Sea surface: a physical and metaphorical border

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Short Note

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ABSTRACT

The sea surface is highly variable insomuch that the current sea level is far from being an average level in relation to the Earth's surface and to the geological history of Earth. This means that the total surface area cannot be precisely defined, due both to its continuous change in altitude but also to the complexity of the landward limit, or the coastline. Sea level variations have been very intense in geological history, also in its recent Quaternary history, with a variability of more than a hundred meters. The surface of the sea clearly distinguishes two separate worlds, the emerged one and the submerged one, the former being easily accessible, the latter much less. Geological theories have been deeply affected by this border because until one century ago, little information was available on the sea bottom, so geologists could not produce really data-based global theories. It seems that geological theories were altogether land-laden, not being able to acquire information on the seabed. Even today the submerged lands continue to be much less accessible and certainly not directly available to the classic geological field surveys, apart from limited shallow areas where it is possible to use scuba equipment.

KEY-WORDS: Sea surface, philosophy, eustasy, geological theories.

INTRODUCTION

The sea level is a very clear physical border, which delimits the emerged world from the submerged one. It is both a vertical border, between air and sea and also a horizontal one, between land and sea (Fig. 1). The submerged landscape, below the sea surface, is much larger than the emerged one since about three quarters of the planet is submerged and it is not within the reach of direct observation, as described by the hypsographic curve, while the remaining part includes the emerged lands (Eakins & Sharman, 2012). The geometry and features of the sea surface are highly complex. It is constantly variable over the short term, due to waves and tides, and over the long term, due to processes such as eustatism, tectonics and glacial isostatic adjustment, or GIA. Considerable evidence is available today on the variations of the current and predicted levels, which will lead to a progressive increase in the sea level up to a maximum of 1 m by 2100, and a consequent transgression on lands that are dry today (IPCC, 2021). This flooding and consequent sea level extremes could be a great danger for the activities and people that live in the coastal zone, affecting up to 779 x10^2 km^2 of coast and 287 million people and in the worst case scenarios (Kirezci, 2020).

In this regard, a historical-philosophical reconsideration of the concept of sea surface and its variations in the context of historical research could tentatively provide a useful background for future studies on this topic. In this paper, we present an overview of the sea surface and its variations through the history of geological theories and discuss the role of the sea level as a physical and metaphorical border.

THE PHYSICAL SURFACE

The sea surface covers about 361 million of km^2, or three quartes of the world, but in terms of boundaries, it is also very complex, since the length of coastlines is practically impossible to quantify since it depends on the observation scale, as was observed well by Mandlebrot (1967).

The surface is affected by changes in elevations ranging in space and time. The highest waves can reach up to 20 m (Hanafin et al., 2012) and are moved by winds, so the higher the intensity the greater the height. Wave period of these waves are up to some seconds. On the contrary, tides are periodic changes of sea level, diurnal or semi-diurnal, and can increase the sea surface up to

