Paleogeography

THE BIRTH AND DEATH OF A BIG POND

Seen from today's perspective, the oceans seem to be a permanent and unchanging element of the Earth's landscape. Yet various oceans have been formed and "consumed" in the planet's ancient history.

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More than 100 years ago, Alfred Wegener, an outstanding German geophysicist, posited a new theory related to processes shaping the Earth, which he called "continental drift." He envisioned that the continents actually changed location in relation to one another and with respect to the Earth's axis of rotation.

Wegener claimed that 300 million years ago, back in the Carboniferous, there was once a supercontinent called Pangea. The present continents and oceans formed as a result of its subsequent disintegration. The evidence he pointed to included the matching edges of the continents, especially around the southern Atlantic, the distribution of fossils and similarities of geological structures on the opposite sides of the ocean, and also various climatological and biological data.

Wegener's theory met with harsh criticism from the conservative European geology professors of the day, especially German ones. But 50 years later, geophysical research and observations of the oceans bore out the validity of its general assumptions.

According to these observations, our contemporary oceans were first created in the Mesozoic, about 200–100 million years ago. The conclusive evidence of mainly applied to oceanic expansion, however; as to their disappearance (or consumption) there was still no certainty. In this regard, some scholars tended to accept what was then known as the Expanding Earth hypothesis, positing that the Earth's radius is increasing, thus leading to the associated oceanic growth. Satellite technologies, as well as radio telescope observations, have now made it possible to measure the continental movements against the oceans. Very Long Baseline Interferometry [VLBI] uses a network of radio telescopes located on different continents; data from Asia and America allowed their movement towards with each other, and thus the rate of closure of the Pacific Ocean, to be measured, thus contradicting the Expanding Earth hypothesis. According to the modern theory of plate tectonics, oceans may disappear as a consequence of oceanic crust immersing in the subduction zones. The material of the former crust then melts into the Earth's mantle and after

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works in the fields of paleogeography, plate tectonics, world geology, regional geology (CIS, Arctic, Tethys, Middle East, Mediterranean Sea, Vietnam, Australia, Atlantic, America, Carpathians), and paleoclimatic modeling. He is also interested in petroleum geology, which includes assessing the hydrocarbon potential of new regions, basins, and prospecting fields, selecting a basin exploration strategy and new hydrocarbon prospecting methods.

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many millions of years it returns to the surface of the planet, creating new oceanic crust. This has actually been confirmed by seismic tomography of the Earth's crust and mantle, revealing the deep immersion of the Farallon plate, a part of the Pacific Ocean.

Another major weakness of the Expanding Earth hypothesis was that it only covered the period from the disintegration of Pangea. However, the Earth has existed for almost 5 billion years, and we now know that the continents were moving, the oceans rising and closing long before then. The formation of Pangea is associated with the consumption of the early Paleozoic oceans. These oceans left behind traces in the form of ophiolites, containing rock complexes that make up the oceanic crust. Paleozoic ophiolites are known from classic sites including Newfoundland, Cornwall, and Norway. Ophiolites from Bayankhongor in Mongolia are located at the very heart of the Asian continent, thousands of kilometers from the nearest contemporary ocean. In Poland, ophiolites that are about 400 million years old can be admired on hiking trails on the Ślęża Massif.

In the past…

Geologists continue to amass various kinds of data, such as the contemporary boundaries of plates, isochrones of oceanic magnetic anomalies, oceanic fracture lines, bathymetric data, SEASAT and GEOSAT altimetry data, ocean and continent boundaries, continental tectonic elements, the prevalence of ophiolites, magma rocks of collision zones, as well as paleomagnetism data, all together in an electronic data bank. Its analysis of such data using the Plates, Paleomap and GPlates software then enables us to create maps of the location of ancient continents and oceans. They illustrate various stages in the geodynamic evolution of the Earth, running from the origin and growth of oceans, through their slow disappearance and "consumption," all the way to the merger and collision of continents and the formation of new supercontinents.

