WHEN THINGS GOT *REALLY* HARD — 4.4 BILLION YEARS AGO

4.6 billion years ago, as Earth formed, its surface was hot and molten. Over its first 200 hundred million years, the surface cooled and hardened. By 4.4 billion years ago, a crust had formed. Finding old crust on our planet is challenging, because the rocks have had 4.4 billion years to be buried, metamorphosed, cut by faults, broken up by mountain building, or eroded to sediment!

The Earth consists of two kinds of crust:

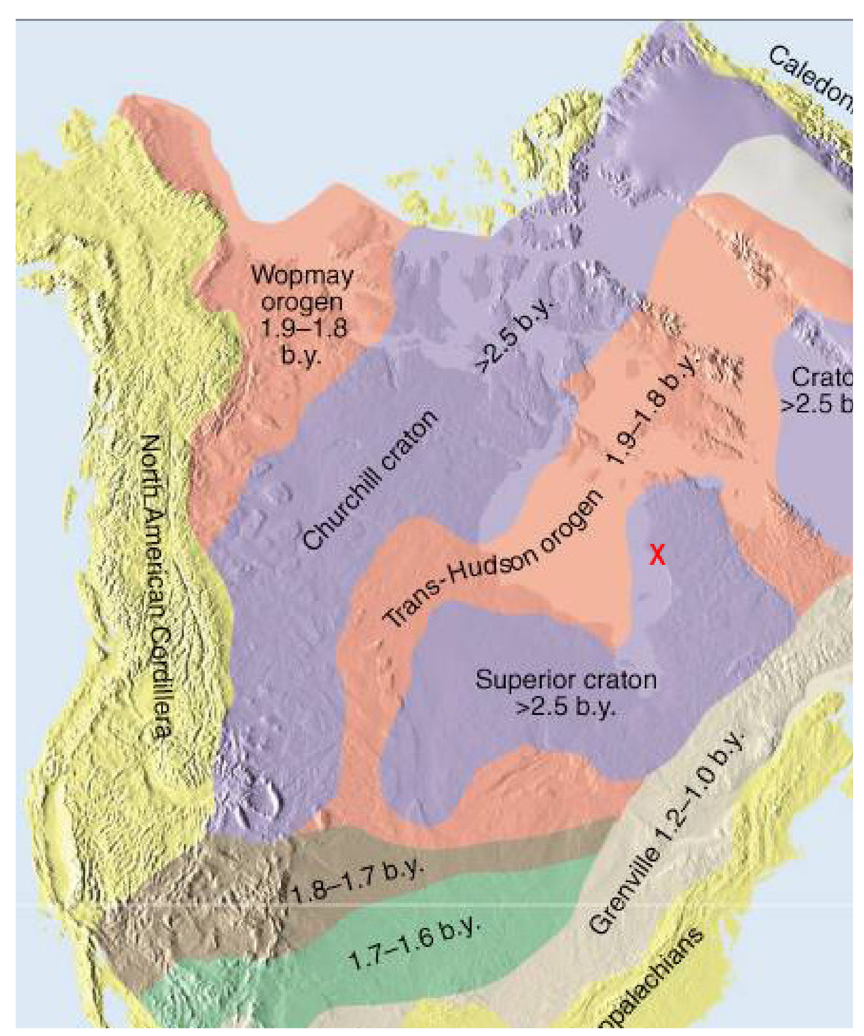
Oceanic Crust is thin (no more than 5 km thick) and underlies most of the world's ocean. It is denser than continental crust and made up primarily of the rock, **basalt**. Ocean crust forms where there are rifts in stretched and thinned crust, and molten mantle rock can easily and quickly rise to the surface. These rifts are called **seafloor spreading centers**. Oceanic crust is embedded in a larger structure called a plate, which is pushed away from the active rifting to make room for more magmas. As plates are pushed away, they get older and colder and denser. After at most 200 million years, the plate becomes so dense that it sinks back into the mantle (**subduction**), and the embedded oceanic crust is recycled. Thus oceanic crust on our planet is young and records only recent Earth history.

