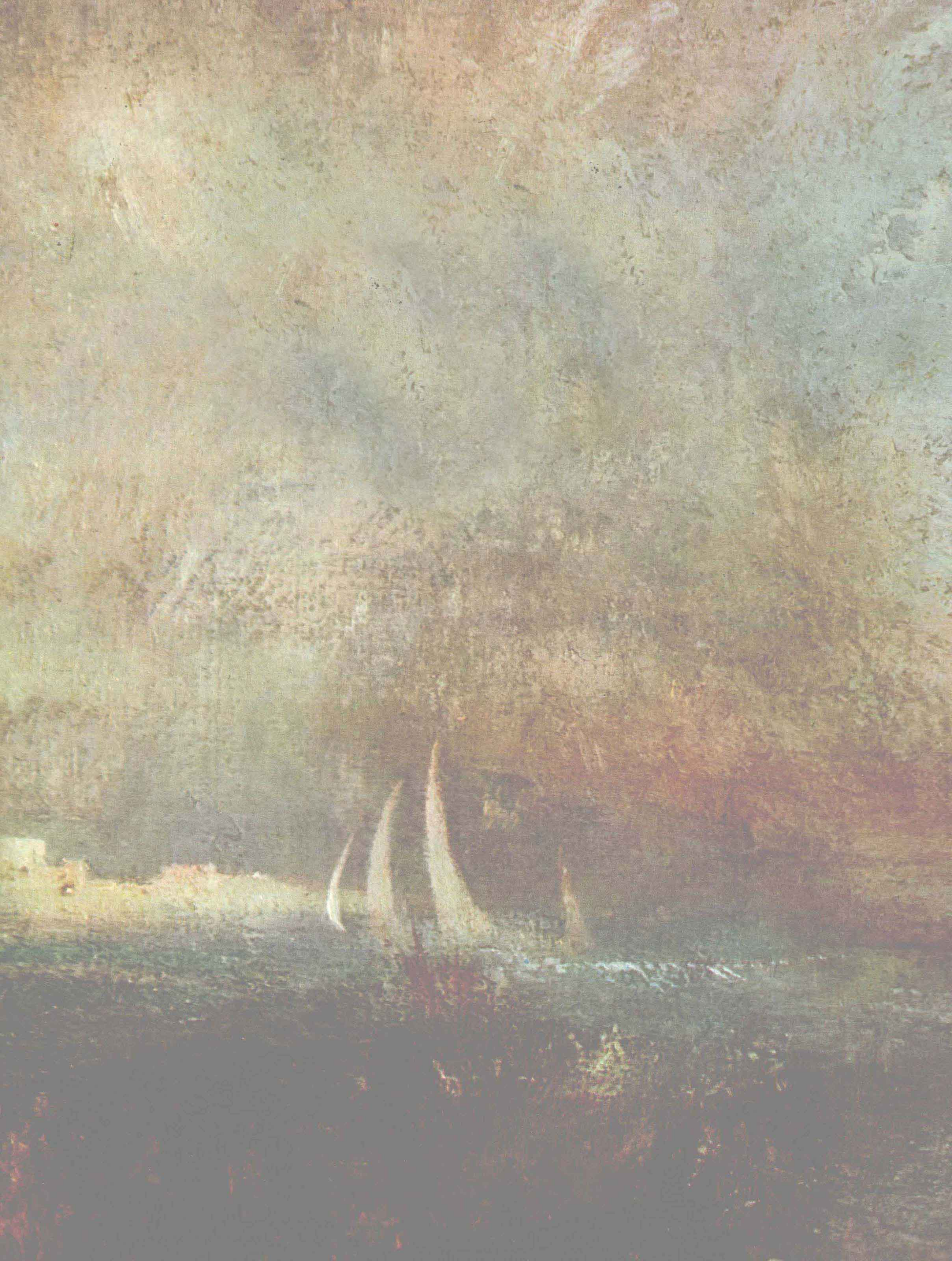
SEAS, MAPS, AND MEN:

An atlas-history of man's exploration of the ocea

A book for all those who feel the fascination of
seas—and enjoy the stories of men who explore th
Rich with full-color illustrations, including new, un
maps of the landscapes *under* the deeps and sha

SEAS, MAPS, AND MEN



SEAS, MAPS, AND MEN

An Atlas-History of Man's Exploration of the Deep

General Editor G. E. R. Deacon, C. B. E., F. R. S.
Director, National Institute of Oceanography, England

CRESCENT BOOKS

Contents

Acknowledgment is made for various quotations appearing in this book: pp. 66–73 from *Nautilus 90 North*, by Commander William Anderson and Clay Blair, Jr., by permission of Hodder & Stoughton Ltd., London; pp. 57 from *The First Crossing of Greenland*, by F. Nansen, by permission of Longmans, Green & Co. Limited, London; pp. 57–65 from *Farthest North*, by F. Nansen, by permission of Constable and Company Limited, London; pp. 36–45 from the *Journals of Captain Cook on his Voyage Of Discovery*, ed. by J. C. Beaglehole, by permission of the Hakluyt Society.

