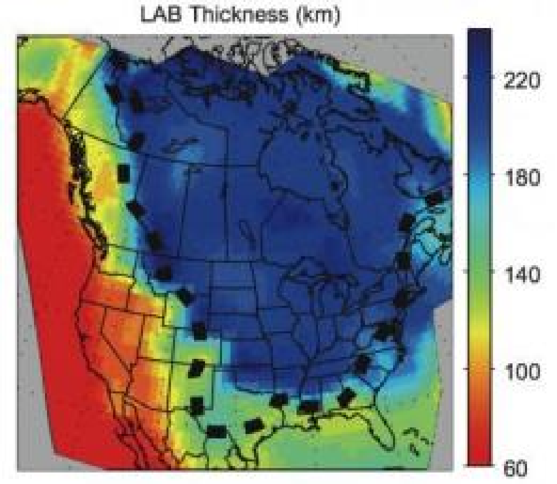
North American continent is a layer cake, scientists discover

August 25 2010, By Bob Sanders



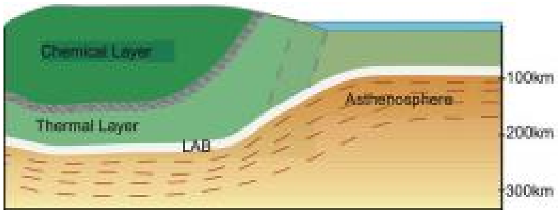
This graphic shows the thickness (in kilometers) of the North American lithosphere. The blue area is about 250 km thick and, based on new findings reported in *Nature*, is composed of a 3-billion-year old craton underlain by younger lithosphere deposited as ocean floor subducted under the continent within the past billion years. The green, yellow and red areas are younger and thinner continental lithosphere added around the margins of the original craton, also by subducting sea floor. The thick broken line indicates the borders of the stable part of the continent. Credit: Barbara Romanowicz and Huaiyu Yuan, UC Berkeley

(PhysOrg.com) -- The North American continent is not one thick, rigid slab, but a layer cake of ancient, 3 billion-year-old rock on top of much newer material probably less than 1 billion years old, according to a new study by seismologists at the University of California, Berkeley.

The finding, which is reported in the Aug. 26 issue of *Nature*, explains inconsistencies arising from new seismic techniques being used to explore the interior of the Earth, and illuminates the mystery of how the Earth's continents formed.

"This is exciting because it is still a mystery how continents grow," said study co-author Barbara Romanowicz, director of the Berkeley Seismological Laboratory and a UC Berkeley professor of earth and planetary science. "We think that most of the North American continent was constructed in the Archean (eon) in several episodes, perhaps as long ago as 3 billion years, though now, with the present regime of plate tectonics, not much new continent is being formed."

The Earth's original continents started forming some 3 billion years ago when the planet was much hotter and convection in the mantle more vigorous, Romanowicz said. The continental rocks rose to the surface - much like scum floats to the top of boiling jam - and eventually formed the lithosphere, Earth's hard outer layer. These old floating pieces of the lithosphere, called cratons, apparently stopped growing about 2 billion years ago as the Earth cooled, though within the last 500 million years, and perhaps for as long as 1 billion years, the modern era of plate tectonics has added new margins to the original cratons, slowly expanding the continents.



A diagram showing the three layers beneath North America. The top layer, the ancient craton, is chemically distinct from younger lithosphere below (the thermal root), which is separated from the asthenosphere by a boundary layer (LAB).(Barbara Romanowicz, UC Berkeley)

"Since the Archean, the continents have been broken up in pieces, glued back together and then broken up again, but those pieces of the very old lithosphere - very old pieces of continents - have been there for a very long time," she said.

One of those original continents is the North American craton, located mostly in the Canadian part of North America. The study suggests that what continental lithosphere has been added since the original North American craton formed was scraped off of the ocean floor as it plunged beneath the continent, not deposited from below by plumes of hot material welling up through the mantle.

The history of the Earth's oldest continental plates is vague because details of their interiors are hidden from geologists. The top 40 km of the lithosphere is crust that is chemically distinct from the mantle below, and while activities such as mountain building can dredge up deeper material, mountain building is rare in the planet's stable cratons. The deep interior of the North American craton is known only from so-called xenoliths - rock inclusions in igneous rock - or xenocrysts such as diamonds that have been delivered to the surface from deep below by volcanoes.

Seismologists, however, have the ability to probe the Earth's interior thanks to seismic waves from earthquakes around the globe, which can be used much like sound waves are used to probe the interior of the human body. Such seismic tomography has established that the bottom of the North American craton is about 250 km deep at its thickest, thinning out toward the margins where new chunks have been added to the continental lithosphere. Below the rigid lithosphere is the softer asthenosphere, on which the continental and oceanic plates ride.

Romanowicz and UC Berkeley postdoctoral fellow Huaiyu Yuan are testing a new technique, seismic azimuthal anisotropy, to look for the boundary between the lithosphere and asthenosphere. The technique takes advantage of the fact that seismic waves travel faster when moving in the same direction that a rock has been stretched than when traveling across the stretch marks. The difference in speed makes it possible to detect layers that have been stretched in different directions.

"As the lithosphere moves over the asthenosphere, the material gets stretched and acquires texture, which indicates the direction in which the plates are moving," she said.

Surprisingly, they found a sharp boundary 150 kilometers below the surface, far too shallow to be the lithosphere-asthenosphere boundary. The scientists believe that the sharp boundary is between two types of lithosphere: the old craton and the younger material that should match the chemical composition of the sea floor. Their interpretation fits with studies of xenoliths and xenocrysts, which indicate that there are two chemically distinct layers within the Archean crust.

Coincidentally, three years ago, researchers using a popular new technique called receiver function studies detected a sharp boundary below the North American craton at a depth of about 120 km. Receiver function studies take advantage of the fact that seismic waves change character - converting from a P wave to an S wave, for example - at sharp boundaries.

"We think they are seeing the same layering we are seeing, a sharp boundary within the lithosphere," Romanowicz said.

The stretch marks revealed by azimuthal anisotropy seem to rule out one theory of how the older continents have accrued more lithosphere.

"One hypothesis was that the bottom part was formed by underplating," Romanowicz said. "You would have a big plume of material, an upwelling, that would get stuck under the root. But what we are observing is not consistent with that. The material would spread in all directions and you would see anisotropy that is pointing like spokes in a bicycle."

"We are seeing a very consistent direction across the whole craton. In the top lithospheric layer the fast axis is, on average, aligned northeast-southwest. In the bottom layer it is aligned more north-south. So underplating doesn't work," she said.

If subduction is adding to the continental lithosphere, on the other hand, the north-south strike of the subduction zones on the east and west sides of the North American craton is consistent with the direction Romanowicz and Yuan found.

"I think our paper will stimulate people to look more carefully at distinguishing the ages of the lithosphere as a function of depth," she said. "Any information we can provide that constrains models of continental formation is really useful to the geodynamicists."

Provided by University of California - Berkeley

Citation: North American continent is a layer cake, scientists discover (2010, August 25) retrieved 25 April 2024 from
https://phys.org/news/2010-08-north-american-continent-layer-cake.html