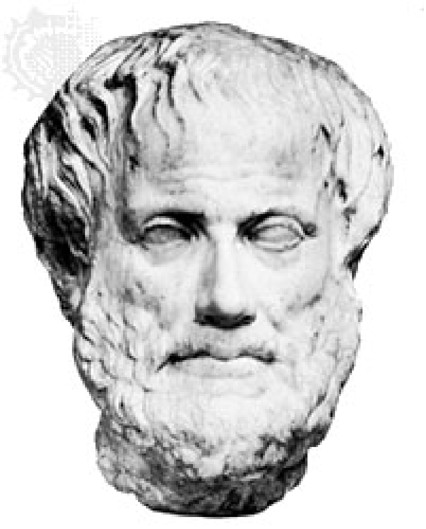
Research History
Physical Geography

The art of reasoning backward:

Most people, if you describe a train of events to them, will tell you what the result would be. They can put those events together in their minds, and argue from them that something will come to pass. There are few people, however, who, if you told them a result, would be able to evolve from their own inner consciousness what the steps were which led up to that result. This power is what I mean when I talk of **reasoning backward**....

-Sherlock Holmes



With the rise of the ancient Mediterranean civilisations of Greece and Rome came the first written accounts of places, landscapes, crops etc.

With some justification, **Aristotle** (384-322 BC) can be said to represent one of the early outstanding individuals in the history of geomorphologic research and thought.

As a Greek, **Aristotle was not constrained by religious inhibitions and a priori reasoning**, and he advanced the idea of a spherical rather than a flat earth and introduced global features such as latitude and longitude.

Among several other intellectual achievements, he theorised about the condensation of atmospheric moisture, the origin of rivers, and from the presence of rock strata he deducted the transition from terrestrial to marine conditions.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SAHARA ATLAS
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Rhodos

Embryos of modern science such as chemistry and weathering however germinated in Arabia, in the area around the rivers Tigris and Euphrates, present Iraq.

While the thinking of European people then was seriously bounded by Catholic theological belief, an Arabic classic named (in translation) ***The Discourses of the Brothers of Purity*** was written in the tenth century in Basra, southeastern Iraq (Said 1950).

This book includes a variety of remarkably modern geomorphological ideas and furthermore contains the earliest known mention of peneplanation, pond evolution, epicontinental seas, weathering, erosion and transport by streams and winds.

Ideas changed little during the Middle Ages when **European scolars returned to the concept of a flat earth** to conform with ecclesiastical teaching.

Certainly the idea that streams have sufficient power to erode their valleys was recognised by few outstanding European individuals such as **Leonardo da Vinci** (1452 -1519), but it was not until the late eighteenth century that the implications of this fundamental concept began to be fully explored.

Up to that time, in the Christian part of the world, the geological timescale was adopted from Bible studies, and it was generally **assumed that the earth was some 6,000 years old**.

Francis Danby (1793-1861): Syndfloden, 1840, oilpainting, 285 x 452 cm, The Tate Gallery, England

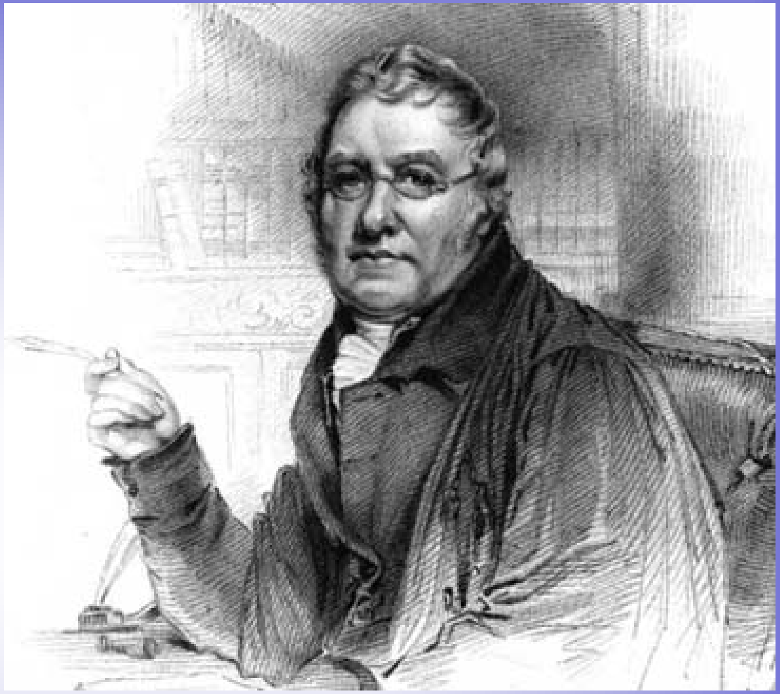
Giordano Bruno (1548-1600): The Forgotten Philosopher

In his book De la Causa, principio et uno, On Cause, Principle, and Unity we find prophetic phrases:

"This entire globe, this star, not being subject to death, and dissolution and annihilation being impossible anywhere in Nature, from time to time renews itself by changing and altering all its parts. There is no absolute up or down, as Aristotle taught; no absolute position in space; but the position of a body is relative to that of other bodies. Everywhere there is incessant relative change in position throughout the universe, and the observer is always at the center of things."

After two years in the custody of the Inquisitor he was taken on February ninth to the palace of the Grand Inquisitor to hear his death sentence, before the expert assessors and the Governor of the City Rome.

Bruno was a pioneer who roused Europe from its long intellectual sleep. He was martyred for his enthusiasm.



By the end of the eighteenth century the diluvial theory, **the proposal of the biblical Flood as a major agent in shaping the face of the earth, was being questioned**. Scientists such as **John Playfair** (1747-1819) were among the first to advance the theory of glaciation and glacier action.

The first modern geomorphic approach in the Christian part of the world was pioneered by **James Hutton** (1726-97).

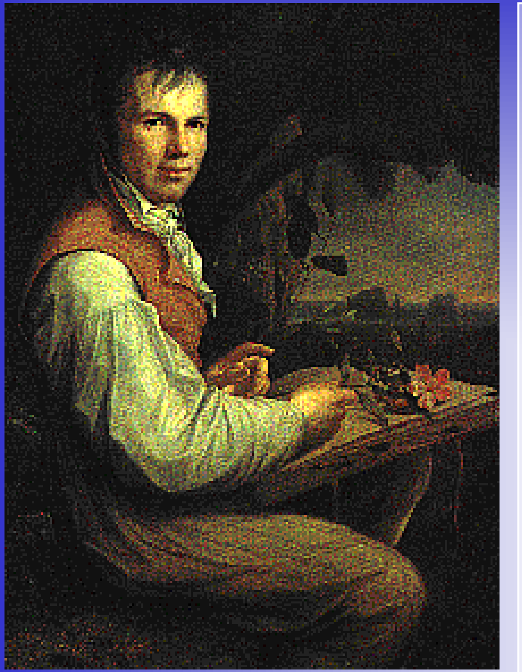
In 1785 Hutton presented a paper (1788) to the Royal Society of Edinburgh, in which he argued that **the landsurface had been shaped by the slow, unremitting erosive action of water, rather than by the catastrophic events** advocated by biblical scholars. This paper aroused little immediate enthusiasm except of hostility.

However, Hutton was not intimidated, and in 1795 he proposed what was later to be known as the Law of Uniformitarianism, which essence is that the present is the key to the past.

John Playfair 1748 - 1819

Geologist, physicist and mathematician. Born in Benvie, Playfair studied at St. Andrews. Having failed to gain professorships at Aberdeen and St. Andrews he became a parish minister.

However he was offered the Chair of Mathematics at the University of Edinburgh in 1785 and later moved to the Chair of Natural Philosophy (1805), which he held until his death. Playfair popularised the the work of James Hutton (1726-97) with his publication *Illustrations of the Huttonian Theory of The Earth* (1802).