The Earth's paleogeography back in the Ordovician (485–445 million years ago) was radically different from its contemporary geography. South America, Africa, Madagascar, the Deccan Peninsula (i.e. India), Antarctica, and Australia were then all part of the Gondwana supercontinent (the name deriving from the Gondi tribe in India). This supercontinent stretched across the area surrounding the South Pole, which is why traces of Paleozoic glaciations can be found there. Northeastern Europe together with Scandinavia then made up an independent continent named Baltica (named after the Baltic Sea). Other independent continents included Siberia and North America, known as Laurentia (the name coming from the St. Lawrence River).

The early Ordovician saw the greatest dispersion of the continents and the emergence of vast oceans. The Iapetus Ocean, considered the predecessor of today's Atlantic, is named after the Titan Iapetus, son of Uranos and Gaia (Earth) in Greek mythology. As an eastern extension of the Iapetus there emerged a Paleoasian Ocean, located between the continents of Gondwana and Siberia. Nowadays, the prominent Bayankhongor ophiolites in Mongolia represent the remains of that Paleoasian Ocean, while the ophiolites of Mariánské Lázně in the western Czech Republic represent the remains of the Iapetus. The estimated distance between Gondwana and Laurentia reached 5,000 km.

In the early Ordovician, part of Poland, northern Germany, the Ardennes, England, Wales, southern Ireland, part of the coastal provinces of Canada and New England all separated from Gondwana. These

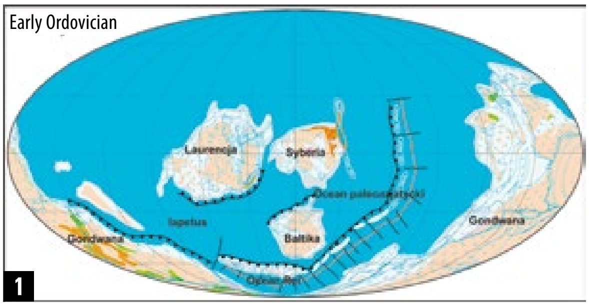

Fig. 1.
Global paleogeography in the early Ordovician. The Gondwana supercontinent is visible, stretching around the South Pole, as are the continents Laurentia (North America), Baltica (north-eastern Europe with Scandinavia) and Siberia. The wide Iapetus Ocean connects in the east with the Paleoasiatic Ocean, whose crust is evidenced by the opulent Bayankhongor ophiolites. The narrow, only just emerging Rheic Ocean is separated from the Iapetus by the parts of Poland, northern Germany, England, Wales, southern Ireland, some coastal provinces of Canada and New England. The black triangles indicate subduction zones.

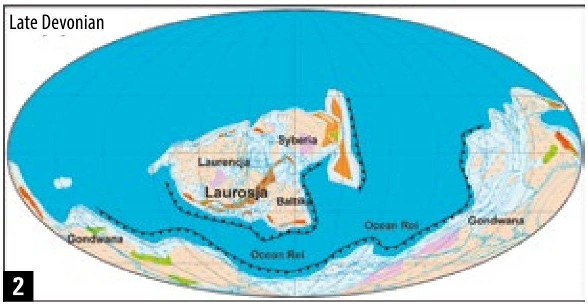

Fig. 2.
Global paleogeography in the Late Silurian. The supercontinents of Laurussia and Gondwana and the wide Rheic Ocean.

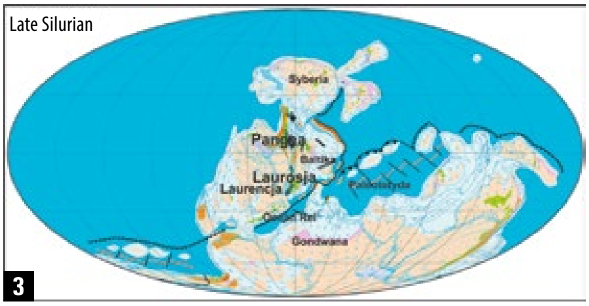

Fig. 3.
Global paleogeography in the Late Devonian. The supercontinents of Laurussia and Gondwana, the emerging Pangea, the narrowed and closing Rheic Ocean and the emerging Paleotethys Ocean.