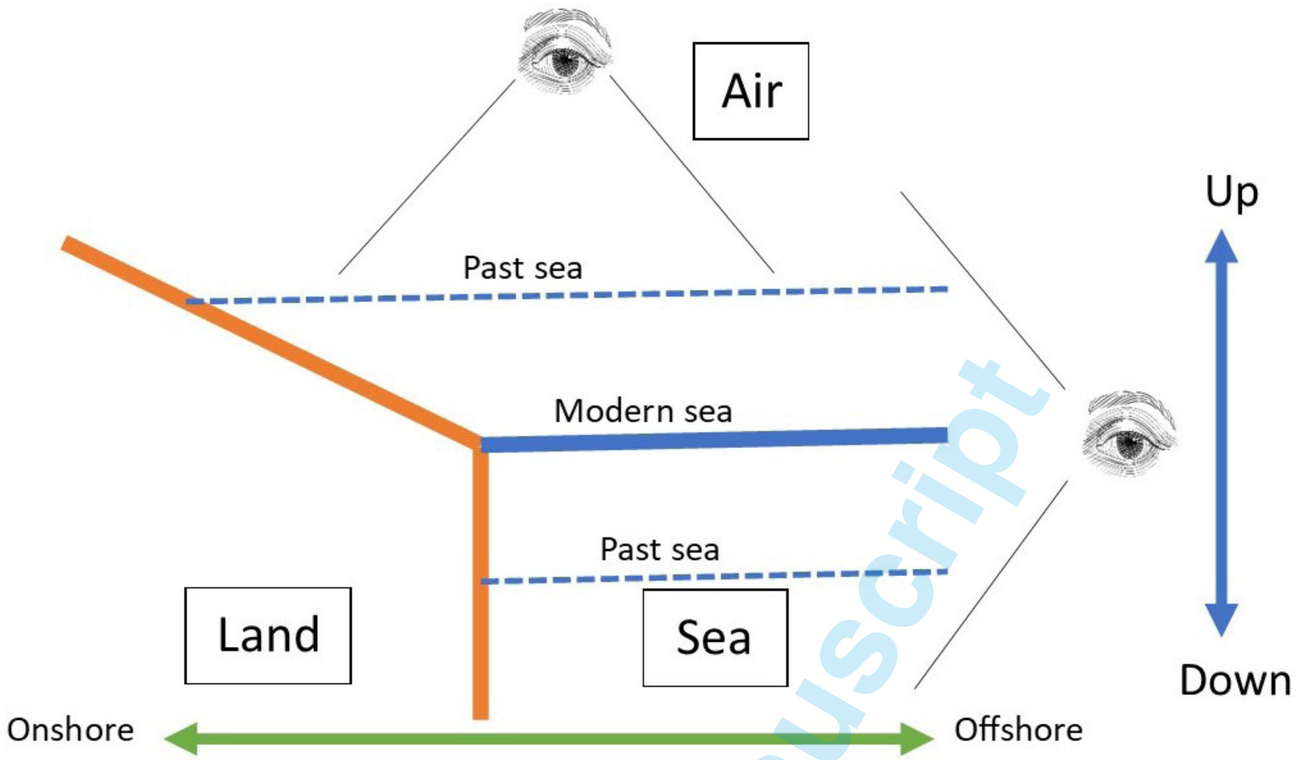

Fig. 1 - Section of the sea surface as a boundary dividing what has emerged from what is submerged.

about 20 m from the mean level. Seiches are also significant movements of the sea surface that depend on the geometry of the basin and can produce variations of some metres (Rabinovich, 2009). Besides these short-term changes in the sea level, there are also long-term ones, both in absolute and relative state. Eustatic variations in sea level are considered to be global changes and are mainly due to glacial melting or expansion. These phenomena affect GIA processes, which are local and depend on the distance from the glaciers (Spada, 2017). Further, tectonic movements are local and can significantly affect sea level changes, in particular in active tectonic areas.

Nowadays, the knowledge of the sea floors is very detailed, but only a small part of them are known by direct observations (Wölfl et al., 2019). There are still active projects to map the parts not yet covered, such as the Nippon Foundation-GEBCO (The General Bathymetric Chart of the Oceans) Seabed 2030 Project that complements and draws on these initiatives and promotes international collaboration and partnership (Wölfl et al., 2019). Therefore, there is still a certain imbalance between the knowledge of the seabed and the emerged surface.

Over geological time the sea level has fluctuated possibly more than 400 metres. During the last 2.6 million years, corresponding to the Quaternary period, the sea level raised and lowered about 150 m, from about -140 m msl during the glacial maximums and about +10 m msl during interglacials (Fig. 2). These changes are due to millennial orbital changes. The forecast of future trends in the Earth's surface processes, including sea level change, is very complex and needs be related to the knowledge of present-day processes (Furlani & Ninfo, 2015). The present, at least for some decades or centuries now, is affected by a rise in sea level which is projected from 0.43 m to 0.84 m in the worst scenario until 2100 (IPCC AR6). This is related, according to the panel, to phenomena due to global warming, for which, increasing the global temperature, would also increase the temperature of the sea, producing steric variations in the volume of the oceans, and melting of continental glaciers. These phenomena would partly be attributable to natural phenomena, but largely to the production of anthropogenic CO_2 (IPCC AR6).