Library of Congress Catalog Card Number 62-14615

Printed in Yugoslavia by Mladinska Knjiga, Ljubljana

About this Book

To an observer in space the planet Earth would appear as a globe largely covered by water. The continental gardens and lesser islands rising out of the sea occupy only 29 per cent of the total surface area of the planet and are surrounded by water with an average depth ranging from two to three miles. Throughout geological time there have been many dramatic changes in the level of the sea in relation to the land. At times a substantial portion of the oceans has been locked up as ice, and coast lines everywhere have been altered. At other times subsidence has drowned coastal areas and cities – sometimes overnight. Today about half of the three hundred major ports and coastal cities built between 3000 B.C. and the fall of the Roman Empire are submerged and many are being excavated by underwater archaeologists.

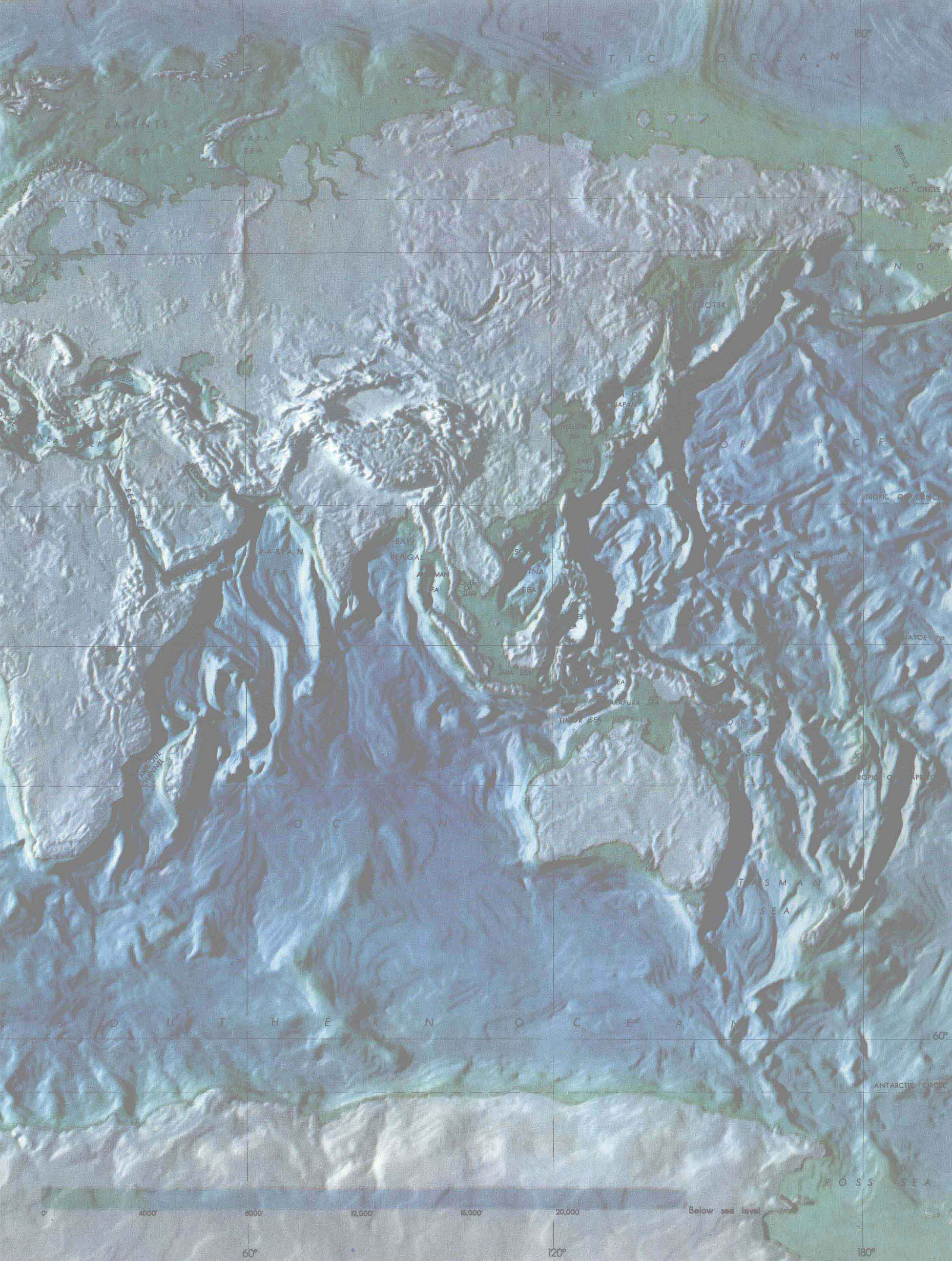
Man's exploration of the oceans began long before recorded history. Curiosity must have been one of the motives but the main inducements were the search for food and wealth. During the fifteenth and sixteenth centuries the search for trade routes to the East and the discovery of new lands were the main driving forces. Soon after James Cook's famous voyages in the late eighteenth century most of the great geographical puzzles of the oceans had been solved. In the following century oceanography was to receive its greatest stimulus from science, which sponsored expeditions like the three-year voyage around the world of the research ship H. M. S. *Challenger*. Today the scientific exploration of the oceans is being carried out by many nations. Like the earlier explorers, the scientist-explorers of the twentieth century continue to search the sea for food, but in addition they are looking for ways to tap the vast mineral wealth and to harness the energy locked up in the oceans; but perhaps more important are the basic studies that are refining our knowledge of the great chain of life in the seas, the currents, the action of waves and tides, and geological and geophysical aspects of the sea floor.