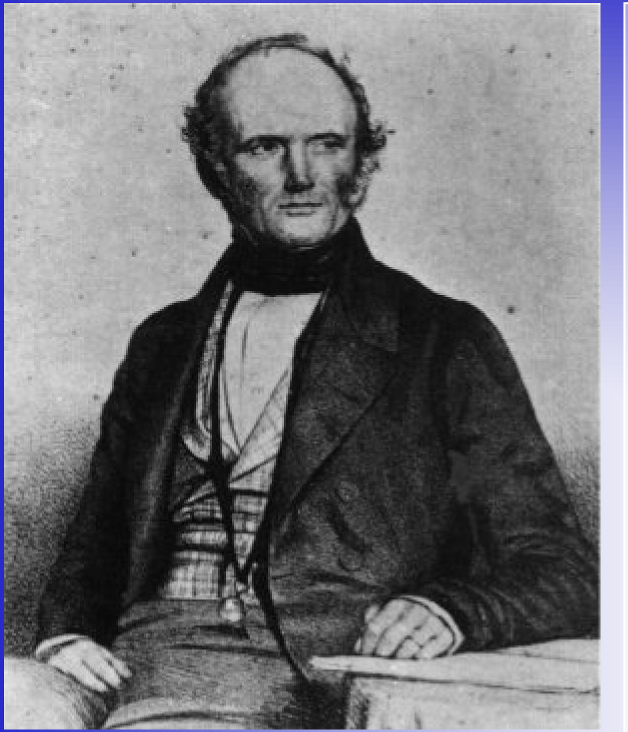


Alexander von Humboldt 1769-1859

Alexander Von Humboldt was born in Berlin, Germany in 1769. Tutors provided his early education which was grounded in languages and mathematics. Once he was old enough, Alexander began to study at the Freiberg Academy of Mines under the famous geologist A.G. Werner.

From 1827 to 1828, Alexander gave public lectures in Berlin. The lectures were so popular that new assembly halls had to be found due to the demand. As von Humboldt got older, he decided to write everything known about the earth. He called his work *Kosmos* and the first volume was published in 1845, when he was 76 years old. Von Humboldt insisted that ***empirical observations is the foundation for any theory***.

Charles Darwin later described him as "the greatest scientific traveler who ever lived." He is widely respected as ***one of the founders of modern geography***. Alexander von Humboldt's travels, experiments, and knowledge simply transformed western science in the nineteenth century.



Sir Charles Lyell 1797 - 1875

Sir Charles Lyell was born in Scotland on November 14, 1797 and died in London on February 22, 1875.

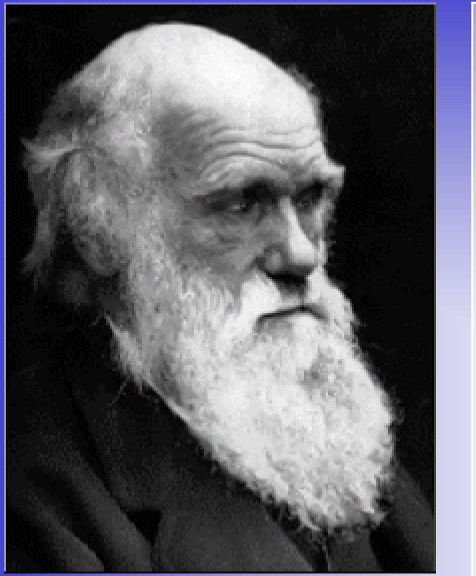
He became an author of *The Geological Evidence of the Antiquity of Man* in 1863 and *Principles of Geology* (12 editions). Lyell argued in this book that, at the time, presently observable geological processes were adequate to explain geological history. He thought the action of the rain, sea, volcanoes and earthquakes explained the geological history of more ancient times.

Lyell rebelled against the prevailing theories of geology of the time. He thought the theories were biased, based on the interpretation of Genesis. He thought it would be more practical to exclude sudden geological catastrophes to vouch for fossil remains of extinct species and believed it was necessary to create a vast time scale for Earth's history. This concept was called Uniformitarianism.

The son of a minister, Jean Louis Rodolphe Agassiz was born on May 28, 1807 in the village of Montier, in the French-speaking part of Switzerland.

Agassiz took up the study of glaciers in 1836 as something of a sideline, but his contributions made him known as the "Father of Glaciology." Observing the glaciers of his native Switzerland, Agassiz realized that in many places signs of glaciation could be seen where no glaciers existed.

Previous scientists had variously explained these features as made by icebergs or floods; Agassiz integrated all these facts to formulate his theory that **a great Ice Age** had once gripped the Earth, and published his theory in *Étude sur les glaciers* in 1840. His later book, *Système glaciare* (1847), presented further evidence for his theory, gathered all over Europe: Agassiz later found even more evidence of glaciation in North America.



Charles Darwin 1809 -1882

From 1831 to 1836 Darwin served as naturalist aboard the H.M.S. Beagle on a British science expedition around the world.

Out of this study grew several related theories: one, evolution did occur; two, evolutionary change was gradual, requiring thousands to millions of years; three, the primary mechanism for evolution was a process called natural selection.

Darwin's theory of evolutionary selection was set forth in his book called, "On the Origin of Species" (1859).

Darwin's work had a tremendous impact on religious thought, and many people strongly opposed the idea because it conflicted with their religious convictions. Darwin avoided talking about the theological and sociological aspects of his work, but other writers used his theories to support their own theories about society.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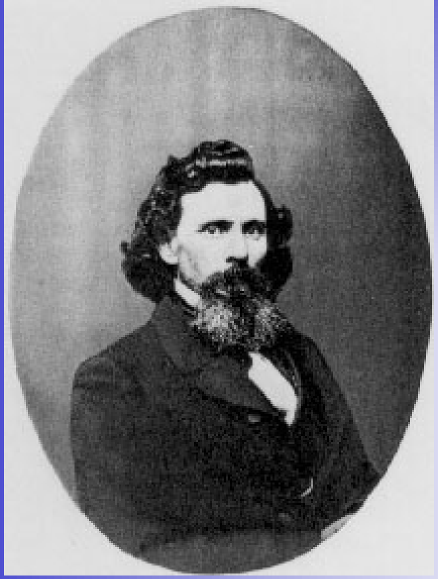
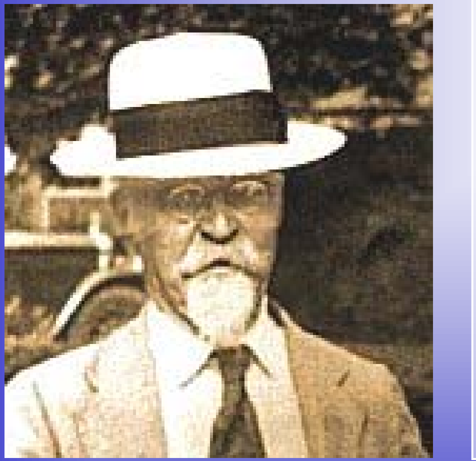


