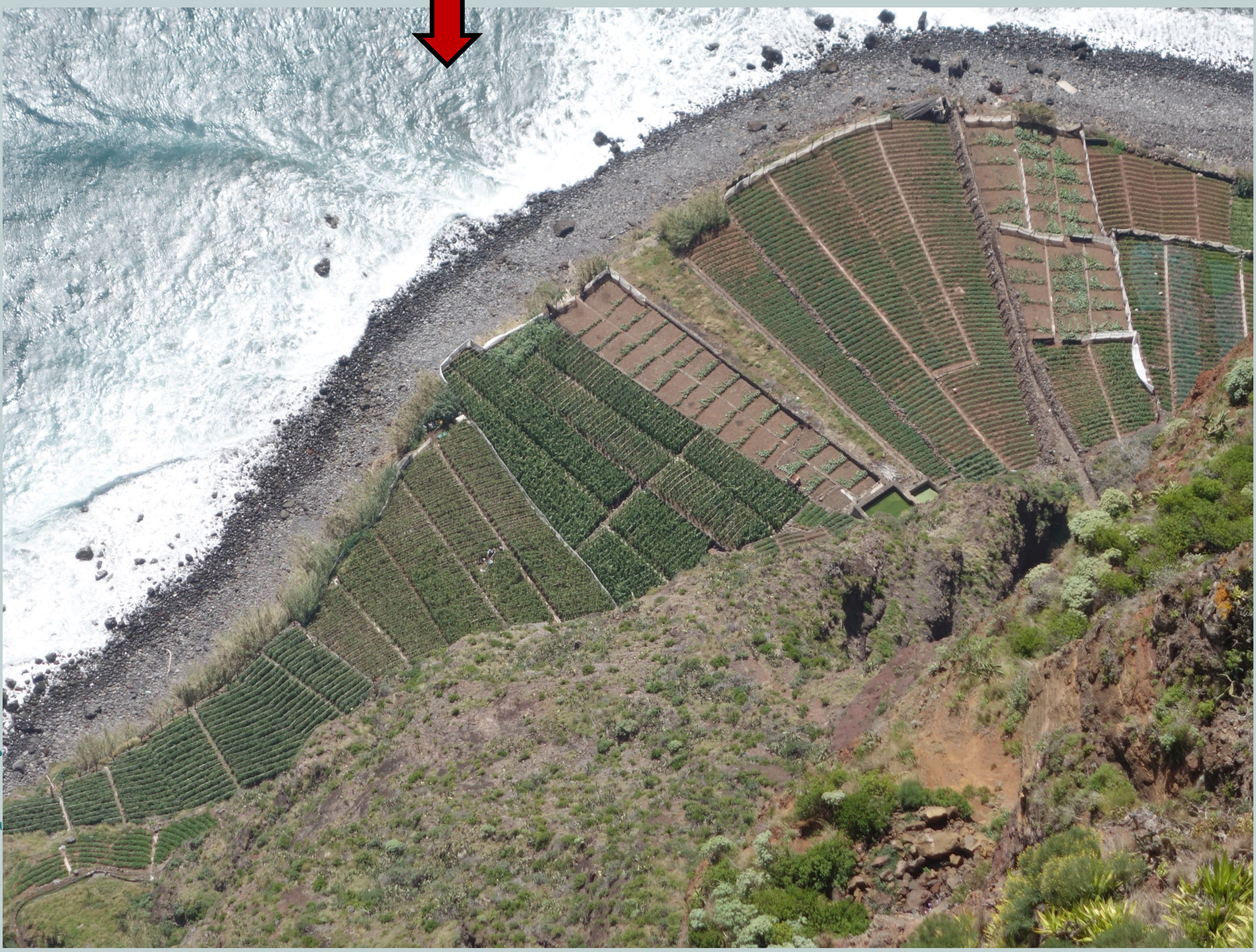
Eastern part of Cabo Girao. Photo A. van Roekel, 2020

Cabo Girão (2), fear of heights on the Miradouro

Although the Miradoura Cabo Girão has more than a thousand visitors every day (and it's worth it!), a few might let their friends or spouses go to the sidewalk and would prefer to stay behind… This is one of the highest cliffs in Europe, 580 metres, but easily accessible. It's similar to the Mirador del Rio in the north of Lanzarote. The view on Madeira is to the open ocean, whereas from the Mirador del Rio (the work of Lanzarote's famous architect César Manrique) you can see the island of La Graciosa with its rocky satellite islets and the salt production lakes at sea level.

At Cabo Girão you see agricultural land at the bottom, called *fajã* in Madeira. These eroded plateaus are formed by 'recent' cliff falls.

