SCHOOL OF OCEAN AND EARTH SCIENCE AND TECHNOLOGY

Press Release

ANCIENT HETEROGENEOUS MANTLE FOUND BELOW ARCTIC OCEAN

Honolulu, HI – Scientists have discovered highly heterogeneous mantle rocks beneath the Gakkel Ridge in the Arctic Ocean. These rocks have survived the mixing process in the deep mantle and some have retained their two billion year old melting signatures, preserved by the complex geologic history of the region. The unprecedented discovery of these rocks indicates that mantle heterogeneity may turn out to be more widespread in mid-ocean ridge settings than inferred from the more commonly studied erupted lavas. The results are published in the March 20th edition of the prestigious journal Nature.

The international team, co-led by Assistant Specialist Eric Hellebrand of the Department of Geology and Geophysics at the University of Hawaii at Manoa (UHM), carried out two sampling expeditions aboard a German icebreaker to the inhospitable Gakkel Ridge in the Arctic Ocean near the North Pole. The ridge itself lies 5000 meters (3 miles) deep in the ocean beneath the Arctic ice cap, and is considered the slowest spreading ridge on Earth. By using dredging equipment, the scientists were able to recover samples of mantle rock from the ocean floor. The samples were labeled, catalogued and then cut into slices thinner than a human hair so they could be examined under a microscope. That is when Hellebrand, along with UHM Postdoctoral Researcher and co-author Anette von der Handt, realized that they had found something that, for many geologists, is as rare and fascinating as moon rocks; Mantle rocks devoid of sea floor alteration. Even more, on analysis of the isotopes of osmium, a noble metal rarer than platinum, the samples turned out to be 2 billion years old.

A dredge collects samples aboard the German Research Vessel R/V Polarstern in the Arctic Ocean. Image credit: Heinz Feldmann, Max-Planck Institute for Chemistry, Mainz, Germany

Jonathan Snow, a co-author on the paper and an assistant professor of Geosciences at University of Houston said “We can’t exaggerate how important these rocks are – they’re a window into that deep part of the earth.” In the paper, the team reports that osmium isotopic measurements obtained from the retrieved samples show records that these mantle rocks underwent partial melting some 2 billion years ago, and have been chemically isolated in the mantle since. This age information is retained in the natural decay of the element Rhenium to an isotope of Osmium. Partial melting removes Rhenium from the mantle into the basaltic melt, thereby freezing in the osmium isotopic composition at the time of melting.

The German research ice breaker Polarstern, from which the dredging was performed. Image credit: Anette von der Handt, SOEST/UH

The creation of new ocean floor at mid-ocean ridges is the direct result of convection in the Earth mantle, the layer between 7 and 3000 km depth in the Earth. This is the region that melts to form the most abundant volcanic rocks, called basalts, which erupt on the seafloor. At the slowest spreading mid-ocean ridges, this basaltic crust is very thin or in many places completely absent, allowing direct access to the uppermost mantle. “Compared to the varied and ancient continental crust, most geologists think of the mantle as a relatively homogeneous region of the deep Earth”, Hellebrand says. “Some variations in composition, or heterogeneities, are well known, and are seen in volcanic rocks from Hawaii and Iceland.” These heterogeneities occur in the Earth by extracting certain elements (called lithophiles) and concentrating them in these unique enriched regions. Crustal processes produce these heterogeneous regions, which are then transported in more homogeneous or depleted mantle as the mantle convects within the Earth. This model is frequently referred to as a "plum pudding", where the lithophile-enriched "plums" sit in a "pudding" of well-mixed depleted mantle.

Because the mantle is slowly moving and churning within the earth, geologists believe the mantle is a layer of well-mixed rock. Fresh mantle rock wells up at ridges to create new crust. As the continental plates move, this crust slowly makes it way to a subduction zone, a plate boundary where one plate slides underneath another and the crust is pushed back into the mantle from which it came.
This whole process takes about 200 million years and so it was surprising to find rocks that had not been remixed inside the mantle for two billion years.

The discovery of ancient melt depletions upwelling in the mantle beneath the Gakkel Ridge suggests that there may be different flavors of "plums" in the mantle, including both enriched and depleted varieties. If so, this means that the Earth's deep mantle is an even less homogeneous place than scientists had thought it was, and instead may preserve a geologic history as complex and ancient as that of the continental crust. “That it is seen in dredge hauls located quite far away from each other in different sections of the ridge shows that the heterogeneity exists on a range of scales” says von der Handt.

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