

THE BLACK SEA

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ABSTRACT

The article was written during the meteorology and oceanography classes conducted at the Polish Naval Academy in Gdynia as part of the term paper task, and during the ERASMUS+ program.

The Black Sea is a natural inland water basin situated between Europe and Asia and has the aspect of a deep basin, oriented from west to east, an intercontinental sea, being connected to the Mediterranean Sea through the Bosphorus Strait and to the Azov Sea through the Kerch Strait. The actual shape of the Black Sea probably appeared about 40 million years ago, at the end of the Paleolithic period, respectively, when the structural raises from Asia Minor detached the Caspian basin from the Mediterranean basin; the Black Sea gradually separated from the Caspian region about 25 million years ago. The subsequent geological evolution produced changes to the sea level and associated with the action of the Ice Age glaciers, formed intermittent connections with the Mediterranean basin (this phenomenon happened about 6–8 million years ago).

The aim of the article was to illustrate the geographical, as well as the chemical and physical characteristics of the Black Sea water.

Keywords:

Black Sea, geographical conditions, chemical/physical characteristics

INTRODUCTION

Oceanography is the study of the physical, chemical, geological forms, and biological features of the ocean, including the ocean's ancient history, its current condition, and its future.

With a maximum depth of ~2 200 m, a surface area of $4.2 \times 10^5 \text{ km}^2$ and a volume of $5.3 \times 10^5 \text{ km}^3$, the Black Sea is a unique marine environment, representing the largest land-locked basin in the world. Its waters are in a state of almost complete isolation from the world ocean, as a result of the restricted exchange with the Mediterranean Sea through the Turkish Straits System (the Bosphorus, Dardanelles Straits and the Sea of Marmara). As a result, the basin is almost completely anoxic, containing oxygen in the upper 150 m depth (13% of the sea volume) and hydrogen sulfide in the deep waters.

People wonder why our sea is called "black". On sunny days, the sea-water is blue-green and when the sky is heavy clouded, it is silver-grey or azure. Ancient Greeks first called it Pontus Axeinus meaning an "inhospitable sea". In comparison to the Mediterranean, they found it cold and stormy, and even dangerous because of the wild tribes inhabiting its shores. It took a few centuries for the Ancient Greeks to get to know the Black Sea and its human inhabitants, before they changed their mind and started calling it Pontus Euxinus ("Hospitable Sea"), often referring to it in a friendly way, simply as the Pontus. Its treasures were reflected in the myth of the Golden Fleece, and Herodotus describes it as the most remarkable of all seas. There are several hypotheses for the origin of its present name. Historians say that it is an old name given by the Persians. Hydrologists explain it by the Black sea's ability to tint metal objects black, due to high content of dissolved hydrogen sulphide. Biologists tend to explain it with the fact that there is no oxygen and virtually no life in its depths. Whatever the origin of its present name, the Black Sea is unlike any other sea in the world, and it is greatly important for all people living around it, for it sustains them and supports their economy by attracting millions of tourists.

GEOGRAPHICAL CHARACTERISTICS

The map shows the Black Sea, an inland sea between Eastern Europe and Western Asia. It is bounded by the Eastern European Plain to the north, the Balkans to the west, the Caucasus Mountains to the east, and the Anatolian Peninsula (or Asia Minor, the largest part of Turkey) to the south.

There are six countries with coastlines on the Black Sea (clockwise), Ukraine, Russia, Georgia, Turkey, Bulgaria, and Romania. The Black Sea (without the Sea of Azov) has a surface area of $436\,400 \text{ km}^2$, which is somewhat larger than Germany or slightly larger than the US state of California.

An estimated 16 to 17 million people live in the coastal regions of the Black Sea.



Figure 1. Detailed map of the Black Sea

The map shows the Black Sea and surrounding countries with international borders, national capitals, major cities, important trade ports, rivers and lakes, main roads, primary railroads, and major coastal airports. Territories in other countries occupied by Russia are marked in red.

Earth's mountain-building machinery formed the Black Sea basin several million years ago. Large-scale movements of the Earth's crust uplifted the mountain ranges that divided the ancient Tethys Ocean into several water basins, such as the Paratethys Ocean. The mega lake of the late Miocene was probably the largest lake in Earth's history and extended from the region east of the Alps across Central Europe to Central Asia. Its remnants include the Black Sea, the Sea of Azov, the Caspian Sea, and the Aral Sea.

Rivers

The Black Sea receives water from a 2-million-square-kilometer drainage basin that covers about one-third of the area of mainland Europe. Several large rivers flow into the Black Sea, such as the Danube, the Dnieper, the Dniester, the Southern Bug, the Russian Don and the Kuban rivers,

Western Georgia's Rioni river, and the Turkish Kızılırmak and Sakarya rivers.

A system of inland waterways, the Unified Deep-Water System of European Russia (UDWS), connects the Black Sea with the Caspian Sea, the Baltic Sea and the White Sea. The Black Sea is connected to the North Sea via the Danube and the Rhine-Main-Danube Canal.