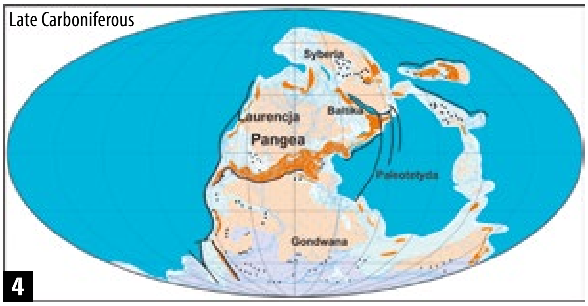

Fig. 4.
Global paleogeography in the Late Carboniferous. The Pangea supercontinent, with its central mountain range and the Paleotethys Ocean. The Rheic Ocean was consumed; its remains are evidenced, for instance, by the ophiolites of mount Ślęża in Poland.

5

Fig. 5.
Gabbros (igneous rocks) of Bayankhongor ophiolite, Mongolia. These gabbros were part of the so-called oceanic ophiolite series. In the contemporary oceanic crust, the layer containing such gabbros reaches a thickness of approx. 5km and is located below the basalt and sedimentary rocks.

6

Fig. 6.
Pillow-shaped basalts of Bayankhongor ophiolite, Mongolia. Basalts of this kind are formed by the lava of underwater volcanic eruptions. Lava, while cooling down in contact with seawater, forms characteristic pillow-shaped rocks.

7

Fig. 7.
Gabbros of the Ślęża Massif ophiolite, Lower Silesia, Poland.

8

Fig. 8
Cumulates of Ślęża Massif ophiolites, Lower Silesia. These cumulates formed as a result of the gravitational differentiation of ultrabasic magma in the lowest part of the ophiolite complex. In the contemporary oceanic bed, ultrabasic rocks represent the highest part of the upper mantle of the Earth.

continental fragments are called Avalonia (named after the Avalon peninsula in Newfoundland). The separation of Avalonia from Gondwana led to the formation of the Rheic Ocean (after the Greek Titan Rea, the sister of Iapetus and the mother of the Greek gods, Zeus, Poseidon and others). A subduction zone developed along the central part of Gondwana, directly affecting the drift of Avalonia. In the Silurian, the Iapetus Ocean was consumed and closed up as a result of the collision of Baltica, Avalonia and Laurentia. The period of mountain formation resulting from this collision is known as the Caledonian orogeny (after the Caledonian Mountains in Scotland).

The merger of several smaller continents in the late Silurian gave rise to the Laurussia supercontinent. The Rheic Ocean next became subject to subduction and consumption. The ocean was then very wide, stretching between Gondwana, Laurussia and Siberia; its closure ended about 300 million years ago in the Carboniferous. The cause was the collision between Gondwana and Laurussia, and the consequence was a mountain-forming era known in Europe as the Variscan orogeny (after the mythical Germanic tribe of Varisci, inhabiting central Europe in antiquity). The Pangea supercontinent, which Wegener first described, emerged in the Carboniferous as a consequence of this orogeny. A huge mountain range ran through Pangea's center, the height of which could exceed 10 kilometers, higher than today's Himalayas. In the shade of these mountains massive coal seams formed; they are the source of our name for the Carboniferous geological period. Poland's Sudety Mountains once belonged to the central, Variscan mountain range of Pangea. The ophiolites of Ślęża Mountain, in turn, represent the remains of the crust of the closed-up Rheic Ocean.

…and in the future

The way we describe and interpret the course of ancient geological processes is nowadays based on the principle of actualism (or uniformitarianism). This principle, formulated at the turn of the eighteenth and nineteenth centuries by British scientists James Hutton and Charles Lyell, assumes that past physical and chemical processes were similar to those of today, as summed up by the phrase: "the present is the key to the past". Recently, a modification of this principle – "the past is the key to the future" – has been gaining much currency. This kind of reverse-actualism is invoked, in particular, by geologists speaking out in the global warming debate. They note that in the geological past, changes in temperature were considerably greater than today, and so they can also be expected to occur in the future without human intervention – although the latter may accelerate them. Reconstructing the history of the formation and closure of the world's oceans allows us to predict the evolution of continents and oceans in the future. For instance, we can expect the Pacific Ocean to close up entirely in about 200 million years.

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Further reading:

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