PHYS.ORG

Tracing the history of Earth

November 3 2010, By Morgan Bettex, MIT News

Graphic: Christine Daniloff

Although scientists have a general idea of when major events occurred during Earth's 4.5-billion-year history, geologists would like to be able to pinpoint the exact dates of those events. Precise dates for the sequence and duration of geological events provide insight into fundamental questions about Earth's history, such as when and why mass extinctions occurred, how long it takes for mountain ranges to form, and the age of Earth's oldest fossils and crust.

One challenge for geochronologists — scientists who determine the age of rocks and minerals — in their quest to develop a geological timescale is how to standardize procedures to allow for precise, accurate dating using different techniques and laboratories. To determine the age of a rock, they measure the abundance of radioactive elements and the elements they turn into over time inside the minerals that make up rocks — the number of atoms of those elements provides an estimate of a rock's age. To measure this, geochronologists add a tracer, or a solution containing synthetic radioactive elements, to a sample. The problem is that different labs use different tracers, which makes it difficult to compare data with enough precision.

As part of an international initiative known as EARTHTIME, funded by the National Science Foundation, a group of geochronologists led by Sam Bowring, the Robert R. Shrock Professor of Earth and Planetary Sciences in MIT's Department of Earth and Planetary Sciences, has developed a "community tracer" that is now being distributed to qualified labs around the globe. The researchers hope that by calibrating this tracer together, they can share the most accurate data and work together to determine precise dates for a range of geologic problems.

"Absolute dates hold the answers to when — and how fast — something occurred, which helps to sort out cause-and-effect relationships that may otherwise be purely speculative," says Noah McLean, a doctoral student in Bowring's Radiogenic Isotope Lab. McLean presented details about the tracer calibration at the Geological Society of America's annual meeting on Wednesday. In particular, McLean described new approaches to assessing and minimizing all sources of uncertainty in the calibration. And less uncertainty can ultimately lead to more precise and accurate dates.

The new tracer is a major advance for geochronology, says James Mattinson, a geologist at the University of California, Santa Barbara, because "in the past, it has been impossible to know whether slight differences in ages reported by different labs have actual geologic meaning or instead result from inaccurate tracer calibration within individual labs."

Rock clocks

Isotopic tracers are essential for dating geologic samples, such as layers of volcanic ash that have been deposited throughout Earth's history. Minerals in that ash contain radioactive elements that can be thought of as ticking clocks, including two isotopes (atoms of the same element that have different numbers of neutrons) of uranium (U) that slowly turn into two different isotopes of lead (Pb) as they decay. Because researchers know the half-life — or how long it takes for half of an isotope to change into another isotope — of both uranium isotopes, they can measure the ratios of U to Pb inside the minerals to estimate when the minerals formed.

But geochronologists can only measure one element at a time using a mass spectrometer, which is an instrument that uses a magnetic field to separate different isotopes of the same element. To determine the amount of both elements, they use a tracer that contains known amounts of highly enriched U and Pb isotopes. After scientists add the tracer to the sample and dissolve it, the spectrometer chemically separates U and Pb from other elements present, and measures their isotopes. Researchers then measure the ratio of natural U to synthetic U, and because they know the number of synthetic U atoms, they use algebra to figure out the number of natural U atoms in the sample. After repeating this process for Pb, they can determine the final ratio of natural U to natural Pb in the sample, which gives them two estimates of the rock's age — one for each pair of U and Pb isotopes.

Limiting uncertainty

Although this technique has been used for decades, McLean says, geochronologists have never been able to make extremely precise measurements — better than 0.1 percent, or one part in 1,000 — of the composition of the tracers they use. Imprecisely calibrated tracers have, accordingly, limited the level at which they can compare data.

For the past four years, McLean has worked with Bowring and others in the EARTHTIME community to create a large supply of a precisely calibrated tracer. This involved mixing synthetic isotopes of uranium and lead in precise proportions, taking hundreds of measurements of the contents and plotting tens of thousands of data points to determine the exact ratio of the isotopes in the tracer. McLean also developed mathematical techniques to help geochronologists evaluate the range of random and systematic uncertainties associated with the equations they use to determine these ratios.

He plans to continue to analyze ways to limit these uncertainties, noting that the tracer issue is only “one small piece” of the uncertainty that must be considered when dating rocks, including mass spectrometer effects and lab contamination.

This story is republished courtesy of MIT News (web.mit.edu/newsoffice/), a popular site that covers news about MIT research, innovation and teaching.

Provided by Massachusetts Institute of Technology