The shadow relief maps appearing throughout this book stress the features of the ocean floor rather than those of the land. In most of the maps, therefore, the coloring of the land has been subdued or treated in such a way that the reader's eye is directed to the sea areas. Wherever physical configuration of the ocean floor is important, relief coloring has been used: the lighter blues denoting shallower water and the darker blues deeper water. In many maps color is used to provide additional information. For example, a range of red tones on the currents map (pages 204-05) shows the surface temperature of the sea. On another map a sequence of colors ranging from yellow to green denotes the relative fertility of the sea. Keys accompanying all such maps explain the meanings of the colors.

The world map on pages 6 and 7 shows the main features of the ocean floor – the great abyssal plains, mountain ranges, ridges, and continental shelves. The coloring of the water ranges from light blue (shallow water) to deep blue (deeper water). ▶

Wolfgang Foges EDITORIAL DIRECTOR
Roy A. Gallant EDITORIAL ADVISER
Shirley Carpenter GEOGRAPHICAL DIRECTOR
Hans Erni ART DIRECTOR
Judy Hannington ART EDITOR

180°
120°
60°
ARCTIC OCEAN
BEAUFORT SEA
ARCTIC CIRCLE
BERING SEA
GULF OF ALASKA
HUDSON BAY
NORTH
TROPIC OF CANCER
GULF OF MEXICO
CARIBBEAN SEA
OCEAN
EQUATOR
SOUTH
PACIFIC OCEAN
ATLANTIC
STR. OF MAGELLAN
SOUTHERN OCEAN
ANTARCTIC CIRCLE
WEDDELL SEA
ROSS SEA
Equatorial scale
1000
0
1000
2000
3000
4000
Miles



120°
180°
BARENTS SEA
ARCTIC CIRCLE
BERING SEA
YELLOW SEA
EAST CHINA SEA
RED SEA
BAY OF BENGAL
GULF OF SIAM
JAVA SEA
TIMOR SEA
ARAFURA SEA
TASMAN SEA
S O U T H E R N   O C E A N
60°
ANTARCTIC CIRCLE
ROSS SEA
0'
4000'
8000'
12,000'
16,000'
20,000'
Below sea level
60°
120°
180°

The Earth and its Oceans

T. F. Gaskell

If the Earth were formed from four to five thousand million years ago, as we now believe, and if the oceans were formed soon afterwards, then our planet's mantle of water is very old. Even though we have no direct evidence of what happened in those misty beginnings, we can deduce a sequence of events that might account for the formation of our planet and its restless seas.

On the one hand, the Earth and its companion planets making up the solar system could have been formed cold – as a result of large nuclei of matter sweeping up gas, dust, and solid particles spread out around the newborn Sun. Over millions of years this sweeping-up process would have continued, each planetary nucleus capturing and drawing into itself larger and larger aggregates of matter.

On the other hand, according to a quite different theory, the Earth was formed hot, having condensed from a whirling mass of hot gaseous material thrown off from the Sun. Whether the Earth was formed hot *or* cold, there is little doubt that soon after its formation it became a molten globe. If not, then we have no satisfactory way to explain the distribution of heavy and light matter within our planet. We now know that the core is made up of the densest material, iron-nickel, and has a diameter of about 4000 miles. Surrounding the core is the mantle, 2000 miles deep and made up of lighter silicate rocks rich in iron and magnesium. The outer shell of the Earth, a five- to twenty-mile-thin crust, is made up of still lighter rocks – the kinds we see at the surface.