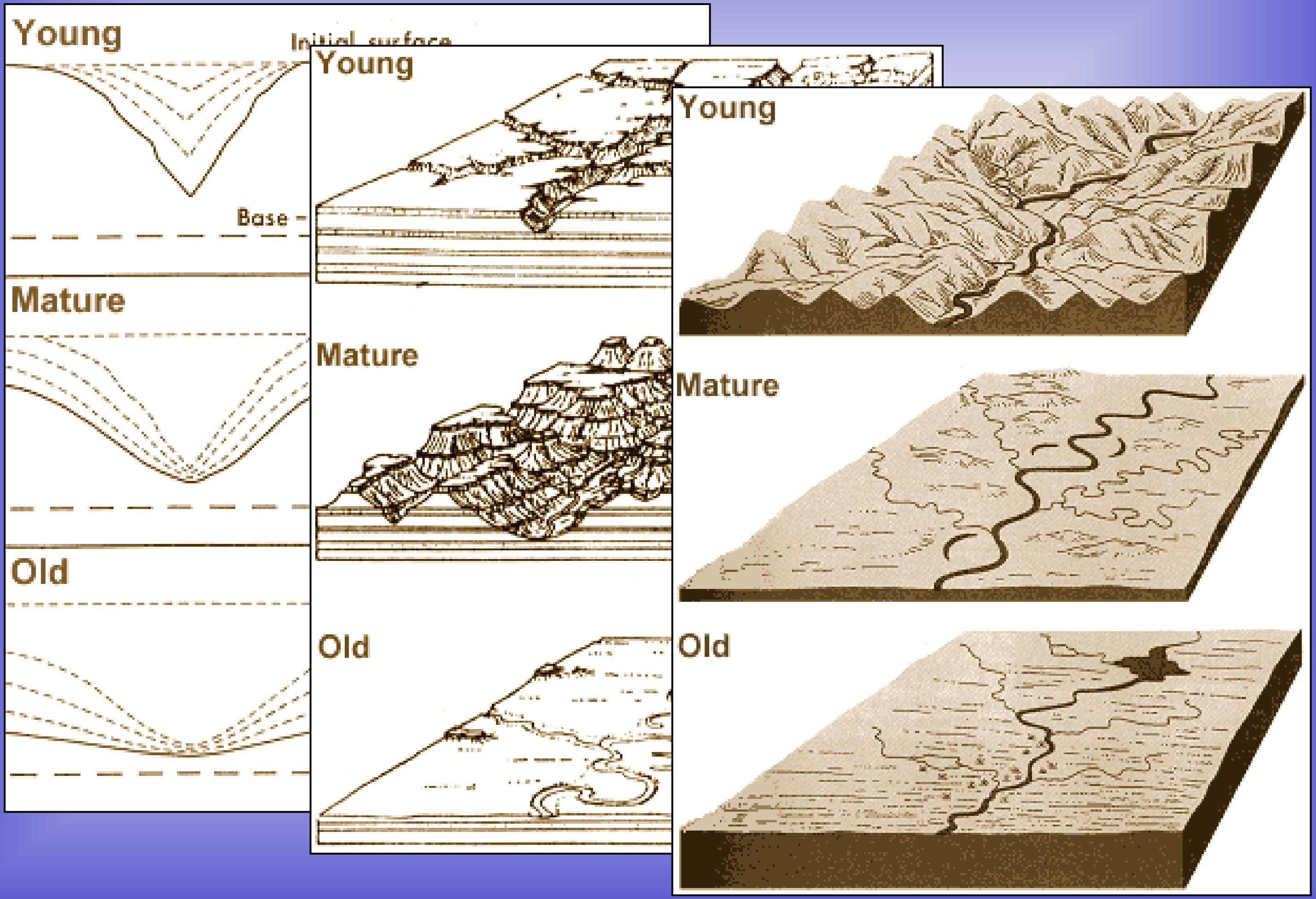


William Morris Davis 1850-1934

Davis' contributions cover the separate field of geography, geology, and meteorology. He had an emphasis throughout his career on education in both the high school level as well as the college level. Davis' most influential concept was the "**cycle of erosion**". He worked on refining and detailing this concept for most of his professional career. Many of his early publications layed the foundation for this concept but it is the essay "*the rivers of pennsylvania,1889*" where he first states and defines the concept.

Davis was influenced by Darwin's organic evolution theory. In a 1883 writing he states "it seems most probable, that the many pre-existent streams in each river basin concentrated their water in a single channel of overflow, and that this one channel survives- a fine example of natural selection."

Cycle of erosion



Davis assumed that rapid uplift of a landmass was followed by a prolonged period of no movement in which erosive features would erode the slope to **a peneplain or flat surface** (Hart, 1986).

Other authors have argued with Davis by saying excluding the possible effects of **climatic change** or of **continual movements of base level** from the scheme is not rational.

Old peneplain surface in NE Greenland.


Old peneplain surface in central southern Norway (Finse).

Walther Penck 1888-1923

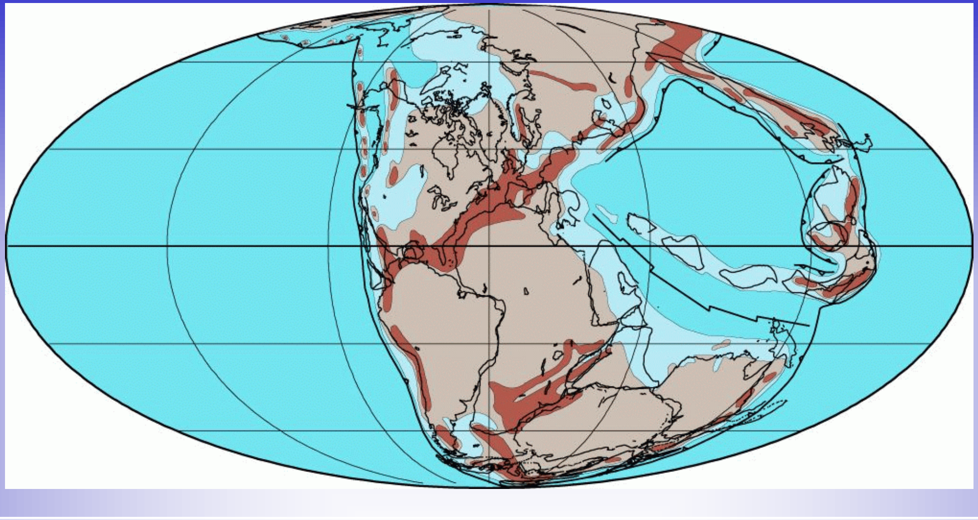
Walther Penck, a German geomorphologist, was a revolutionary individual who looked beyond the traditional boundaries of the field.

Walther Penck saw geomorphology as an instrument to obtain information about crustal movement, unlike Davis who used geomorphology to simply describe things.

Penck’s model of landscape development takes into account the possibility that crustal uplift is continuous and long-lived, rather than discontinuous and short lived crustal movement as required by the Davisian scheme. Penck thought slopes and landforms develop by retreating and eventually declining in angle.

Alfred Wegener 1880-1930:

"Scientists still do not appear to understand sufficiently that all earth sciences must contribute evidence toward unveiling the state of our planet in earlier times, and that the truth of the matter can only be reached by combing all this evidence. . . It is only by combing the information furnished by all the earth sciences that we can hope to determine 'truth' here, that is to say, to find the picture that sets out all the known facts in the best arrangement and that therefore has the highest degree of probability. Further, we have to be prepared always for the possibility that each new discovery, no matter what science furnishes it, may modify the conclusions we draw." Alfred Wegener. *The Origins of Continents and Oceans* (4th edition).



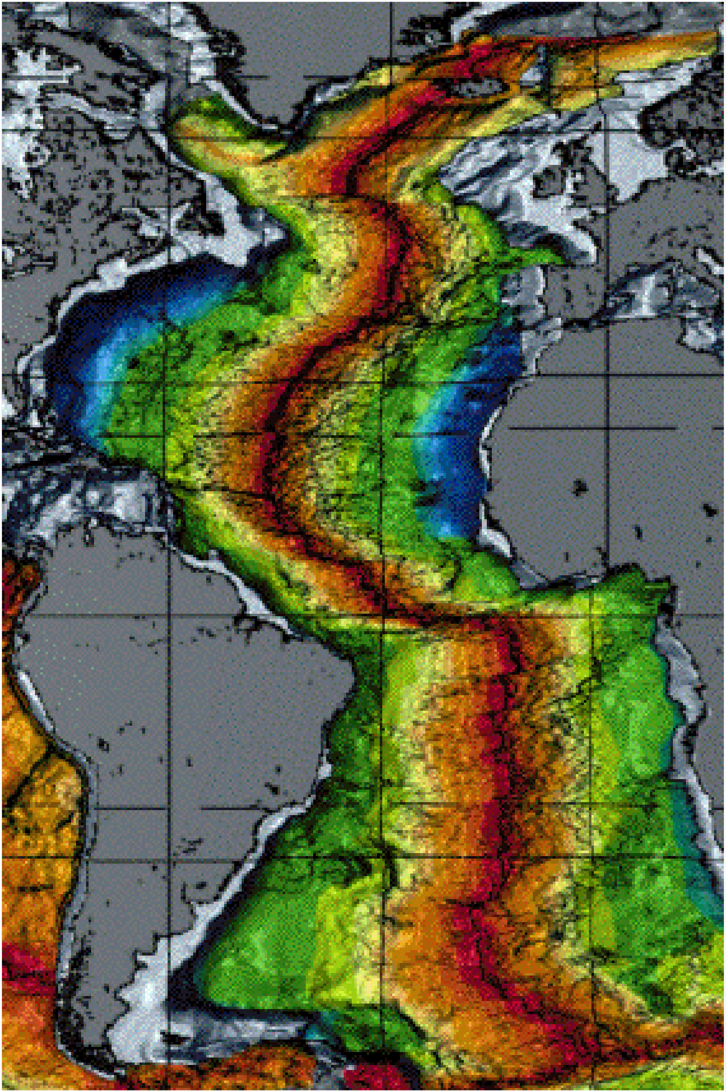
Wegener found that large-scale geological features on separated continents often matched very closely when the continents were brought together. For example, the Appalachian mountains of eastern North America matched with the Scottish Highlands, and the distinctive rock strata of the Karroo system of South Africa were identical to those of the Santa Catarina system in Brazil. Wegener also found that the fossils found in a certain place often indicated a climate utterly different from the climate of today: for example, fossils of tropical plants, such as ferns and cycads, are found today on the Arctic island of Spitsbergen. All of these facts supported Wegener's theory of **“continental drift”**. In 1915 the first edition of *The Origin of Continents and Oceans*, a book outlining Wegener's theory, was published; expanded editions were published in 1920, 1922, and 1929.