Continental Crust is thick (from 20-100 km thick) and generally rises above sea level (some parts are flooded today—the continental shelves). Continental crust is the least dense material on our planet (and hence can never subduct into the underlying mantle). It consists of many different rocks types, though its average composition is similar to the rock, **granite**. Continental crust forms when magmas erupt through thick crust (instead of at thin seafloor spreading centers). But how does crust get thick? The first step is to let volcanoes grow atop the crust. When old oceanic crust tries to sink back into the mantle, any large volcanic islands that sit atop it will get cause it to stick. Pressures build until the high relief is scraped off. Multiple islands will accrete together (like a train wreck), and the crust thickens further. In this way, the first continental crust formed. Through repetition of this process over time, continents grew thicker and thicker and more granitic in composition.

Oldest rocks — 4.28 billion years old!

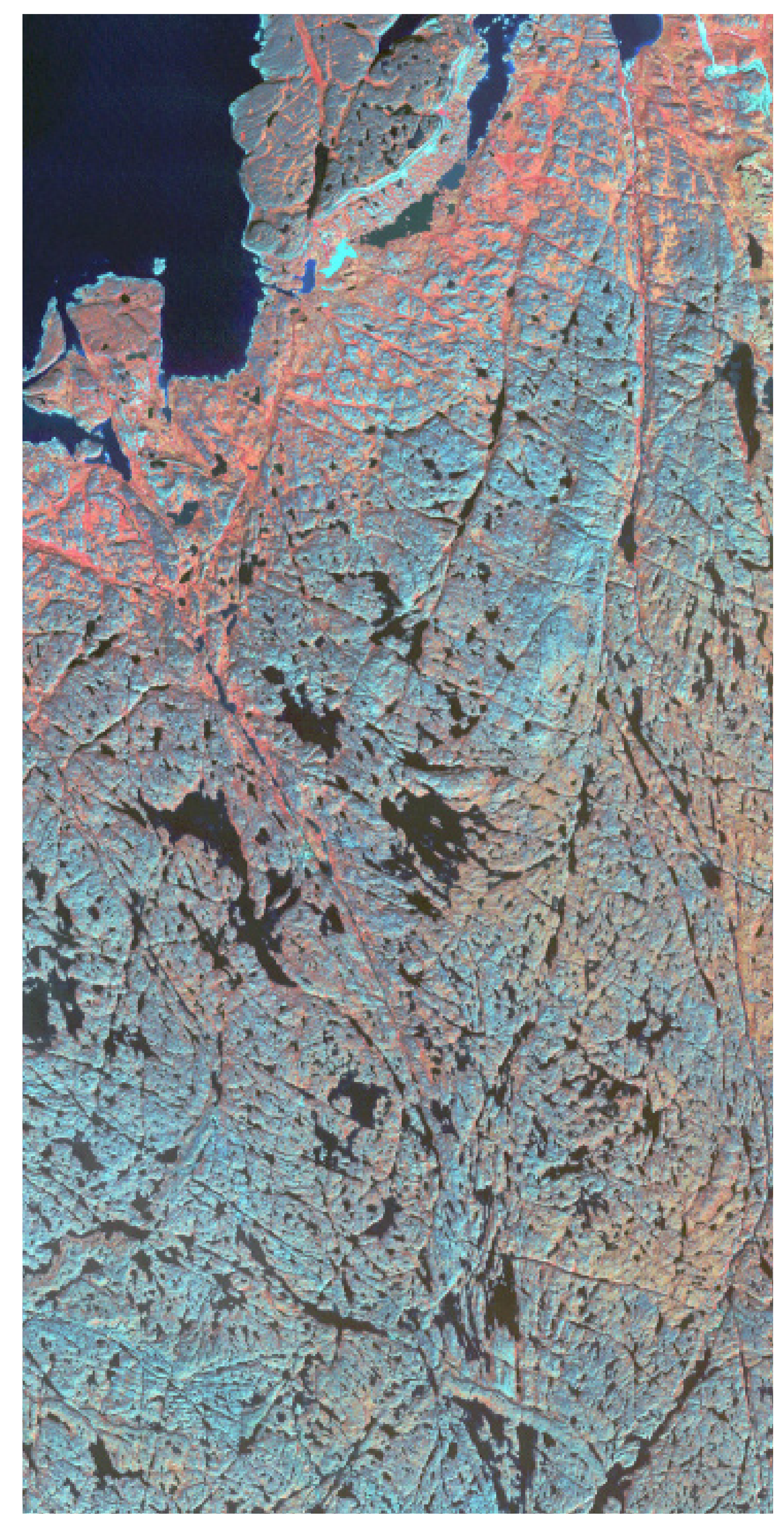
The oldest rocks ever discovered are from the core of the North American continent, the Canadian Shield. These rocks are metamorphosed basalts. The oldest is 4.28 billion years old, which was determined by radiometric dating. The rock itself is made up of fine ribbon-like bands of alternating magnetite and quartz. This feature is typical of rock precipitated in deep sea hydrothermal vents—which have been touted as potential habitats for early life on Earth. The ancient rocks were found in Northern Quebec, along the coast of Hudson Bay.