Islands

In proportion to its size, the Black Sea is sparsely endowed with islands and archipelagos. There are about ten small islands; the most famous today is Snake Island (Zmiinyi Island), located 35 km off the coast of southeastern Ukraine.

Mountains

Major mountain ranges bordering the Black Sea are the mountains of southern Crimea, the Crimean Mountains, the Caucasus Mountains, a mountain range between the Black Sea and the Caspian Sea, the Pontic Mountains (Kaçkar Dağları) in northern Anatolia, and the Strandzha, a low mountain range in southeastern Bulgaria and Turkey (East Thrace).

The highest mountains are Mount Kaçkar at 3 937 m in the Pontic Alps, Mount Ararat at 5 137 m, a dormant volcano in the Armenian highlands, and Mount Elbrus in the Caucasus Mountains at 5 642 m, the highest and most prominent peak in Russia and Europe.

Ports

Some of the most important ports on the Black Sea include:

- On the west coast is the port city of Constanta, the largest port in Romania and the largest seaport on the Black Sea.
- Burgas and Varna are Bulgaria's major ports.
- The Russian Port of Novorossiysk maintains a timber port, a shipyard, and an oil terminal; it provides grain handling facilities and is home to a Russian naval base.
- On the southeast coast of the Black Sea lies the seaport of Batumi, Georgia's largest container, cargo, and ferry port. 70 km to the north of Batumi lies Poti, a major port city and industrial center and home to the coast guard of Georgia.

- Samsun, Trabzon, Ereğli and Zonguldak are major Turkish Black Sea ports.

One of the major geographical features of the Black Sea is the Crimean Peninsula, which would almost be an island if it were not connected to the mainland by the narrow Isthmus of Perekop. At 27 000 km², Crimea is about the size of Massachusetts or slightly larger than the state of Israel.



Figure 2. Crimean Peninsula

PHYSICAL CHARACTERISTICS

Gravity, buoyancy, and wind are the dominant forces acting on the sea and all act together to produce its dynamics of currents, tides, and mixing. The gravitational attraction of the moon distorts the ocean surface to produce tides, though in the case of the Black Sea, its surface area is too small for significant surface tides. Buoyancy however, acts to keep less dense layers of water floating on top of denser ones and they remain virtually unmixed unless the buoyancy of either layer changes considerably through warming of the denser layers or cooling of the lighter ones, or if their salt content changes or there is sufficient wind or tidal energy to mix the layers together.

The Black Sea has developed two major water layers separated by a strong density gradient, or pycnocline (see Figure 3. Pycnocline.). The lower layer, below about 70-150 m (the depth varies from place to place) is saltier and colder than the upper layer. The average surface salinity is 18.2‰, though it can be much lower near river discharges. The lower layer has an average salinity of 21.8‰. This difference is maintained by the 36‰ Mediterranean water supplying the lower layer through the

Bosphorous and rivers and rain diluting the upper layer. 3.6‰ doesn't sound like a huge difference but is sufficient to prevent the bottom, hydrogen sulfide rich water from reaching the sea surface and escaping to the atmosphere. For most of the year, this is also helped by the fact that surface waters are usually warmer than deeper ones.

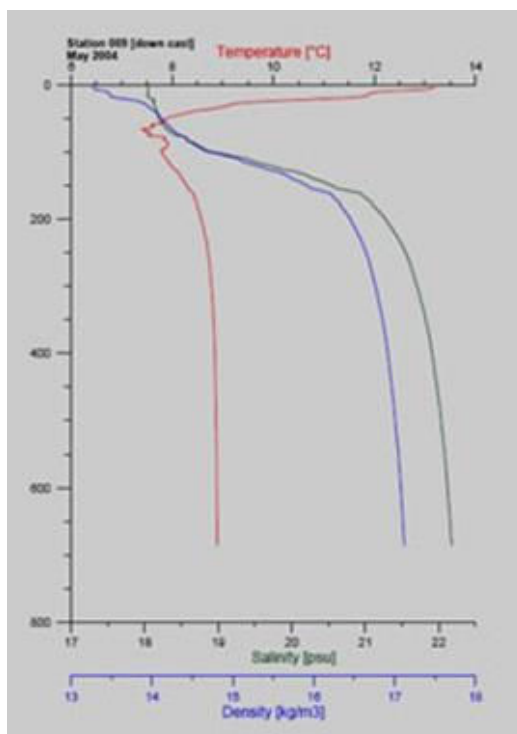


Figure 3. Pycnocline

Profile of salinity (green line), temperature (red) and density (blue) in the Western basin of the Black Sea in the 2004 cruise of the RV *Akademik*. The layer nearest the surface (1) has uniform density because it is mixed by the wind and waves; it is therefore termed the 'upper mixed layer'. The zone marked '2' is the permanent pycnocline. The deep-water region (3) has very little variation in density and until recently it has been difficult to study its mixing and circulation. The temperature profile shows how the water is warmed near the surface (this cruise was in late spring) but quickly cools with depth until a Cold Intermediate Layer of about 7°C is reached (4). The deeper sea is warmer, partly reflecting the warmer Mediterranean source water and partly heating from geothermal processes below the sea floor.