Reaction to Wegener's theory was almost uniformly hostile, and often exceptionally harsh and scathing;

Dr. Rollin T. Chamberlin of the University of Chicago said, "*Wegener's hypothesis in general is of the footloose type, in that it takes considerable liberty with our globe, and is less bound by restrictions or tied down by awkward, ugly facts than most of its rival theories*."

Part of the problem was that Wegener had no convincing mechanism for how the continents might move.

Another problem was that flaws in Wegener's original data caused him to make some incorrect and outlandish predictions: he suggested that North America and Europe were moving apart at over 250 cm per year (about ten times the fastest rates seen today, and about a hundred times faster than the measured rate for North America and Europe).



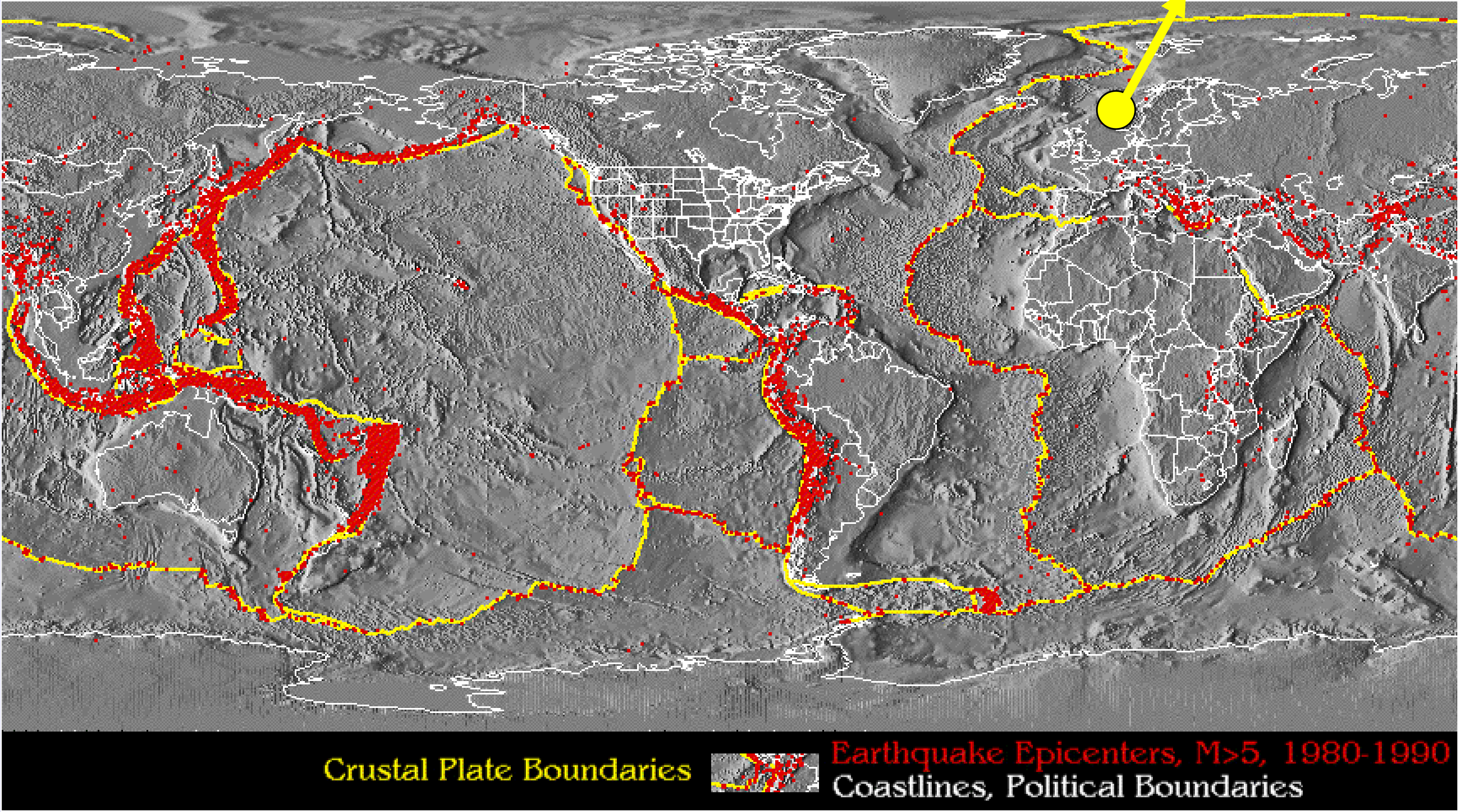
What prompted the revival of **continental drift**?

In large part it was increased exploration of the Earth's crust, notably the ocean floor, beginning in the 1950s and continuing on to the present day.