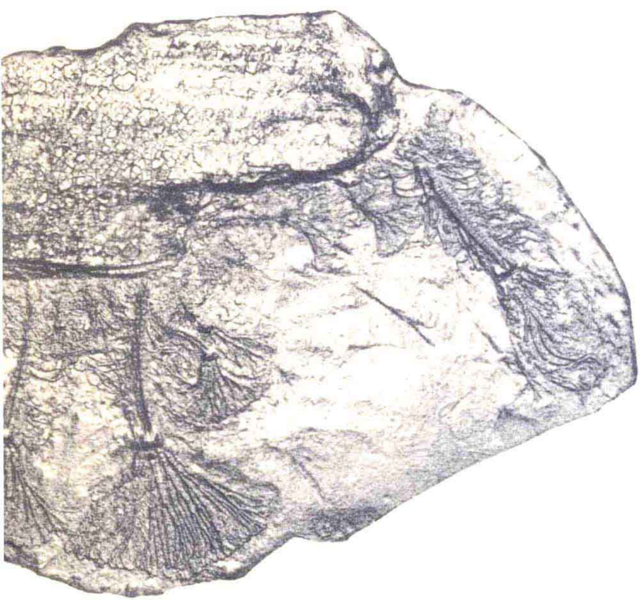
As a molten globe, the Earth would have lost heat rapidly. In about 10,000 years it would give off enough heat to allow a substantial part of the crust to solidify. It was sometime during this infant stage in the Earth's life that the oceans began to form. At first, the water that later flowed into land basins was locked up in the molten rock since at high temperatures and pressures water and rock can mix in any proportion. But as the primordial rock cooled and solidified, the water was squeezed out, evaporated, and added to the Earth's primeval atmosphere. It was a fortunate chance that the Earth was large enough to retain its atmosphere, for unless a planet is of a certain minimum size it cannot hold an appreciable atmosphere by gravitational attraction, so the atmosphere will leak off into space. There is no atmosphere to speak of on the Moon, and relatively little on Mars.

While the crust was cooling and giving off water vapor to the atmosphere, massive clouds formed and released rain in torrents. For how many tens or hundreds of years the first rains poured down onto the cooling crust – first steaming back into the atmosphere because the surface rocks were still above the boiling point of water – we cannot say. But gradually the surface rocks grew cool enough so that the rains no longer boiled away. The waters collected in pools, cascaded into depressions and flowed as rivers, sculpturing the land and ever seeking the lowest levels. Gradually the first basins began to fill, but they were not the sea and ocean basins we know today.

"And the spirit of God moved upon the face of the waters." This medieval impression of the Creation Story is depicted in a mosaic of 1182 in the dome of Monreale Cathedral, Sicily. (Only a section is shown here.)


INPNCIPIO
CREAVIT
DS CELV ATRA

These chalk cliffs at Etretat, Normandy, are slowly being cut away by wave action. It is in sedimentary rocks like these, which have been uplifted from the sea floor, that fossils of sea creatures are found. Below is a fossil of a sea lily which grew on the sea floor in Mesozoic times.



The distribution of water over the Earth has changed throughout geological time. Today 70.8 per cent of our planet's surface is covered by oceans that average two to three miles deep, the total water area being 139,480,000 square miles. The rocks composing the floors on which the deep water rests are quite different from the rocks making up the continental gardens that rise out of the seas. The floors of the large, deep oceans appear to be permanent and not to change places with the continents by buckling and rising up to the surface, but this is not to say that the ocean floors are flat, featureless expanses. Wrinkling of the deep-ocean crustal rocks has formed a network of great mountains and valleys ranging over the floors of the oceans. Valleys like the Marianas Trench in the Pacific could accommodate Mount Everest with room to spare. But the crustal rocks under these deep oceans are only a few miles thick compared with the twenty miles or so of the continental gardens.

When geologists examine rocks they try to picture what forces were at work inside our planet when the rocks were formed. Solidified lavas are the result of great outpourings from ancient fissures or from volcanoes. Other rocks, such as limestones and sandstones, are shallow water deposits compressed by their own weight in the course of time, and they often contain abundant remains of animal life that existed when the fine deposits began to rain down. These animal remains provide wonderful markers for the geologist. While some plants or animals continue to evolve gradually, others suddenly die out and may be replaced by still others, so the existence of certain characteristic fossil remains of past life gives the geologist proof that a rock was formed during a certain period in geological history.