From Cabo Girão to the east. Photo A. van Roekel



Central part of Cabo Girão. Photo A. van Roekel

Cabo Girão (3), Fajã dos Padres

This piece of land at the foot of the cliff just west from Cabo Girão, Fajã dos Padres, is known as an ancient vineyard founded by Jesuit priests in the 16the century. Leaving the cable car, you can sense immediately that this place has a microclimate. The heat radiates from the massive vertical rock, which reaches a height of 250 metres here. The cable car was originally built for the farmers, but these days brings lucky visitors down, a spectacular experience as the dykes are on eyesight. In the past, the farm could only be reached by ship.

Exposed dyke in eroded tuff layers. Detail of photo below from another angle. Photo A. van Roekel.

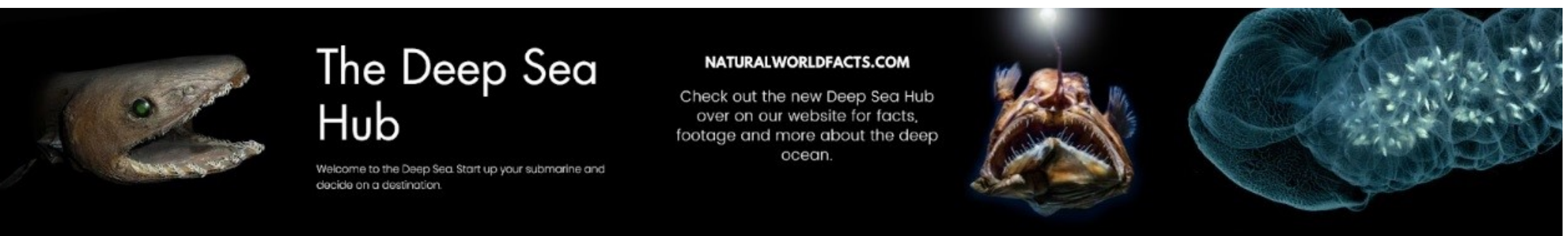
Colourful tuff sediments, cut by dykes. Photos A. van Roekel.

Watch this!

Sailing on the SMM and subsequently writing this edition of our *GeoNewsletter*, I came across some great videos and maritime stories and art that I want to share with you. Just click on the images to learn more!

Sailing on the *Santa Maria Manuela* also means getting to know the amazing history of the ship, which once was part of the Portuguese White Fleet. SMM was built as a mother ship for cod fishing near Newfoundland and Greenland in the 20th century, made of German steel that was supposed to be used for building war ships. As Portugal was neutral in the Second World War, the steel was used to build two hulls of fishing vessels. Get to know the history of the SMM via the links on this page.
For a wide range of documentaries about the deep sea and seamounts by marine biologist and science communicator Leo Richards: click on the banners.
Madeira is part of the Macaronesian Archipelago, comprising also the Azores, Canary Islands and Cape Verde Islands. To get a broader view of the geological context, I would like to draw your attention to the chapter about the North-East Atlantic Islands (see list of references). As the Canary Island of Tenerife has been an important landmark in maritime history, with the Teide ever present above the clouds, I would recommend you to check out these videos: *The geology of Tenerife* and *Origin of an Ocean - Geology of the Atlantic*, both by professor Valentin Troll from Uppsala University (Sweden) on his YouTube Channel.


***The Fog Warning* by Winslow Homer.**



.

Sailing south of Madeira, with a view on the Desertas Islands. Photo A. van Roekel.

Sources and reading suggestions (in alphabetical order)

⇒ Carracedo, Juan Carlos, Troll, Valentin R. (2020). North-East Atlantic Islands: The Macaronesian Archipelagos. In: Encyclopedia of Geology / David Alderton and Scott A. Elias (Eds.), Volume 1-6, Second Edition,v. 4, p. 674-699. Link.

⇒ Geological Society of Glasgow. A field guide to the geology of Madeira. Supplement 02-2018. Link to pdf.

⇒ Lo Iacono, Claudio, et al., (2012). Large, deepwater slope failures: Implications for landslide-generated tsunamis. Geology 40 (10): 931–934. doi: https://doi.org/10.1130/G33446.1

⇒ Mata, João, et al. (2010). Geologia de Portugal, Volume II – Geologia Meso-cenozóica de Portugal. Link

⇒ National Geographic (1968). Centro de Estudos do Mar CEMAR. Historical documentary about the Portuguese cod fishing fleet. The Lonely Dorymen - Portugal's Men of the Sea. Link to this video on YouTube

⇒ Ramalho, R.S. et al. (2015). The emergence of volcanic oceanic islands on a slow-moving plate: The example of Madeira Island, NE Atlantic, American Geophysical Union, 16, https://doi.org/10.1002/2014GC005657

⇒ Roekel, A.L.W. van, (2022). El Hierro, de jongste Canaria. Eiland van aardverschuivingen. Gea, Vol. 55 - Issue 3 p. 16- 23. Dutch version. English version.