HISTORICAL BACKGROUND

In antiquity, the sky, however far and unattainable, was more accessible than the underwater world. The Dendera Zodiac, dated to the mid-1st century AD, shows the Mesopotamian zodiac with great precision (Rogers, 1998), while the submerged world was almost completely unknown until the end of the 19th century and beyond. In his volume Physical Geography, Kant (1803) wrote "*Captain Phis in his voyage to the Arctic Pole found no bottom at 4680 feet, and this is the greatest depth measured ... from what has been mentioned above, it can be demonstrated how varied the depth of the sea must be, and how inconstant it is The greatest depth, however, can hardly be determined, since the means to measure it are lacking, and conjectures in consequence must almost replace certainty ... and if the depths of the sea were in proportion to our mountains, and if there were places where the sea was a geographical mile deep, how could one know the depth? ... To say something about it, it is believed that the greatest depths of the sea are in proportion to the highest mountains, and as these*

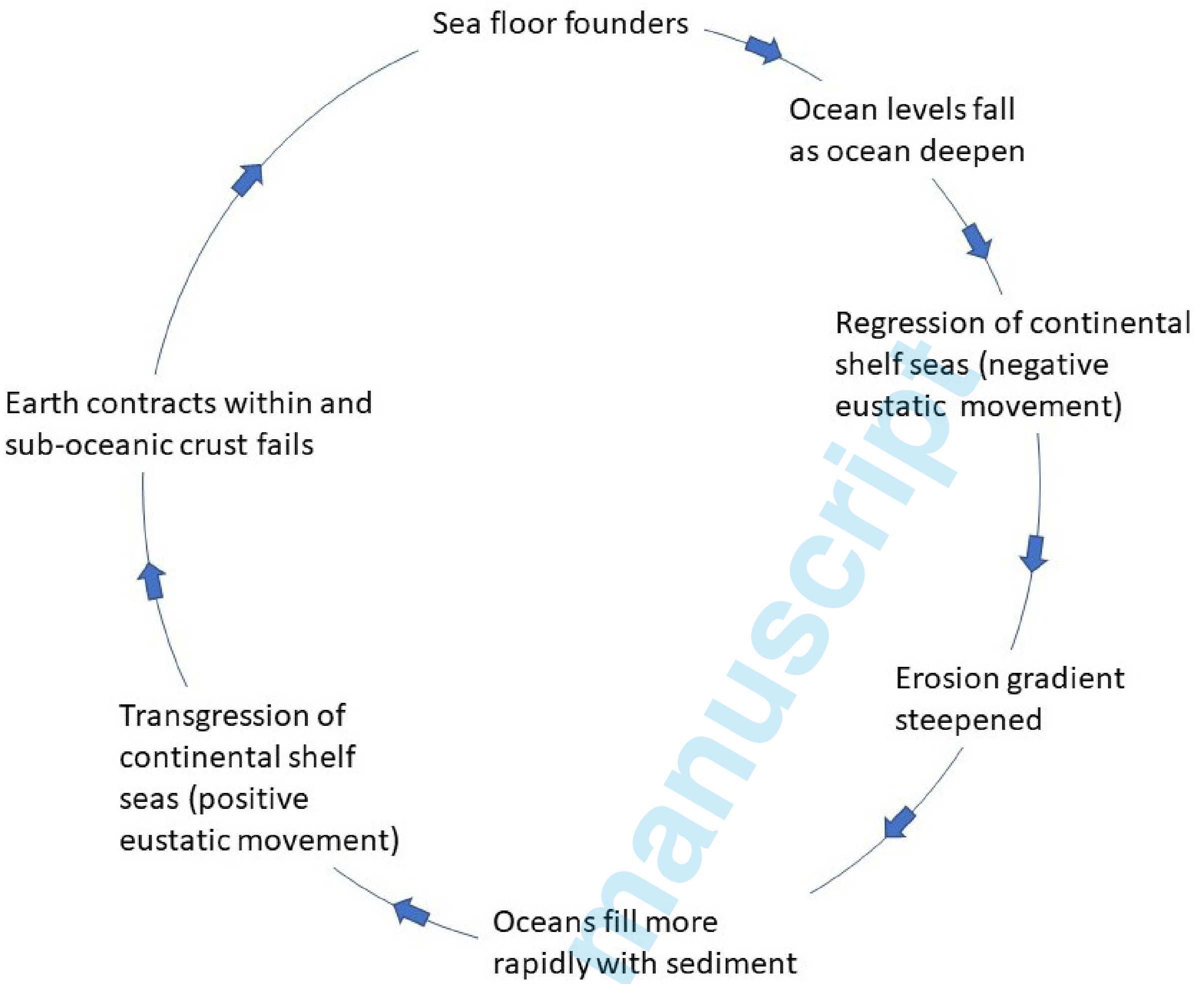

Fig. 2 - Eduard Suess's eustatic theory of oceanic transgression (modified from Suess 1904-1909).