Sample of the oldest rock – highly metamorphosed basalt referred to as FAUX AMPHIBOLITE. The rock consists of fine ribbon-like bands of alternating magnetite and quartz, typical of rock precipitated in deep sea hydrothermal vents—which have been touted as potential habitats for early life on Earth. Photo by Don Francis ©



Terrane map of North America showing the age of rocks and structures (either exposed or sitting under surface sediment). X marks the location of the oldest rocks found on the coast of the Hudson Bay in Northern Quebec, 40 km south of Inukjuak in an area known as the Nuvvuagittuq greenstone belt. Prentice Hall Publishing ©

Greenstones of the Nuvvuagittuq Belt on the coast of the Hudson Bay in Northern Quebec. Greenstones are metamorphosed basalts and represent the cores of the earliest continents (which formed from accreted oceanic crust or basalt). Photo by Science/AAAS ©

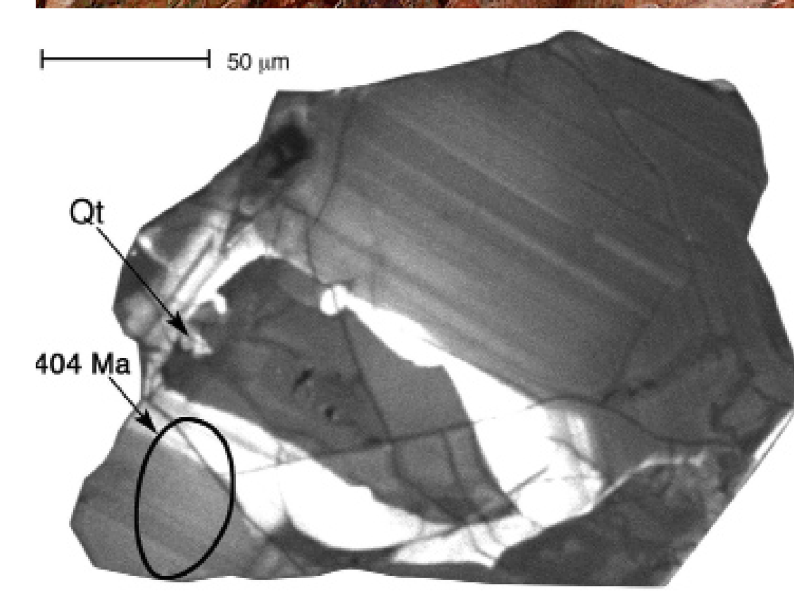


Satellite image of The Canadian Shield, Northwest Territories, Canada—location of the world's oldest known complete rock. The image is focused on the area called "Churchill district," most of which is composed of metamorphic rock or granite. There is no vegetation in the area, only numerous scars made during Ice Ages. The width of this image is ~35 km.