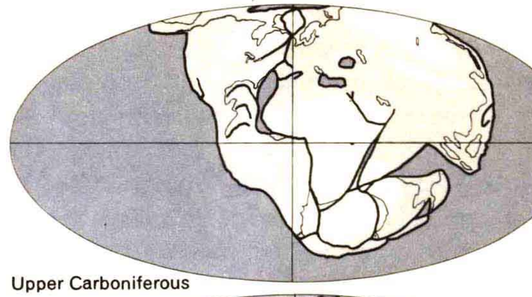
By examining rocks from different parts of the world we can tell which parts of the continents were covered by water at any particular time. About a hundred million years ago the whole of southeast England was a shallow sea in which thick deposits of chalk were being laid down. This sea extended across the present site of the English Channel into Europe. In a similar way large parts of the North American continent have been submerged by shallow water at one time or another. The continental areas have been subjected to a continuous series of warpings and tiltings. Great mountain ranges such as the Rockies and the Himalayas were formed of shallow water deposits together with volcanic lavas which forced their way to the surface when these deposits were being folded and pushed upward. These mountains are already being worn away by wind, frost, and rain to form new sedimentary rocks. And so the process of reworking the continental rocks goes on inexorably with the world distribution of shallow seas varying from one geological period to another.

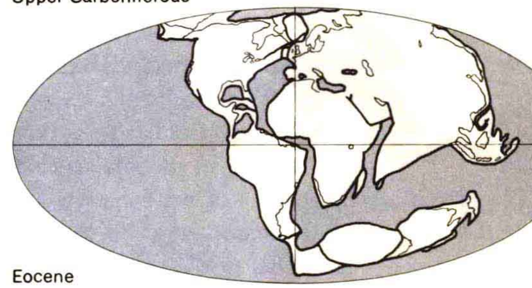
Some of the geological reconstructions of the shallow seas of the past do not make sense, and there is a large body of evidence suggesting that entire blocks of continental rock have moved as a whole relative to each other. A glance at the map here will show, for example, that Africa and South America would fit together very well if we could move them toward each other across the Atlantic. And the fit is even better if the continents are joined at the edges of their continental shelves, rather than at the present-day coast lines.

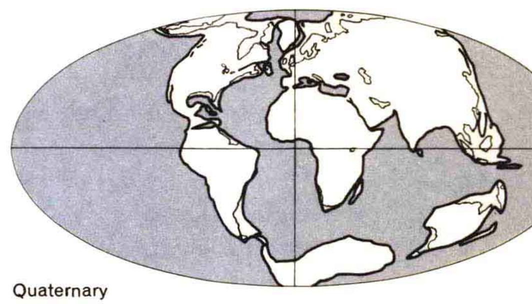
We can carry this exercise even further by grouping all the continents to form one large land mass, which has been called Pangaea. Such a reconstruction fits India neatly between south Africa and Antarctica, with Madagascar and Ceylon forming useful space-fillers. The German geologist Alfred Wegener and his associates worked very hard on this type of jigsaw puzzle, and Pangaea is only one of the super-continent possibilities that exist. Their arguments do not rest merely on the fitting together of shapes. Rock formations of some of these separate land masses show a strong correspondence both in the continuity of mountain ranges and in the composition of the rocks themselves.

This theory of continental drift has attracted strong criticism because it is difficult to visualize solid granitic continents moving about through the dense, basaltic rock floor of the oceans. However, the most recent evidence shows that time seems to be on the side of some kind of slow drifting. Possibly there have been heat changes in the past which permitted large-scale continental movement.

Although the Earth has been cooling since it was first formed, there is a built-in heat generator in the crust and mantle rocks – the inexorable decay of radioactive atoms. Rock is a poor conductor of heat and it forms a blanket which keeps heat inside the Earth. There may, therefore, be periods when the upper part of the mantle is warming up. Earthquake studies have shown that there is a layer of rock about a hundred miles within the mantle which appears to be softer than the normal mantle rock above and below. This could be the effect of a zone of excessive heating, and it may be that from time to time this zone slowly moves toward the surface of the mantle. When it reaches the crust it provides a soft layer on which the continents can move about. There would then be enormous volcanic activity, and heat would be released to such an extent that the mantle would become completely solid, and once more another steady regime of slow accumulation of heat would begin.







According to Wegener's theory of continental drift, the continents known to us today were once a unified land mass that separated into segments, which drifted to their present positions. Pale blue indicates shallow seas; deep blue, deeper oceans. Present coast lines are shown for identification.