rise more than a geographical mile above sea level, so the sea will be able to go inland up to a geographical mile ... As for the depth of the sea along the coast, it has been observed by the famous and experienced Dampier, that it conforms to the coast of the mainland, which is the more valuable, the higher and steeper the coasts. Where there are steep rocks, he says, it is never possible to drop anchor, because of the great depth: where the land slopes gently towards the sea, surely it is as if to give bottom, even if there are mountains located towards the interior of the land…". In ancient times, very little was known about the sea bottom but just as little was known of sea level variations. Data on the bathymetric features of the oceans have increased exponentially over the last hundred years, with numerous oceanographic expeditions and the improvement of sonar technologies.

In the nineteenth century researchers have shown that the sea level has undergone many significant changes over the course of the planet's geological history (Dott, 1992a). Pythias in the journey in Britain beyond the pillars of Hercules, first observed the cyclical nature of the tides (very large in the western Atlantic Sea). However, the fact that sea level changes has its ultimate root in the flood myths of several ancient civilizations and in 17th century sacred theories, which sought geologic evidence concerning the Great Deluge. For example, the Holy Bible proposed a single sea level change event due to the Great Deluge. This view greatly affected Medieval theories on the Earth (ref.). Also the 18th century Neptunism view postulated a one-way eustatic fall to explain all rocks of the crust, while competing plutonism postulated uplift of land (Furlani & Musumeci, 2020).

Agassiz's 1840 glacial theory nurtured our modern concept because of the implication of lowered sea level during an ice age, as first noted by MacLaren in 1842: "*If we suppose the region from the 35th parallel to the north pole to be invested with a coat of ice thick enough to reach the summits of Jura, that is, about 5000 French feet, or one English mile in height, it is evident that the abstraction of such a quantity of water from the ocean would materially affect its depth . . . We find that the abstraction of the water necessary to form the said coat of ice would depress the ocean about 800 feet. Admitting further, that one-eighth of the fluid yet remains locked up in the existing polar ices, it follows that the dissolution of the portion which has disappeared would raise the ocean nearly 700 feet. The only very uncertain element here is the depth of the ice; but even if this should be reduced one-half, we would still have an agent capable of producing a change of 350 feet on the level of the sea. We are besides leaving out of view the southern polar region,* *which it is now known embraces a great extent of land. If this was also covered with ice, the change would be much greater than we have assumed*".

The term eustasy was coined by Suess (1888) to define global changes of sea level. He attributed these changes to cyclic oceanic subsidence due to cooling and contraction of the Earth. Chamberlin (1909) proposed a diastrophic tectonic control of sea level as a cause of periodic universal unconformities. Eustasy and cyclicity became fashionable in geological studies, so the sea level was thought to cyclically change in altitude. Glacial sea-level changes remained in the background because Pleistocene glaciation was regarded by some authoritative figures such as J. Barren, W.M. Davis and N.S. Shaler, as only a minor perturbation in the Earth's history—a mere "climatic accident" (Dott, 1992).

The term eustasy was introduced in 1888 (Suess, 1888) to indicate global changes in the sea level but underwent several changes of meaning during the last century (Fig. 2). In particular, Chamberlin, in the following decades, tried to explain regressions and transgressions of the sea with his contractional planetary theory (Chamberlin 1898, 1909). Although he did not use the term eustasy, his arguments had to do with this field of hypothesis (Dott., 1992b). In the 1930s and 1940s, as well as approaching our present, the concept of eustasy was compared and incorporated with hypotheses concerning the global cyclicity of tectonic phenomena, e.g., Milankovitch cycles (Milankovitch, 1920). In 1875, John Wesley Powell proposed the term "Base Level", or ultimate base level, to indicate the lower limit for erosion processes, then used by William Morris Davis in the cycle of erosion theory, closely related to sea level changes (Orme, 2007).

