EARTH SCIENCE

How a world came to be

Birger Schmitz revels in an account of how life and rock evolved together on Earth.

Without geologists, the Western world would probably still hold to the biblical account of how Earth and life were created. Over the past couple of centuries, thousands have devoted their lives to meticulous studies of rocks — analysing the detailed record of what happened on our planet throughout the ages. In *The Story of Earth*, geologist Robert Hazen summarizes elegantly the modern story of creation.

Drawing on the latest research and influenced by advances in astrobiology, Hazen takes a radical standpoint. He introduces the concept of "mineral evolution" — changes in the composition of Earth's rocks — to tell the amazing tale of our planet's intertwined living and non-living spheres.

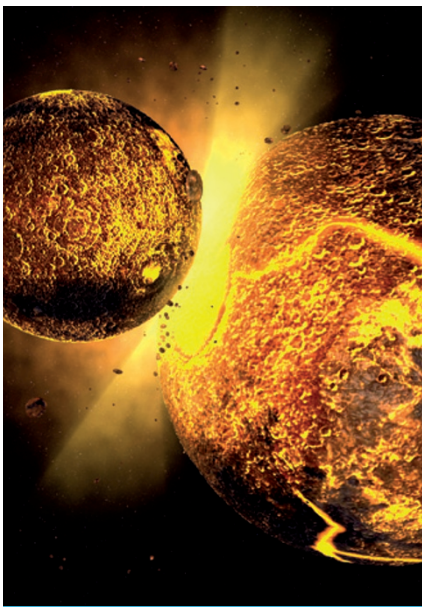
Hazen's saga starts 4.6 billion years ago, when the Solar System formed from a gigantic gas cloud, made up mostly of hydrogen with some helium. The Solar System is a relative newcomer to the Universe, which is three times older. Pristine asteroids that condensed when the Solar System formed and later fell to Earth as meteorites tell us about its origin. The young Earth evolved quickly, within a million years of the Solar System's formation. But 50 million years later, a Mars-sized body dubbed Theia collided with our planet. From the ejecta, the Moon formed.

We have no direct record of what happened on Earth during the planet's first 800 million years because no rocks remain from this time. But Moon rocks, gathered mostly by NASA's Apollo missions of the 1970s, reveal that the Moon and Earth were bombarded heavily by huge asteroids. Almost all of the Moon's craters are from this hellish era; Earth's surface was probably blasted away during it.

How did life begin? Hazen tells the inside story of an experiment at the University of Chicago, Illinois, in the 1950s. Chemists Harold Urey and Stanley Miller used electric sparks to simulate the effects of lightning on a mixture of boiling water and gases meant to mimic the composition of the early Earth's atmosphere. A soup of biomolecules formed, including amino acids and carbohydrates, apparently answering the question of the origin of life. Urey and Miller's influence on the field was so strong, Hazen explains, that competing ideas were obstructed for three decades.

The current view is that the building blocks of life can be produced in any environment, given sources of energy and small carbon-bearing molecules. Lightning is not necessary. Amino acids even abound in some meteorites that come to Earth from the apparently sterile Asteroid Belt.

The first single-celled organisms probably originated around 3.8 billion years ago. In one of the most crucial events in Earth's history, they started to use photosynthesis, and pumped highly reactive oxygen into the atmosphere. About 2.5 billion years ago, the surface of Earth turned from black to red when the basalt crust rusted into soil rich in iron oxide. But it took a much longer time to build up oxygen levels in the oceans.



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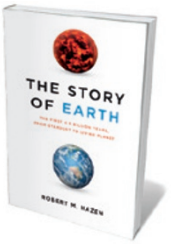
Earth was shaped by violence, including a collision with Theia that created the Moon.

In a period known as the 'boring billion' years, from 1.85 billion to 0.85 billion years ago, the rock record shows no obvious transformative events. The deep ocean was anoxic and inhospitable. But in regions — both at sea and on land — that had been oxygenated, new minerals began to form. Of the roughly 4,500 terrestrial minerals known today, two-thirds could not have formed without oxygen. Beautiful turquoise, azurite and green malachite exist on a fundament provided by the early single-celled organisms.

From about 0.8 billion to 0.5 billion years ago, Earth experienced its most dynamic transformations. They began with three episodes of near-global glaciations — the Snowball Earth. We do not know why Earth suddenly cooled, but we can be thankful for the anomalous behaviour of water. Unlike most compounds, water has a solid phase that is less dense than its liquid phase. If ice did not float, the oceans would have frozen from the bottom up, and would have stayed like that for ever.



The Story of Earth: The First 4.5 Billion Years, From Stardust to Living Planet
ROBERT M. HAZEN
Viking Books: 2012. 320 pp. $27.95, £17.50

During the Snowball Earth, there were no abundant organisms to remove volcanic emissions of carbon dioxide from the atmosphere. A super-greenhouse effect developed and led to rapid melting of the ice. In the wake of Snowball Earth, around 650 million years ago, multicellular organisms evolved. And with the Cambrian Explosion of biodiversity 540 million years ago, all the modern animal phyla arrived. The first organisms with protective shells evolved. The prey–predator game began.

Hazen includes surprises such as that the Earth has an enormous hidden "water ocean". Until the 1990s, the surface oceans were thought to be the largest water repository, storing about 96% of Earth's accessible inventory. But studies of interactions between minerals and water under high pressure now tell us that there is 25 times more water stored in Earth's mantle as in the seas. If it were not for this water there would be no plate tectonics, and no continents. Without continents, no life-sustaining nutrients would have been transported to the oceans by rivers.

Hazen has done his job well. His concise and colourful story of the evolution of our planet and life — how they started from dust, how the evolution of minerals and organisms is intertwined, how the sequence of events depends on countless improbable "if nots" — makes it seem a miracle that we and the rich and diverse nature around us exist. What a wonderful Earth. Let us not destroy what took 4.6 billion years to create. ■

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