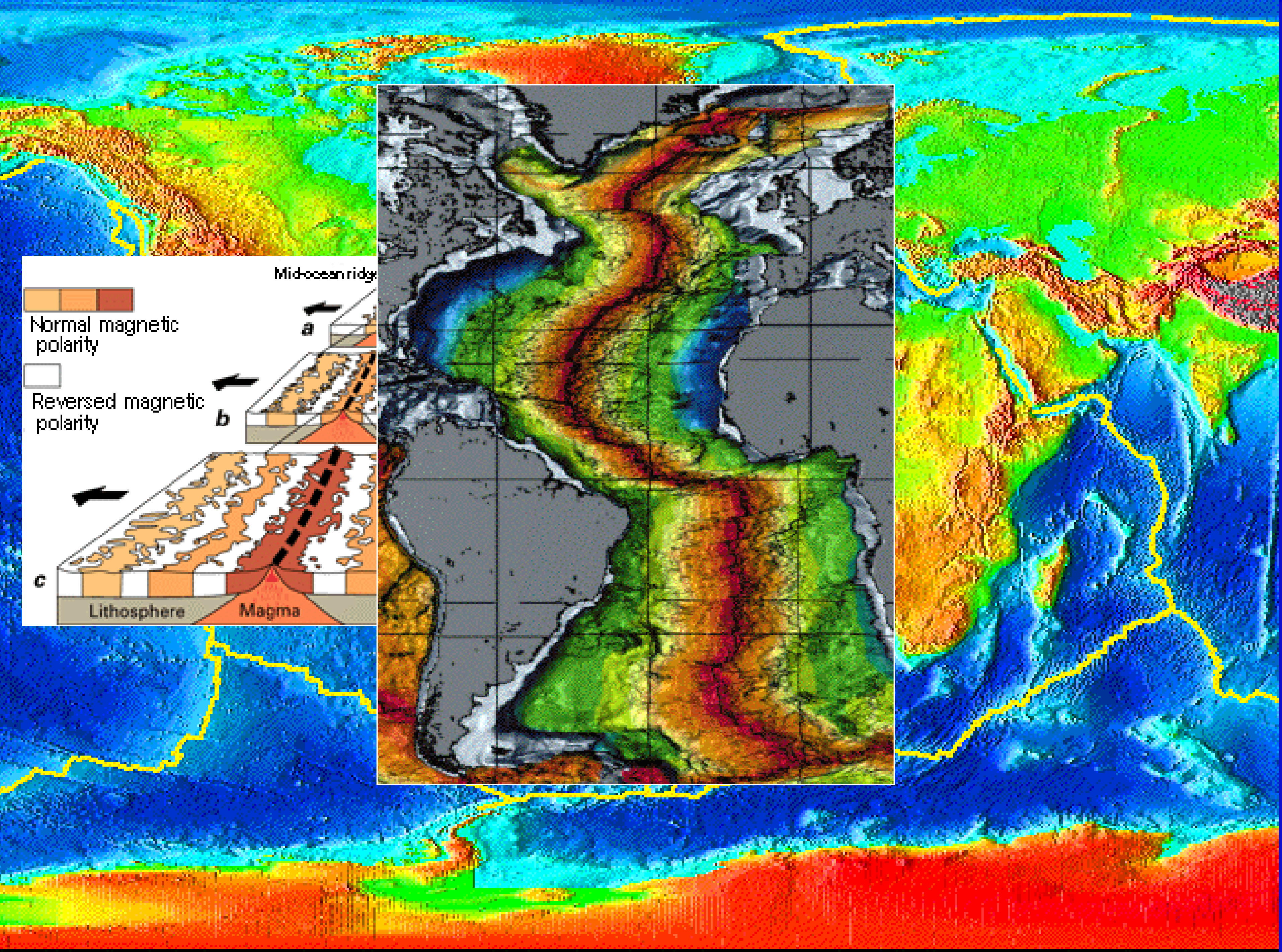
By the late 1960s, **plate techtonics** was well supported and accepted by almost all geologists.

We now know that Wegener's theory was wrong in one major point: continents do not plow through the ocean floor. Instead, both continents and ocean floor form solid **plates**, which "float" on the asthenosphere, the underlying rock that is under such tremendous heat and pressure that it behaves as an extremely viscous liquid.

Norway ?



Map of Earthquake Epicenters, 1980-1990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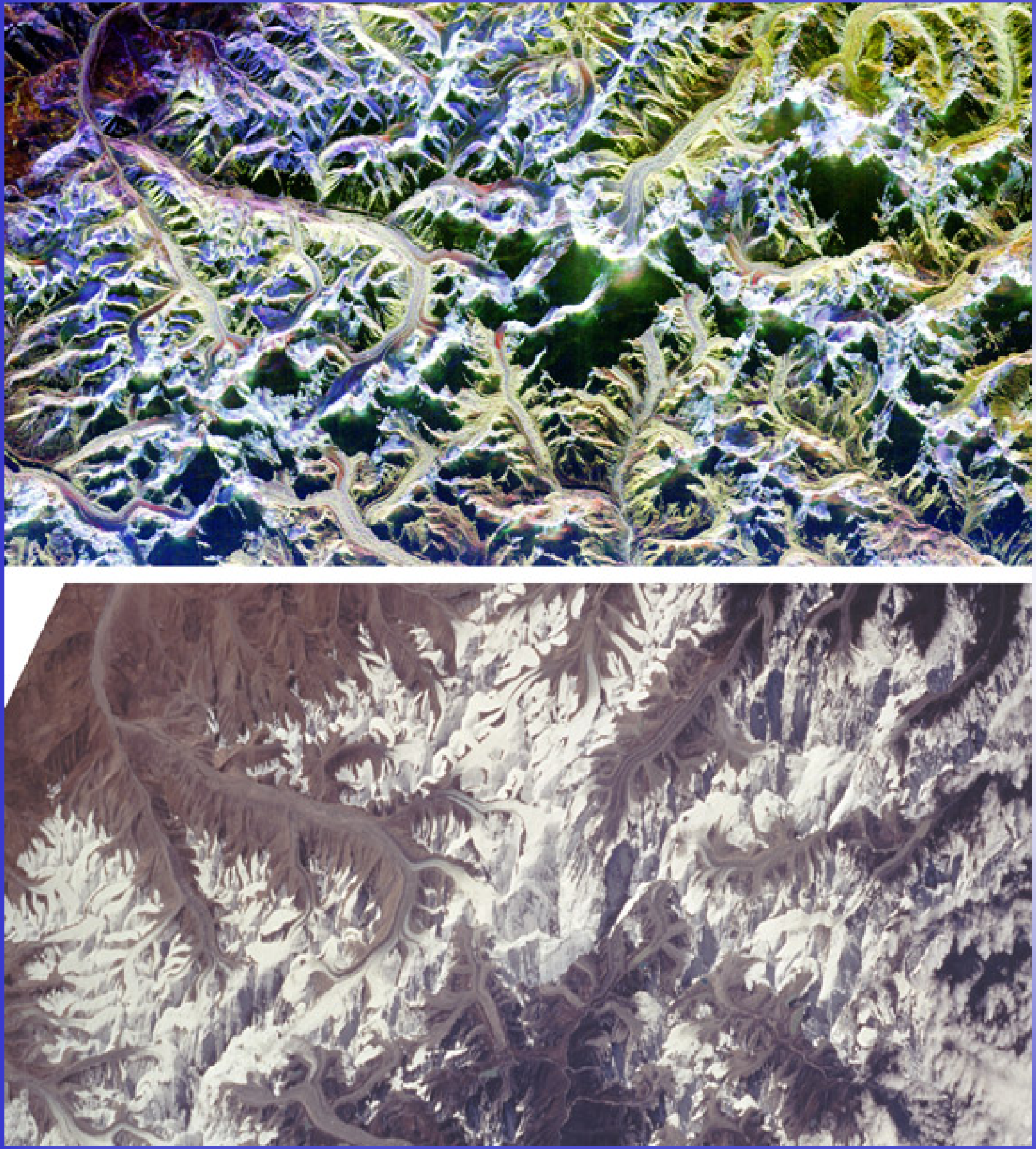