The first field measures of the sea level were collected by Manfredi (1746) in Ravenna (Italy) for application issues. Charles Lyell (1830), in his Principles of Geology, established that ancient sea levels were fixed in the biological indicators at the Serapis temple, as shown in the cover of the book. However, until the beginning of the 20th century, little was known about the seabed. Few tens of years before, Maury (1854) published the first map of the Atlantic seabeds (Fig. 3) in which the ocean ridge was completely unknown. Not until 1912, the map of the Atlantic Ocean by the German oceanographer Gerhard Schott reported for the first time the mid-ocean ridge (Fig. 4). Only in the sixties of the 20th century, thanks to many geophysical campaigns and the great work of interpretation and assembly of bathymetric data by Tharp & Heezen (1977), was a global map of ocean floors produced (Fig. 5).

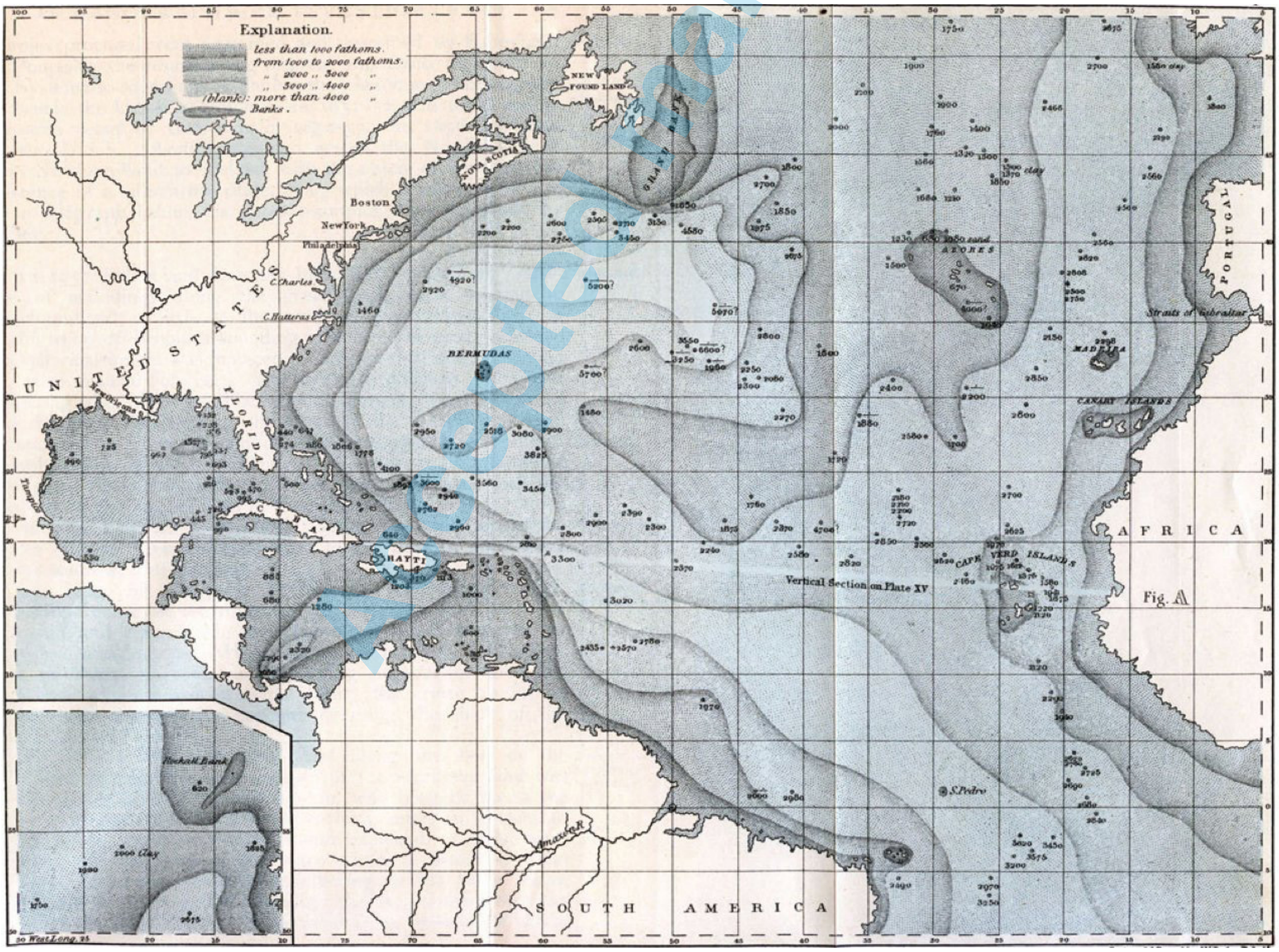

Fig. 3 - Map of the Atlantic Ocean seabed by Lieutenant Maury (1854). Note there is no trace of the oceanic ridge.