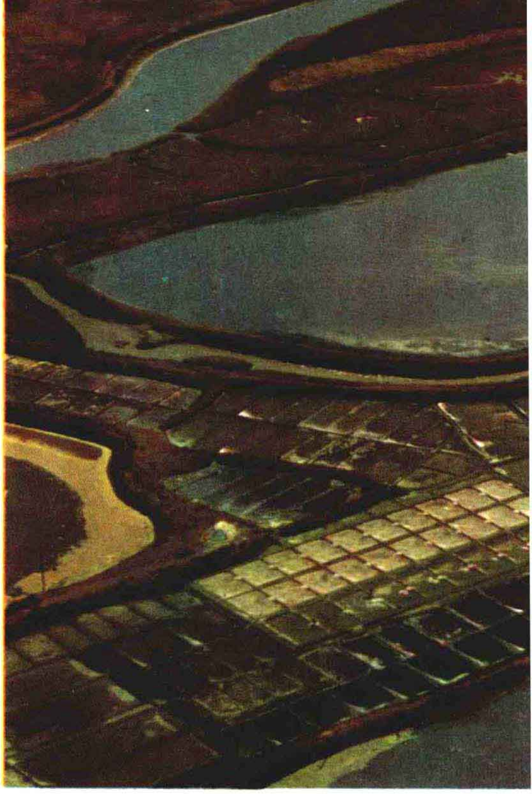
As the distribution of the seas has changed imperceptibly through time, so has their composition. The primeval seas became salty as streams and rivers feeding them washed and dissolved minerals from the land. Although common salt is the main dissolved material in sea water, many other compounds and elements exist in varying proportions. Since the volume of the sea is so great – 330 million cubic miles – the total weight of valuable metals (although they are present in very small concentrations) exceeds that to be found on the land. Industries thrive on the bromine mined from sea water, and fish grow fat and healthy with the help of small amounts of cobalt, nickel, and vanadium that are circulated from the sea-bed sediments by the ponderous underwater movements that form the ocean currents.

From the early days of oceanographic studies we have known that the salinity of sea water varies from place to place, and from shallow to deep water in any one location. As we shall find in the last chapter of this book, salt is one of the markers which tell the oceanographer where the currents are flowing, but the sea is not well stirred; each individual current, like the famous Gulf Stream, keeps its entity for thousands of miles, although a little mixing occurs at the fringes. But the body of water moves on, labeled by its salinity and its temperature until it loses its identity in the shallow seas. In general, cold, salty water sinks and warm water, together with fresh water from rivers, floats on top. These different streams of water circulate round the oceans. Not only do they affect navigation, but their continual stirring and upwelling bring the necessary nutrients for animal life up from the nutrient-rich deep layers. In the relatively still subtropical areas there is usually a dearth of plankton – the basic food of larger fishes. There are few plankton because there are few fresh chemicals brought to the surface layers.

Because the surface of the oceans is exposed to the air and to the warmth of the Sun's rays, evaporation takes place. However, since the oceans are so deep, and because water has a large capacity for holding heat, the temperature of the water stays more or less the same. But in inland lakes like the Dead Sea evaporation leaves great concentrations of dissolved salts, and eventually thick deposits of valuable materials containing sodium, potassium, iodine, and other elements are laid down. A similar process sometimes takes place near shore when deposits of mud form shallow pools, the water of which alternately evaporates and is replenished. In such cases salt deposits are interleaved between the clays and limestones that are formed.

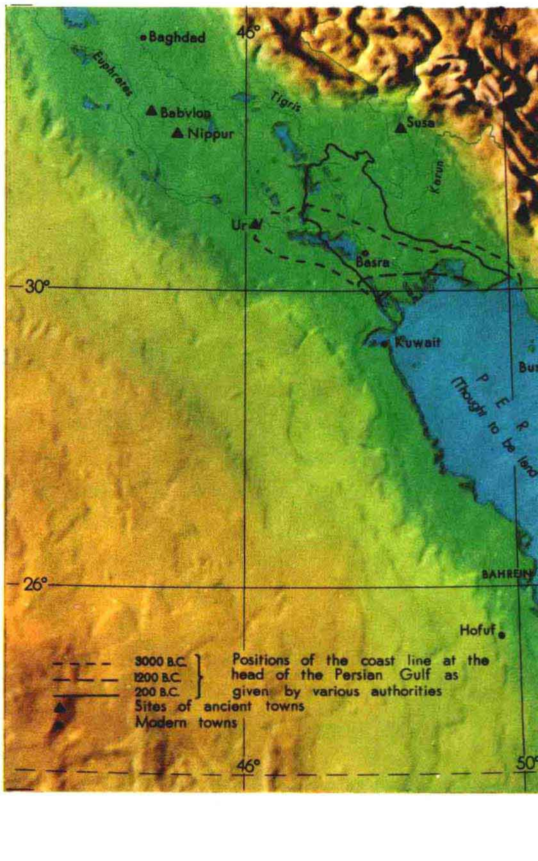
In the deep oceans the deposits are different. Sometimes shallow water material is carried far out onto the abyssal plains of the deep ocean floor by turbidity currents which tumble as underwater avalanches down the continental slopes, but the general picture is one of slow and steady settlement of minute, solid particles from the water. This rain of material includes the skeletal remains of small animals, pebbles carried by ice or by floating tree trunks, fragments of pumice from volcanic outbursts, and dust from outer space. The rate of accumulation of this material on the sea bed is unimaginably slow.