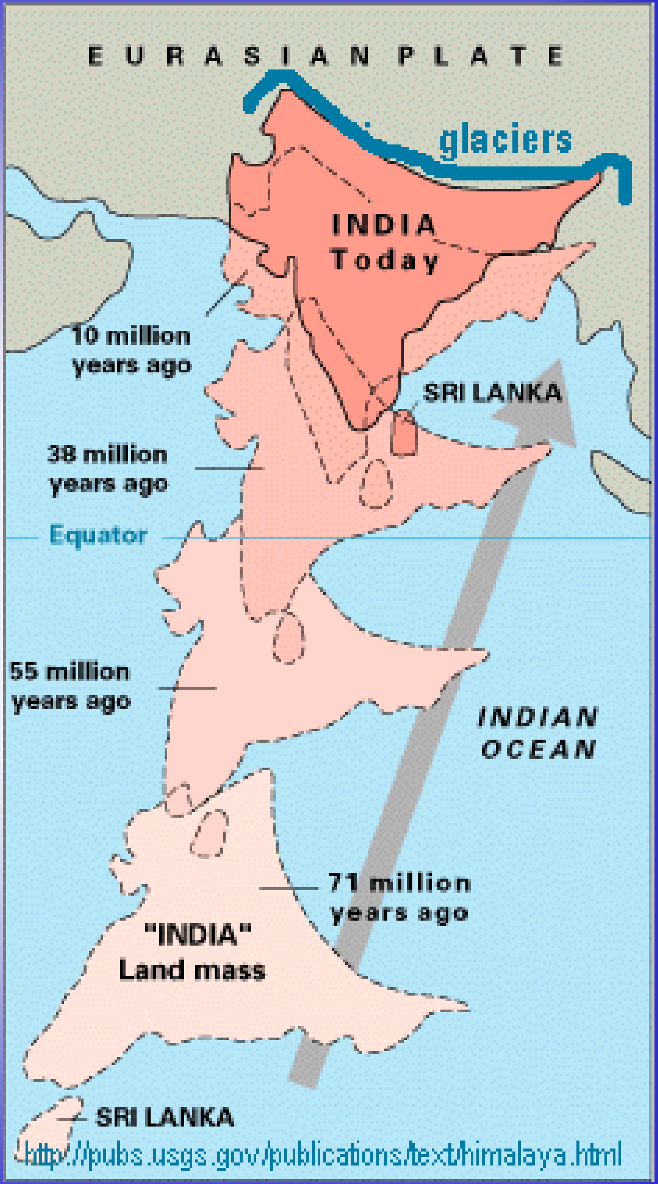

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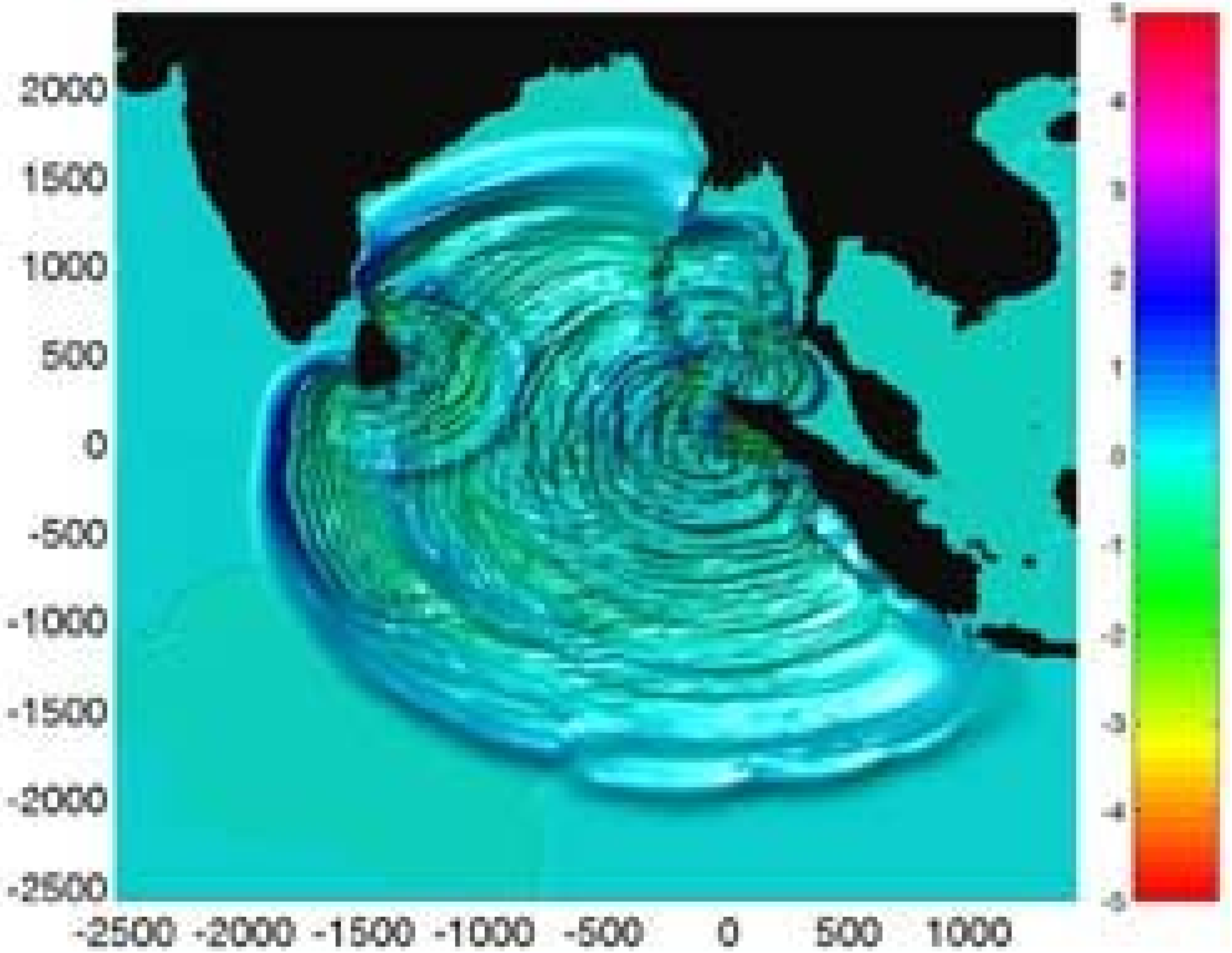
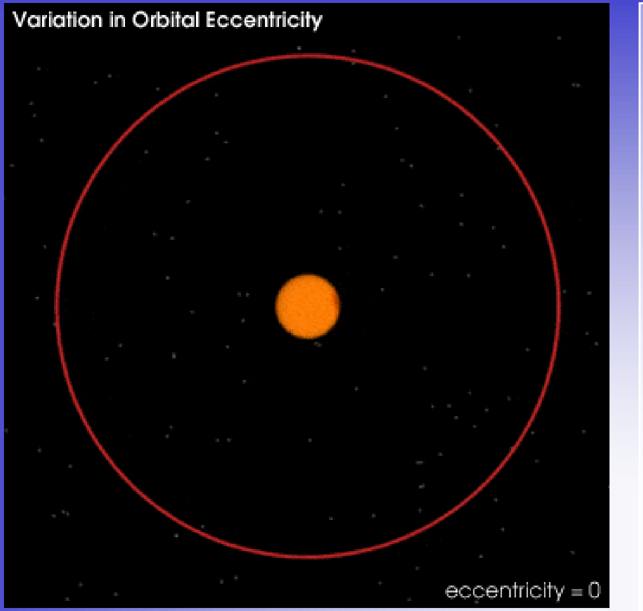


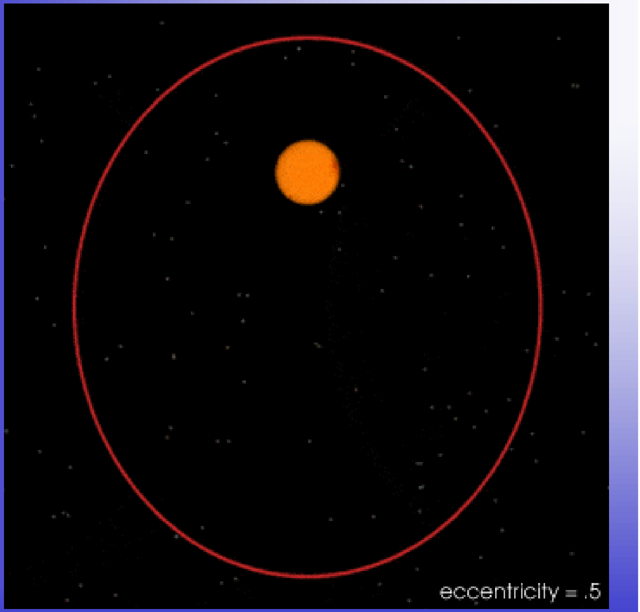
Tsunami at Sumatra 26. December 2004

Milutin Milankovitch 1879-1958

The Serbian astrophysicist Milutin Milankovitch dedicated his career to developing a mathematical theory of climate based on the seasonal and latitudinal variations of solar radiation received by the Earth.

Now known as the Milankovitch Theory, it states that as the Earth travels through space around the sun, cyclical variations in three elements of Earth-sun geometry combine to produce variations in the amount of solar energy that reaches Earth.