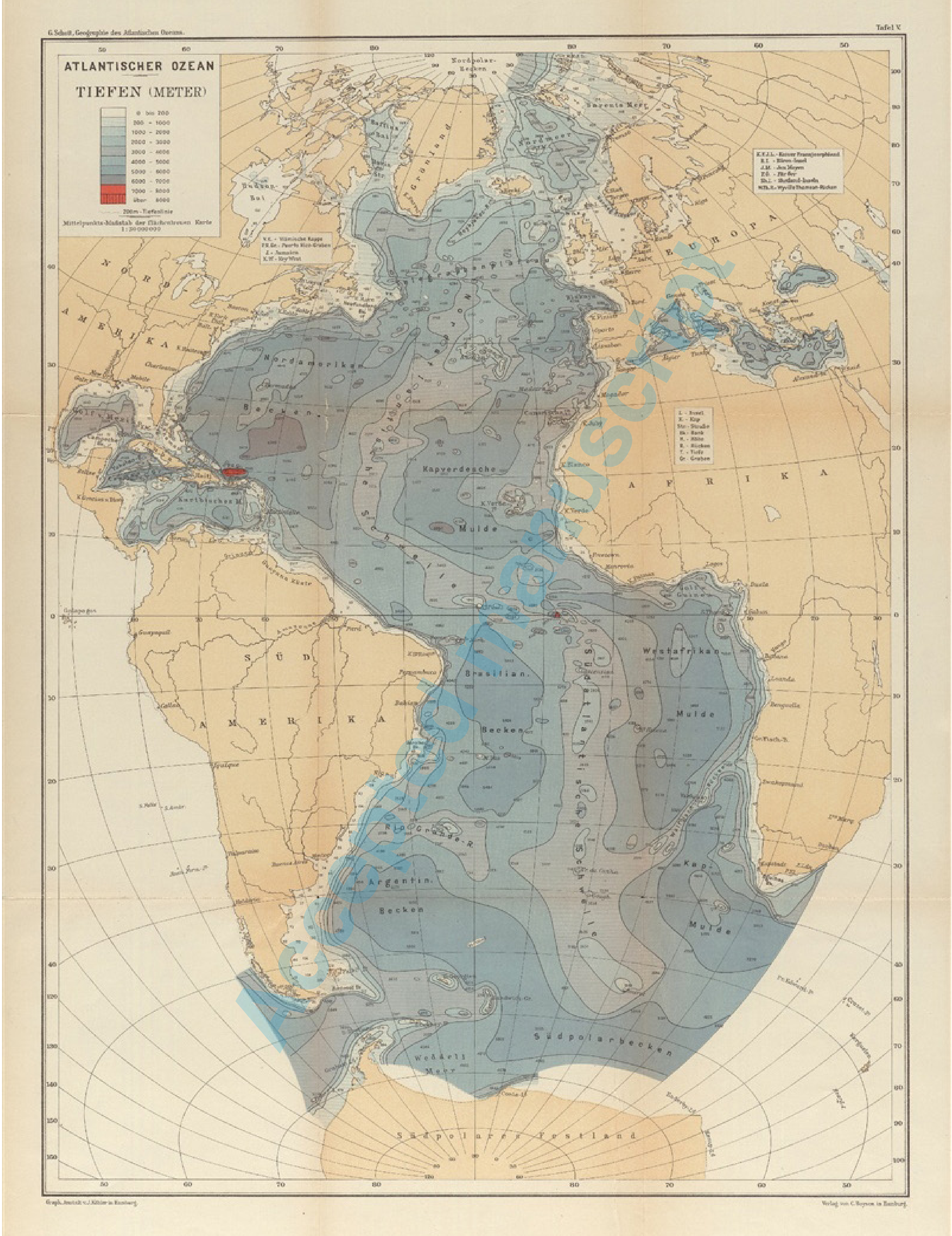

Fig. 4 - 1912 map of the Atlantic Ocean by the German oceanographer Gerhard Schott. The map reports the mid-ocean ridge in the middle part of the Atlantic Ocean.

Fig. 5. Map of the ocean floors (Berann et al., 1977). This map marks both a scientific and an imaginative revolution, since there had never been a map of the entire ocean floor before its publication.