Circulation in the Black Sea is mainly driven by the winds that sweep across it and the buoyancy differences between inflowing freshwater and

the saltier Mediterranean inflow. The consequence is a cyclonic circulation throughout the year though not at constant speed. Those that sail in the Black Sea or live by its shores are keenly aware of the intensity of storms that develop in the sea, particularly in winter.

CHEMICAL CHARACTERISTICS

The Black Sea has a remarkable chemistry that distinguishes it from every other sea on our planet. What makes it really special is that whereas all other seas and oceans (with a few isolated exceptions) have oxygen dissolved in their waters, there is absolutely no oxygen in the Black Sea below a depth of about 100 m. Furthermore, the anoxic (oxygen free) water has a large concentration of hydrogen sulfide, a very poisonous gas that smells of rotten eggs. With the exception of a few highly specialized life forms, most animals and plants cannot survive in anoxic conditions. Hydrogen sulfide is also very poisonous to humans. The surface waters of the sea are less dense than the deeper anoxic layers because they are warmer and have a lower salt content. Fortunately for life in and around the Black Sea, this density difference prevents the anoxic bottom waters from ever reaching the sea surface.

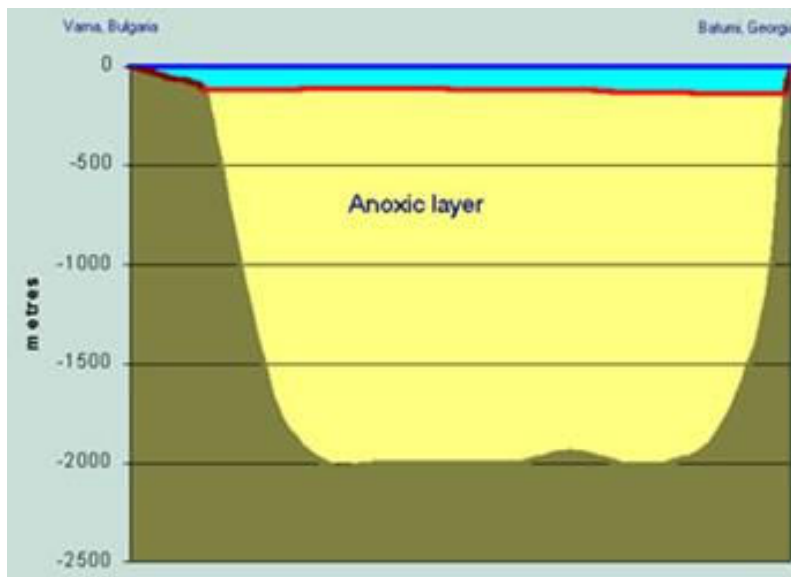


Figure 4. Depth of the anoxic layer in the Black Sea

Image 4. A West-East section of the Black Sea from Varna to Batumi showing the huge volume of anoxic water. Note the shallow shelf off Varna with oxygenated water down to the sea floor.

How did this situation develop? The deep waters of the Black Sea consist of water that has travelled from the Mediterranean through the Sea of

Marmara and the Bosphorus Straits (also known as the Turkish Straits). The Bosphorus too has two layers with outflowing Black Sea water at the top and Mediterranean water at the bottom. The Bosphorus is only about 50 m deep (even shallower in places) and 700 m wide and the incoming Mediterranean water spills into the deepest part of the Black Sea nearly 2 km below. For the bottom layer of the Black Sea – almost 95% of the Sea's volume – this incoming water is the only source of oxygen, and the new water may stay as much as 1 000 years in the bottom before eventually mixing with enough fresh water to reach the surface and start its journey back to the Mediterranean.

Plants use the sun's energy to convert carbon dioxide to living matter and oxygen, a process known as photosynthesis. At night the reverse process, respiration, occurs and some of the oxygen and living matter are consumed and energy is released. The same processes apply to the tiny free-floating plants – phytoplankton – in the sea or the algae found nearer the shore. The photosynthesis equation, without which there would be no oxygen in our atmosphere is written like this:

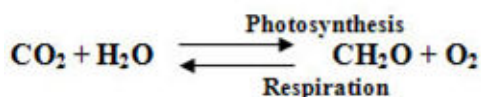


Figure 5. Photosynthesis equation

SUMMARY

In conclusion, the Black Sea is the largest brackish water basin in the world, with varied biotopes and a fauna that has undergone continuous transformations due to the strong opposing influences exerted by fresh waters and the Mediterranean Sea. The waters of the Black Sea have all the characteristics of brackish waters, they have a large variability of total salinity in correlation with the surface, depth and season, a strong ionic variability, not only with respect to the Mediterranean, but also with its different parts. The ecosystem depends on these hydrological conditions.

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