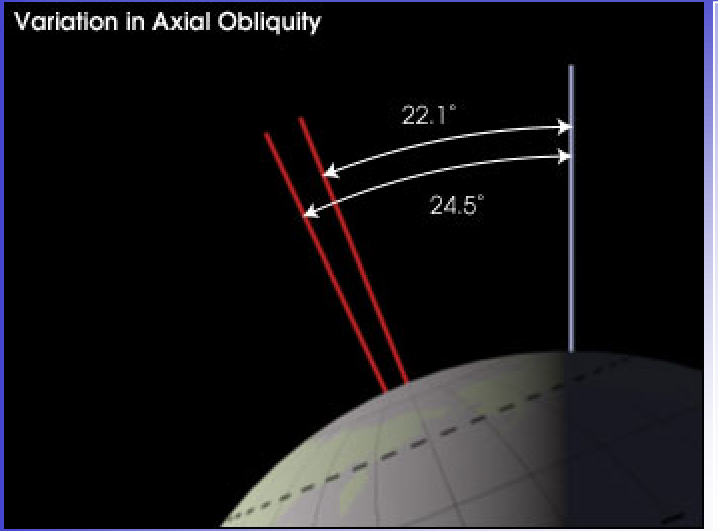




Changes in **orbital eccentricity** affect the Earth-sun distance.

Currently, a difference of only 3 percent (5 million kilometers) exists between closest approach (perihelion), which occurs on or about January 3, and furthest departure (aphelion), which occurs on or about July 4. This difference in distance amounts to about a 6 percent increase in incoming solar radiation (insolation) from July to January.

The shape of the Earth¹s orbit changes from being elliptical (high eccentricity) to being nearly circular (low eccentricity) in a cycle that takes between 90,000 and 100,000 years. When the orbit is highly elliptical, the amount of insolation received at perihelion would be on the order of 20 to 30 percent greater than at aphelion, resulting in a substantially different climate from what we experience today.

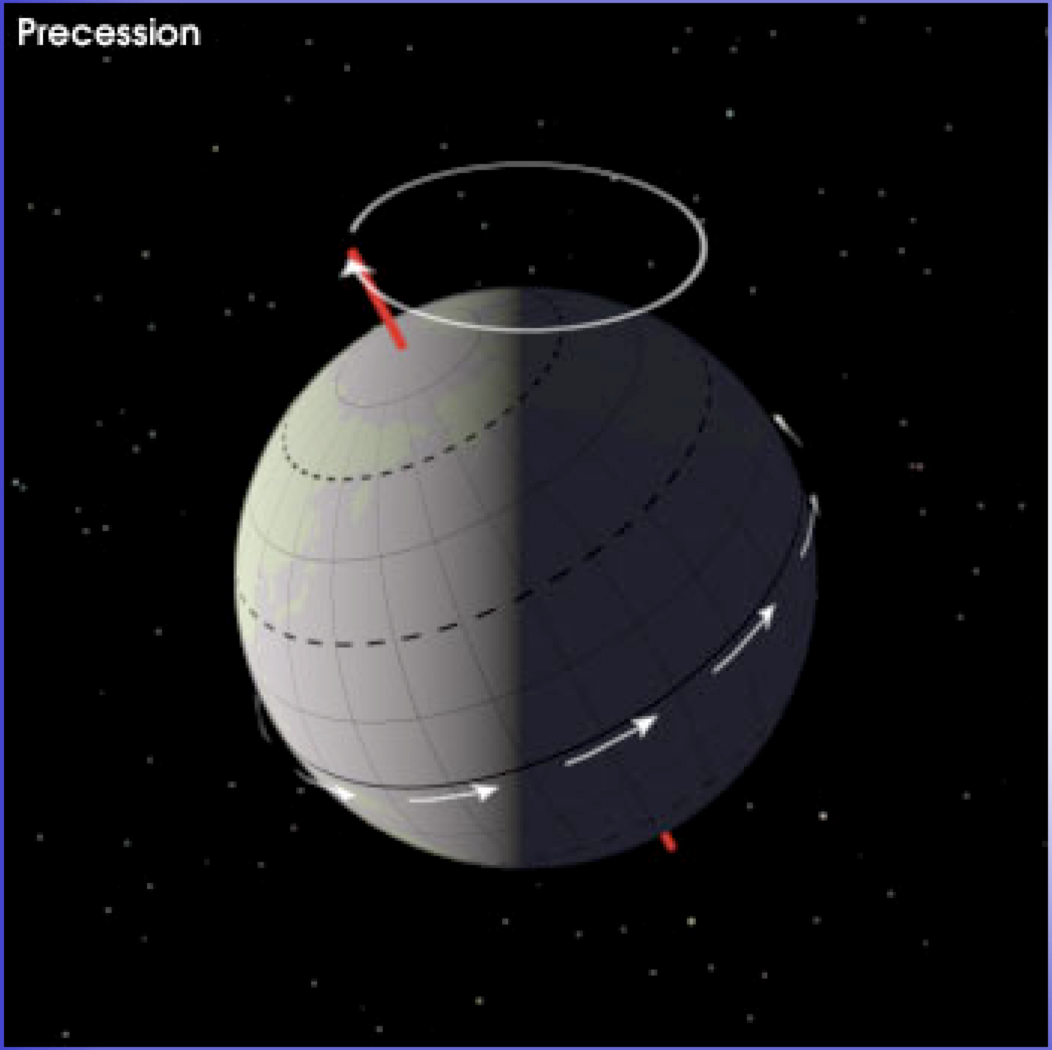


Obliquity (change in axial tilt)

As the axial tilt increases, the seasonal contrast increases so that winters are colder and summers are warmer in both hemispheres.

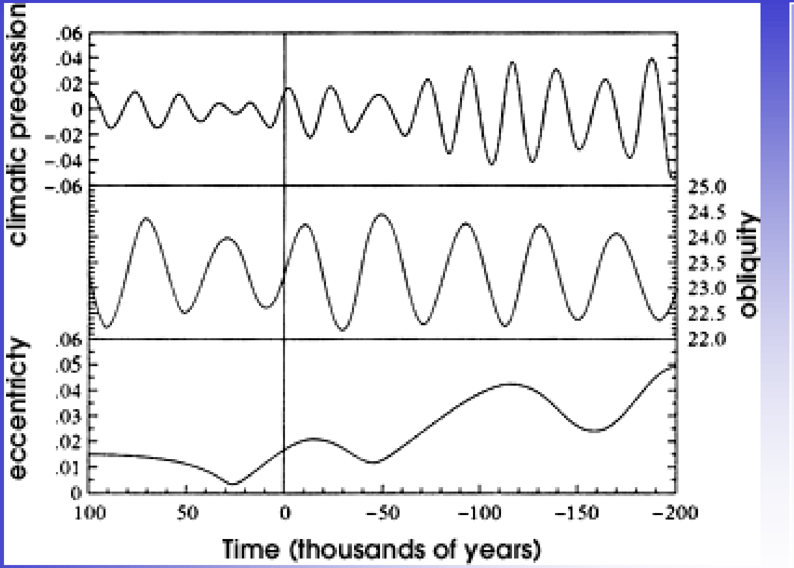
Today, the Earth's axis is tilted 23.5 degrees from the plane of its orbit around the sun. But this tilt changes. During a cycle that averages about 40,000 years, the tilt of the axis varies between 22.1 and 24.5 degrees.

More tilt means more severe seasons—warmer summers and colder winters; less tilt means less severe seasons—cooler summers and milder winters. It's the cool summers that are thought to allow snow and ice to last from year-to-year in high latitudes, eventually building up into massive ice sheets.