PHYLOSOPHICAL CONSIDERATIONS

The sea level plays a very important role as a physical and metaphorical limit: there is an "above" and a "below" this limit. Above the sea level, everything is usually accessible, known, measured, while below it is on the whole inaccessible, unknown and largely still to be measured, as highlighted by Wölfl et al. (2019). This surface, the sea surface - so defined, but also so variable - defines therefore two very distinct environments, the emerged and the submerged landscape, different both for the physical, geological characteristics, etc. As suggested by Nagel (2004), continental landscapes are rougly mirrored by similar landforms at the sea bottom of the oceans so that valleys, plains, valleys, mountains, and volcanoes can be found beneath the sea surface, but higher than on dry land. Nagel (2004) defined the "oceanscapes," at one time unknown and unseen, which resemble familiar landscapes, but on a much grander scale. The interpretation of the data above and below the sea level is based on data collected with entirely different methodologies. The underwater world is not directly accessible, if not minimally to direct observation. But with the interpretation we seek to unite all the data in a common, global vision. Like the rest of geology, field research between land and sea proves to be a subject with a strong historical-interpretative component that is far removed from the classical procedures of physics (Frodeman, 2014). These reflections fall into the dialectical coexistence between methodologies of study more akin to the humanities and applications that are powered by the achievements of the hard sciences. To find an amalgamation is a desirable goal (Thorn & Rhoads, 1996).

The sea surface acts as a kind of swing, moving the coastline in four directions, up and down, and off-shore and on-shore (Fig. 1). The study of any model of sea reconstruction of past sea level shows that periodically the sea surface can change up to over 100 m. In the Quaternary it varies from about -140 m bsl to about +10 m asl (Benjamin et al., 2017), producing a swinging curve, with high and low values of sea level altitude in continuous succession. The current elevation of the sea level was very little present in the past, net of vertical tectonic movements and the GIA (Kominz, 2001). If we tentatively wished to establish a mathematical average of the sea level in the Quaternary, the value would be closer to -50 m bsl rather than 0 m msl. There is a certain tendency to consider the current sea level as an "average condition", while in the course of the geological history of the Earth, it has changed, and it is so highly variable in space and time, that the current one is far from being an average sea level compared to this history. The coastline we observe today, massive and ubiquitous on Earth, is extremely young, sometimes affected by the presence of inherited landforms from past sea levels.

The perimeter which limits the oceans and consequently the sea surface, the coastline, is also complex, mainly natural, but also partly human-made. It is the result of the interplay between inland

and coastal processes, and it continuously varies within limits forced by the total amount of water on the Earth.

The sea, from a philosophical point of view, is an inconsistent border, affected by complex variations, partly unpredictable, especially in the long term. For these reasons, the sea surface strongly affected the development of geological theories, which can be considered earth-laden theories. Our view of the Earth has in any case been strongly influenced by inland geology, since almost no one knew about the ocean floor until only less than a hundred years ago (Greene, 1982). The sea surface has played two fundamental roles in the history of geological theories. On the one hand, it has represented an insurmountable boundary, so that everything below this level was entirely unknown. Almost nothing was known about what was below sea level, in particular the shape of the seabed. Below the sea surface, the inaccessibility was almost total and it was impossible to collect any form of direct data. On the other, above the sea surface, direct observation allowed to collect data and build theories. This has also resulted in a earth-laden approach to Earth sciences that for centuries was heavily influenced by the non-knowledge of the seabed or, in other words, Earth science theories up to the beginning of the last century was affected by a terrestrial bias (Furlani & Musumeci, 2020).

CONCLUSIONS

The sea level has always represented a complex boundary for humans. At a certain point in its history, men began to sail the seas, but naturally navigation took place on the surface of the sea. What lies beneath had been completely unknown for thousands of years; and this physical limit also coincides with a very precise metaphorical limit, as every possible study or theory has been strongly influenced by the impossibility of seeing what is underneath, what the seabed is like and what its characteristics are. Even today, thanks to numerous projects that aim to accurately map the seabed, we have not reached the level of knowledge on the surface. The consequence is that a physical boundary draws a philosophical limit that inexorably pushes researchers to concentrate the theoretical possibilities above this limit, in the most accessible area both from a physical point of view and, at this point, also from an epistemological point of view.

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