⇒ Roekel, A.L.W. van, (2021). Porto Santo, veilige haven dankzij ijstijdzand. Geologie van de Madeira Archipel. Gea, Vol. 54 - Issue 2 p. 19- 26. Dutch version. English version.

⇒ Voorde, Marlies ter. Kans op tsunami bij kust Portugal steeds onderschat. Volkskrant 8 september 2012. Link.

⇒ Website Santa Maria Manuela

⇒ Wyse Jackson, Patrick N. (ed.) (2007). Global peregrinations: four centuries of geological travel. Geological Society, London, Special Publ., 287, https://doi.org/10.1144/SP287.1.

Glossary

- ⇒ Abyssal plain—low part of the seafloor < 1.000 metres
- ⇒ African plate— also known as the Nubian Plate, the African plate is a rotating plate (speed ~2cm/yr), responsible for the closure of the Mediterranean Sea in about 7 million years.
- ⇒ Azores–Gibraltar Fault Zone—plate margin between the African and Eurasian plate between the Azores and Gibraltar.
- ⇒ Basalt—fine-grained igneous rock, formed when mafic (low-viscosity) lava cools.
- ⇒ Basalt column—hexagonal shape of basalt as a result of shrinking during (fast) cooling.
- ⇒ Course—the direction in which the vessel is to be steered.
- ⇒ Dory—a small, shallow-draft boat with a flat bottom and sharp bows; for centuries it has been used as a traditional fishing boat, both in coastal waters and in the open sea.
- ⇒ Dyke—lava that fills a fracture in rock, often (almost) vertical. In 3D-it takes the shape of a plate; in the outcrop it appears as a line. A horizontal intrusion is called a sill.
- ⇒ Eurasian plate—a tectonic plate including most of the landmass consisting of the traditional continents of Asia and Europe (excl. the Arabian Peninsula, India and parts of Siberia).
- ⇒ Hotspot—fixed location in the earth's mantle where magma is anomalously hot compared to the surrounding mantle material, creating a chain of seamounts and volcanic islands in the moving earth's crust. Examples: Canary Islands, Madeira Archipelago, Hawaii.
- ⇒ Hydrothermal vent—fissure on the seabed where hydrothermal fluids, rich in chemicals, escape and minerals are deposited.
- ⇒ Landslide—mass movement event occurring in various environments: in mountain ranges, at coastal cliffs or underwater (submarine landslides).
- ⇒ Lava—volcanic rock formed at the earth's surface from magma.
- ⇒ Magma—molten rock containing a mixture of crystals, liquid melt and dissolved volatiles.
- ⇒ Mid-Atlantic Ridge—volcanic ridge in the middle of the Atlantic Ocean, where two plates move away from each other due to various forces and magma rises up.
- ⇒ Mother ship—a large vessel carrying small boats, such as dories in the case of SMM.
- ⇒ Nautical mile—1 nautical mile equals 1.852 km.
- ⇒ Ocean(ic) island—A mass of volcanic rock and soil, rising from the seafloor, reaching above sea level and completely surrounded by water.
- ⇒ Rift zone—a tectonically active area characterized by a depressed land form where the lithosphere thins due to the upwelling of magma, leading to volcanic activity.
- ⇒ Subaerial—volcanic eruption on or near the Earth's land surface.
- ⇒ Tall ship—a large, traditionally-rigged sailing vessel.
- ⇒ Tectonic plate—slowly moving parts of the Earth's crust, with three types of boundaries: transform, divergent and convergent.
- ⇒ Seamount—submarine volcanic mountain > 1000 metres above the seafloor, near a tectonic plate boundary or above a hotspot. Early phase of an ocean island.
- ⇒ Shield volcano—volcano with shallow slopes, erupting mafic lava which is low in viscosity.
- ⇒ Subduction —the process of a tectonic plate moving below another tectonic plate.
- ⇒ White Fleet—large fleet of Portuguese fishing vessels, painted white during World War II.

Geopress

vuurberg.nl

Geopress
Aemilia de Koningh
www.geopress.nl
geopresservice@gmail.com

Vuurberg
Annemieke van Roekel
www.vuurberg.nl
avroekel@xs4all.nl

0031-6-5247 9731

ISSN: 2950-1520