Precession

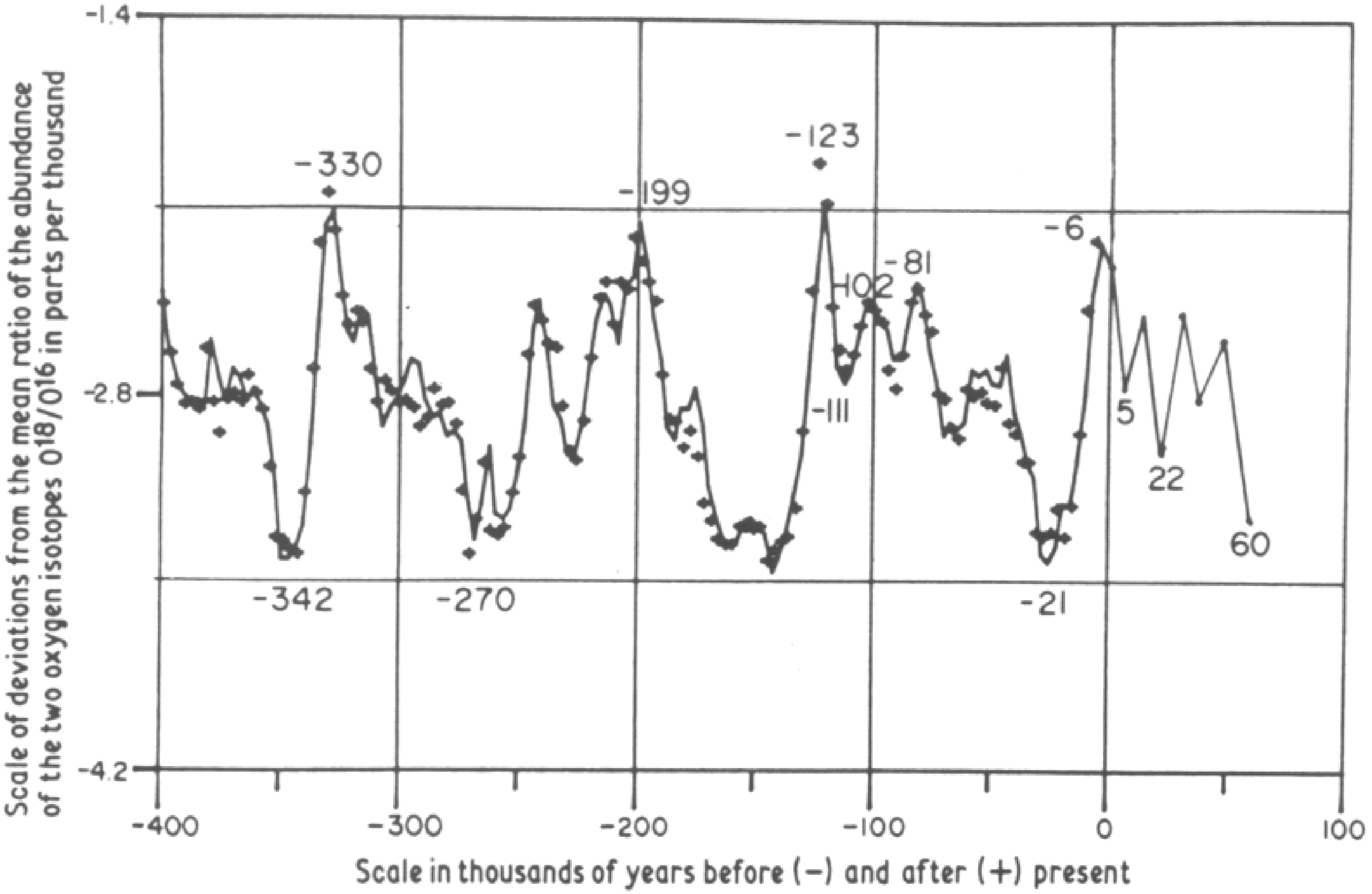
Changes in axial precession alter the dates of perihelion and aphelion, and therefore increase the seasonal contrast in one hemisphere and decrease the seasonal contrast in the other hemisphere.



Graph showing the calculated values for 300,000 years of orbital variation by Berger and Loutre, 1991.

Using these three orbital variations, Milankovitch was able to formulate a comprehensive mathematical model that calculated latitudinal differences in insolation and the corresponding surface temperature for 600,000 years prior to the year 1800. He then attempted to correlate these changes with the growth and retreat of the Ice Ages. To do this, Milankovitch assumed that radiation changes in some latitudes and seasons are more important to ice sheet growth and decay than those in others. Then, at the suggestion of German Climatologist Vladimir Köppen, he chose summer insolation at 65 degrees North as the most important latitude and season to model, reasoning that great ice sheets grew near this latitude and that cooler summers might reduce summer snowmelt, leading to a positive annual snow budget and ice sheet growth.

For about 50 years, however, Milankovitch's theory was largely ignored.


Scale of deviations from the mean ratio of the abundance of the two oxygen isotopes O^{18}/O^{16} in parts per thousand
-1.4
-2.8
-4.2
-400
-300
-200
-100
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100
Scale in thousands of years before (−) and after (+) present
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-123
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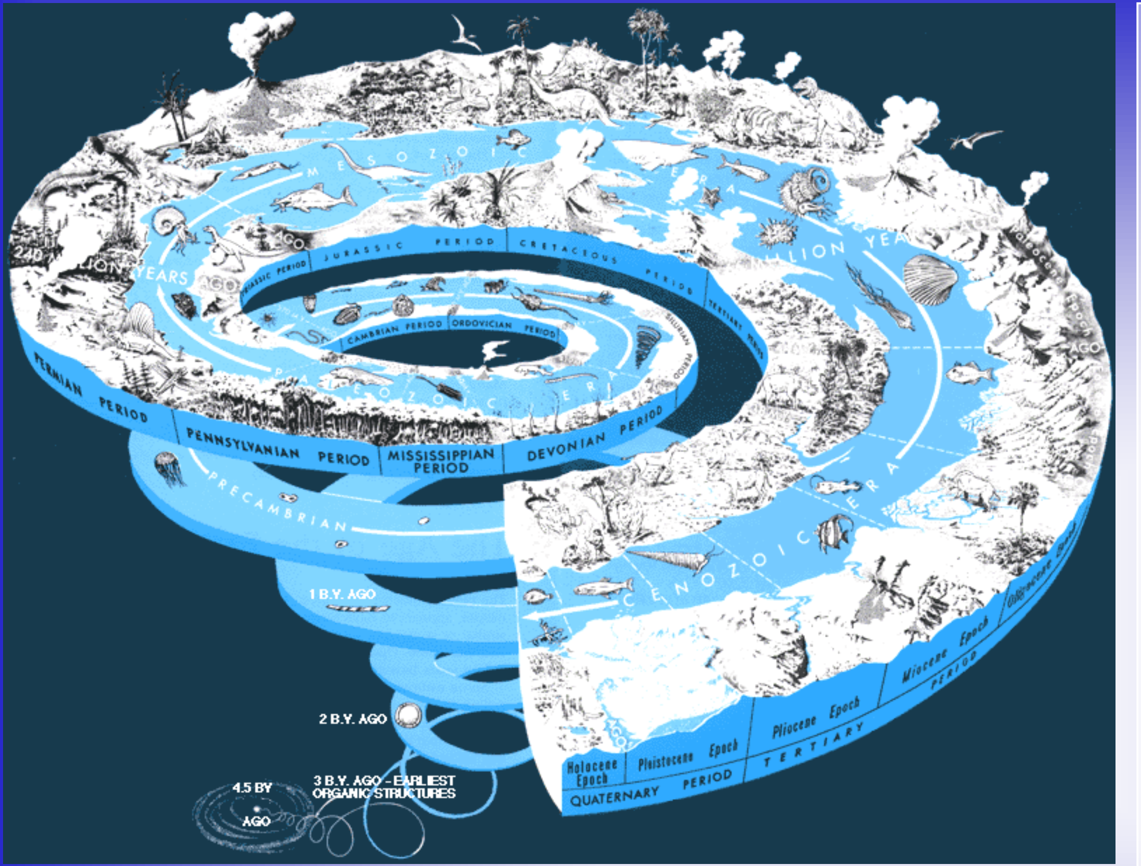

The Earth is 4.5 billion years or more according to recent estimates

Most of the evidence for an ancient Earth is contained in the rocks that form the Earth's crust.

Contained in rocks once molten are radioactive elements whose isotopes provide Earth with an atomic clock. Within these rocks, "parent" isotopes decay at a predictable rate to form "daughter" isotopes. By determining the relative amounts of parent and daughter isotopes, the age of these rocks can be calculated.

Techtonic history
Continental drift
Orbital changes
Warm tertiary climate
Quaternary glaciations
Quaternary interglacials

In landscapes elements of high and low age may be found near to each other.