Age after age such material has been filtering down continuously to the sea floor. Once it is encased in sediments, which can

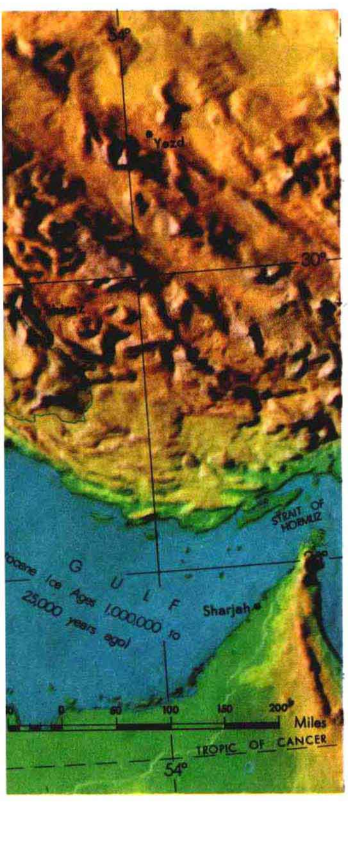


At Batz, near St. Nazaire, Brittany, sea water is pumped into large enclosures called "pans," where it is allowed to evaporate. The remaining salt is then raked into piles.

Within historical times the land has gained over the sea in the Persian Gulf area. Over the years the Tigris and Euphrates rivers have altered the coast line by carrying sediments far out into the gulf. Coast line positions since 3000 B.C. are shown according to various authorities.



be dredged up and studied by the oceanographer, it becomes a book to the past, providing a record of twenty-million-year-old volcanic eruptions, or spasms of prolific animal life. But recently an even more subtle way has been devised to trace back into geological history and reveal past surface temperatures of the oceans. When water evaporates, those water molecules that contain the lighter isotope of oxygen are lost more rapidly to the atmosphere than are the heavier water molecules. During warm conditions the surface water contains an extra abundance of heavy oxygen isotopes, and this is reflected in the composition of animals which grow and live near the surface. When the animals die and sink to the sea floor their skeletons have locked up inside them the oxygen isotope ratio from which the surface temperature can be calculated. So besides the qualitative evidence of cycles of activity in geological history, the sediments of the ocean floor contain a history of the environmental conditions.



The oceanographer must take great care when he collects samples of these ocean sediments. Deposits from turbidity currents can mislead him; also, there are burrowing animals that live in the top few feet of the sea floor. These creatures have been brought up in core samples, and they have been seen by oceanographers who have penetrated the deeps in bathyscaphes. The difficulty of selecting an undisturbed sediment hunting ground is one with which geologists are familiar in their work on land.

Seismic measurements in the oceans show that more than a thousand feet of claylike material covers the deep, flat parts of the oceans. Compared with the rate of sedimentation in shallow water – 40,000 feet have accumulated in the Persian Gulf in the last hundred million years alone – this is only a thin veneer of material. Until we can study cores brought up from the bottom part of the

In parts of northern Canada and Europe great stretches of barren rock lie exposed. These areas were scraped clean by the massive ice sheets that advanced southward during the last ice age. As the ice melted, thousands of lakes were formed in the rock hollows.

sea-bed sediments, we cannot be certain of the history of the oceans. Such a core sample down to the rock bed of the sediments is the oceanographer's dream, and we seem to be on the verge of realizing it. In March 1961, oceanographers working on the Mohole Project (an attempt to drill a hole right through the Earth's crust to the mantle) at Guadalupe Island went through two miles of water, 500 feet of sediments, and fifty feet of rock. More core samples of such great depths would add enormously to our knowledge of the oceans' history.

From time to time throughout geological history great quantities of the Earth's water have been locked up as ice during ice ages. We are, in fact, today living in the dying grips of an ice age which reached its fourth climax about 10,000 years ago, and which began between 500,000 and a million years ago. About one-tenth of the total land surface is glaciated today.

