Radioactive Crystals Help Identify and Date Ore Deposits

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Reddish-brown crystals of a radioactive mineral called monazite can act as microscopic clocks that allow geologists to date rock formations that have been altered by the action of high-temperature fluids, a process that frequently leads to the formation of rich ore deposits.

That is the conclusion of a study performed by a team of geologists headed by John C. Ayers, professor of earth and environmental sciences at Vanderbilt University, published in the August 1 issue of the journal *Geology*.

"Monazite crystals contain thorium, which is radioactive," Ayers said. "Thorium decays into lead. So, by measuring the ratio of thorium to lead we can date a crystal's age. What we have shown is that monazite dissolves readily in high-temperature fluids, resetting its radioactive clock, so that it can be used to date areas altered by hydrothermal activity."

That is important because geologists have difficulty detecting and characterizing areas that have been affected by hydrothermal action millions of years ago. The fluids involved have usually disappeared and the minerals they leave behind can be hard to identify and cannot be used to determine the date when they were altered.

According to Ayers, monazite's ability to reliably date hydrothermal events should be particularly useful in three specific settings:

• Contact metamorphic aureoles. These are areas surrounding intrusions of molten rock that solidify below the surface and are called plutons. The rising magma heats the water in the surrounding rock. The hot fluid spreads outward from the intrusion, changing the chemical composition and mineralogy of the rock with which it comes into contact. This is the primary process that produces ore deposits.

• Earthquake fault zones. When a large earthquake occurs, rock is ground up and fluids are heated to high temperatures, so at least some of the monazites within a fault zone should have dissolved and recrystallized. As a result, they could provide the date of the last major earthquake that occurred on the fault.

• Ultrahigh pressure terrains. These are geological areas created when continents collide. For example, the Dabie Mountains in east-central China that Ayers has studied include an ultrahigh pressure terrain created as the crustal plate carrying south China pushed northward into the plate carrying north China. In these areas, pieces of the crust are pushed deep underground and then are regurgitated back up to the surface after they have been altered by the extreme temperatures and pressures that they encounter at depth. Monazite can be used to date these unusual rocks.

Monazite is a phosphate that contains rare earth metals. It forms hard crystals that range in color from yellow to brown to orange-brown and vary in transparency from translucent to opaque. The name comes from the Greek mona `zein (to be solitary) because it is usually found in isolated crystals. Monazite is an important ore for thorium, lanthanum and cerium and it is found in trace amounts in many ordinary rock formations.

Geologists have been using monazite and zircon crystals for dating purposes for some time. Geologists are using monazite to date thousands of rock formations around the world each year. However, they have generally assumed that monazite, like zircon, is not affected by hydrothermal activity. So the new results will force them to reassess their interpretation of the meaning of these dates in some areas.

Ayers and his colleagues performed a detailed analysis of the monazites in the Birch Creek area of the White Mountains in eastern California. The area contains a granite pluton that has been extensively studied. It was created by an intrusion of magma about 80 million years ago, which pushed up into a layer of 500-million-year-old sedimentary rock before solidifying.

Masters student Miranda Loflin spent almost a month at Birch Creek where she collected samples at 22 sites lying along a straight line called a transect that extended outward from the edge of the granite pluton. Back in the lab, she and Ayers dated the samples. They also took another set of measurements designed to differentiate between pristine crystals and those that had been recrystallized due to hydrothermal activity: their oxygen isotope composition. Oxygen comes in several different forms that all have the same basic chemical behavior but have slightly different weights. These are called isotopes. When minerals form they inherit their oxygen isotope ratios from the surrounding fluid. So the researchers figured that the monazite grains found in the 500-million-year-old should have a different oxygen isotope ratio than those which were dissolved in fluid and recrystallized 80 million years ago.

The analysis – performed with the assistance of fellow Vanderbilt geologist Calvin Miller; Mark D. Barton from the University of Arizona, Tucson; and Christopher Coath from the University of Bristol, UK – confirmed that the dates of monazite crystals more than a half kilometer from the intrusion agreed with the 500 million year age of the older sedimentary layer and had oxygen isotope ratios that differed markedly from those of crystals within the granite itself and in the half-kilometer area immediately surrounding the pluton.

In contrast, they report that the age and the isotope composition of the crystals within a half kilometer of the intrusion have dates and isotope ratios identical with those within the granite.

The results confirm that monazite crystals can be used to identify and date rocks that have been altered by hydrothermal events. Not only do they show that the radioactive clocks of these particles are reset in such events, but that it is possible to identify monazite grains that have undergone hydrothermal alteration by measuring their oxygen isotope ratios.

A multimedia version of this story is available on Exploration, Vanderbilt's online research magazine, at www.vanderbilt.edu/exploration … tories/monazite.html

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