Adjusting the atomic clock

Unravelling the Earth's 4.5-billion-year history is a mammoth task. Joe Hiess and Dan Condon describe how their work has uncovered a systematic flaw in the assumptions behind one of science's key dating methods – and how correcting it will move some accepted dates by nearly a million years.

The planet's oldest minerals are over four billion years old; younger rocks may have formed only a few hundred thousand years ago. For researchers probing this huge span of time in the rock record – a discipline known as geochronology – isotope analysis is crucial; a dating method using different varieties of the same element, with varying atomic weights which decay predictably over time.

One of the most important of these techniques is based on uranium. As the radioactive uranium isotopes ^{238}U and ^{235}U decay, they turn into the lead isotopes ^{206}Pb and ^{207}Pb. By determining how much of each parent and daughter isotope there is in a rock or mineral sample, geochronologists can establish when its radiometric clock began to tick – that is, when it formed.

In doing this, for decades they've assumed that the present-day ratio of the parent uranium isotopes $^{238}U/^{235}U$ was the same everywhere, at 137.88. But recent studies have shown that the ratio varies in minerals formed in cool environments, such as calcite from fossil coral or cave deposits. If this variation is also the case for the high-temperature minerals typically used for geochronology, such as zircon, then the U-Pb dates produced could be off by some significant but unknown amount of time.

Understanding the isotopic composition of uranium is vital for calibrating the geological timescale and placing Earth events in sequence. So we need to reassess the absolute $^{238}U/^{235}U$ ratio in these mineral time capsules, measure it accurately, and see if it varies naturally. We undertook a major study to determine these ratios in uranium-bearing minerals typically used for geochronology, studying samples from a wide range of geologic settings – rocks from every continent, ranging in age from less than a million to 3.88 billion years.

This involved dissolving the minerals in strong acids, purifying their uranium and analysing the composition of different isotopes using sophisticated mass spectrometers.

We discovered that yes, there is real variation in uranium isotope ratios between samples that formed in high-temperature magmatic environments where rocks melt and solidify. We also found that uranium-rich minerals like zircon have the same isotopic composition as many common igneous rocks and meteorites: a $^{238}U/^{235}U$ ratio of around 137.818.

This new value may not sound too far from the old one, but it will affect all previous U-Pb age measurements, spanning much of Earth's history – some dates will change by up to 800,000 years.

But this discovery means geologists working on Earth science problems all over the world will now be able to estimate the age of rocks with much greater accuracy. ■

Isotopes are measured by mass spectrometers.

MORE INFORMATION

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