Oldest zircons — 4.4 billion years old!

Even older than the Canadian Shield rocks are zircons found in the Jack HIlls of Western Australia. The oldest zircon ever found was dated at 4.4 billion years old through radiometric dating methods. Zircons are minerals that crystallize from magmas and thus become part of a larger rock, typically a granite. The age of the zircons is the age of crystallization, and hence the age of the granite. Over time, granites, which form at depth in the crust, uplift (surface rocks erode and expose them). The granite breaks down physically and chemically at Earth's surface, and the most resistant minerals are carried away by wind, running water, glaciers, and gravity. During transit by water, more chemical break down occurs. Minerals turn to rust, or clay, or completely dissolve. Zircons, however, are chemically stable and do not break down. So they remain in the piles of sand, at the bottom of lakes or rivers or in sand dunes. When these sediment piles later are buried and cemented to form sandstone, the zircon is trapped. Over increased time and burial, the sandstone can get heated and put under pressure and metamorphose. When we study the zircons in these metamorphic rocks, we find evidence of their journey, but mostly we see back to the time when they originally formed. The age of the zircons reflects the age, not of the rock in which they're found, but of the older rock that no longer exists. From the 4.4-billion-year-old Jack Hills zircons, we learn how far back continental crust existed. We also know that oceanic crust likely existed for tens of millions of years prior.

Interlayered red metamorphosed sandstones of the Jack Hills, Australia—source of the world's oldest zircons. The rocks are 3 billion-year-old metamorphozed sedimentary rocks. Individual zircons found within originally crystallized from a magma 4.4 billion years ago. Photo by Bruce Watson ©



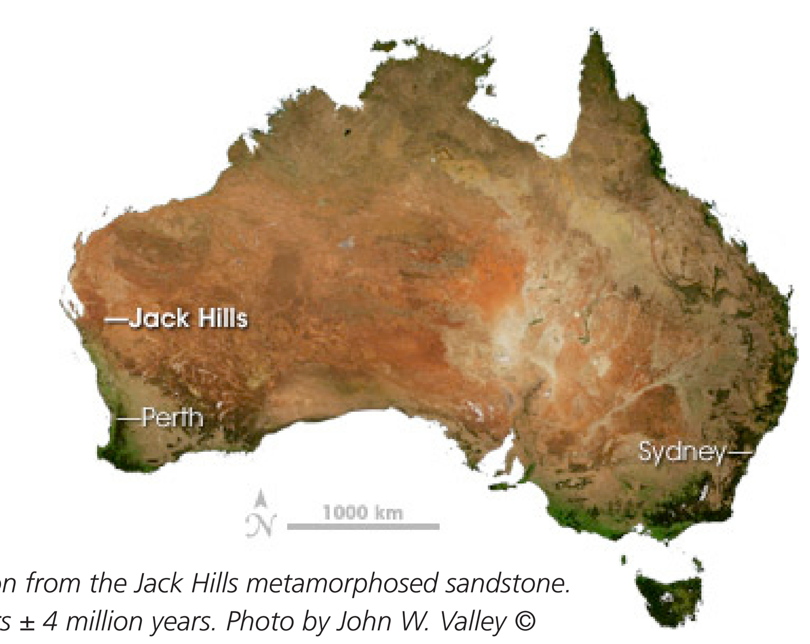


Image of the oldest known material from the Earth, a single crystal of zircon from the Jack Hills metamorphosed sandstone. The crystallization age of the marked section in the core is 4.40 billion years ± 4 million years. Photo by John W. Valley ©