While the continents move up and down on a time scale represented by tens to hundreds of millions of years, invasions and retreats of ice over large parts of the land may take place over periods of tens of thousands of years. Although there is no general agreement about the mechanisms that touch off an ice age, we do not have to take them on trust, as we do wandering continents. The Greenland and the Antarctic icecaps and the glaciers of the Alps and other mountains are there for us to examine, and we can see the marks that glaciation leaves behind. These same marks – rocks scarred by ice, valleys with rounded slopes, deposits of material at the foot of glaciers – can be seen in ancient rocks. At least three other major periods of glaciation have been discovered, ranging back to the Pre-Cambrian of 700 million years ago.

The amount of water locked up as ice during an ice age is an appreciable fraction even of the enormous volume of the oceans. For example, if the Greenland and Antarctic icecaps should melt suddenly, the level of the sea would rise by about 300 feet – enough to turn New York, London, and Paris into underwater cities. But the picture is not quite so simple; as the great weight of ice is removed from the land, the land rises up, causing subsidence elsewhere. By examining old shore lines we find that interglacial periods have taken place in the past, during which most of the Earth's ice must have melted. We can estimate the dates of these warming-up periods from fossil evidence and carbon-14 dating, which is more precise for recent times (the last 20,000 years). From 18,000 to 6000 years ago the seas have risen nearly 300 feet, so it is not surprising that early records of man's history mention floods and deluges. A sea-level rise of 300 feet today would alter all but the steepest rising coast lines and flood many of our most concentrated centers of population, simply because such a great percentage of the land is relatively low. This has undoubtedly happened at least once during man's period of habitation of the planet. At the end of the last interglacial period, such large-scale flooding over the earth must have taken place. Although the rise of sea level averaged only one foot in forty years during a warming-up period, the past encroachment of water over certain areas would almost certainly have been in catastrophic bursts, when rain and wind and tide conspired to produce great floods.

The present sea level has been maintained within about ten feet either way for the past 6000 years, but that does not mean that the present cycle of ice ages has come to an end. There could be another advance of ice over the land with the consequent reduction of sea level by about 300 feet. On the other hand, the ever-present threat of the Antarctic and Greenland ice melting, with a consequent rise of 300 feet in sea level, is still with man.

Although we do not know just what controls the delicate balance, it seems probable that both the major icecaps provide some sort of stability. They appear to be held in deep basins by rings of mountains, whereas the ice sheets which covered Canada, part of the United States, Asia, and northern Europe were not held and could spread out thinly and so be more readily dispersed. It is important, then, to measure the present-day rate of snow accumulation on the icecaps and compare it with the rate of evaporation, and to measure the escape of ice that plunges over the rims of the containing mountains and tumbles into the sea.

It is an easy matter to explain the rise and fall in sea level: glacial ice simply melts and becomes part of the sea or water freezes. But the mechanisms that touch off these processes are much more difficult to explain. We have already seen that the radioactivity of the mantle rocks may provide a periodic heating up of the Earth's crust and so alter world climate from time to time, and there are other mechanisms that may be associated with warming our planet. Changes in the carbon dioxide content of the atmosphere, for instance, may affect world climate. An atmospheric blanket of carbon dioxide would produce a greenhouse effect and trap the reflected long-wave (heat) radiations of the Earth and so trigger off a warming up period which would melt the remaining ice and drown all the low-lying land. However, carbon dioxide is absorbed in sea water, and circulation of the large volume of water in the oceans may be adequate to preserve a fairly constant balance of carbon dioxide between air and water and thus provide a steadying influence.

But there are other ways of shielding the Earth from the Sun's rays and thus upsetting the delicate balance which controls climate. The Earth could become enveloped in a cloud of meteoric dust; continuous volcanic activity over a long period of time could throw up a screen of fine ash in the sky; or there could be a long-term change in the intensity of solar radiation. Also, a change in inclination of the Earth's axis could cause the regions of ice to shift location. It would seem that any number of these conditions could conspire and touch off another period of cooling. A cooler Earth would have longer and more severe winters. Snow rather than rain would fall and would tend to remain rather than be melted and washed away. Thick accumulations of snow would form ice patches and in turn these would grow into icecaps or glaciers, which creep downhill forcing a retreat of life before them.

But the slow march of glaciers does not constitute the entire invasion of ice. The extension of winter conditions far away from the polar regions, plus the slow accumulation of snow, are the real mechanisms that advance an ice age. And the sea is the provider of the snow. During an ice age it may give up as much as two to five per cent of its volume in the form of ice and snow, but when the mechanisms that touch off the ice age reverse, the sea reclaims its loss as the ice melts. And so the cycle goes on, apparently without end, from water to rain and snow and ice and then back to water again.

If the Greenland and Antarctic icecaps should melt suddenly, the level of the oceans would rise about 300 feet. This would turn New York, London, Paris, and Tokyo into submerged cities, leaving only the tops of the highest buildings rising out of the water.