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Authors: Cowen, Robert C.

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Abstract: States that geologists are learning to utilize the atomic byproducts of this cosmic-ray bombardment to date landforms with unprecedented precision over an age range that extended back 14 million years. Comments from Paul Bierman of the University of Vermont in Burlington; Tracing of human impacts on land by scientist; Information on the speeding particles from outer space which smashes through the atmosphere; Details on dating techniques.

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COSMIC RAYS TELL HISTORY OF THE LAND

Scientists get first glimpse of the past and future of erosion

Speeding particles from outer space smash through the atmosphere, irradiate the land, and open a new window :into the past.

Geologists are learning to use the atomic byproducts of this cosmic-ray bombardment to date land forms with unprecedented precision over an age range that extends back 14 million years.

Paul Bierman of the University of Vermont in Burlington says that is "opening a window that we just haven't been able to look through before . . . a window for us to [see] how quickly Earth's :surface is responding" to erosion.

This, in turn, helps scientists trace human impacts on the land. It helps link climate and landform changes in the effort to better understand global climate change. It gives insight into such practical issues, for example, as how fast erosion is eating away at Nevada's Yucca Mountain, the proposed site for storing high-level nuclear waste.

The new dating techniques are not perfect. They still have substantial uncertainties, according to Dr. Bierman and several of his colleagues. Nevertheless, John Gosse of the Los Alamos National Laboratory in New Mexico points out that "we've been able to resolve problems [with these techniques] . . . that have never been able to be answered before. This is really the first time that we can quantify erosion rates."

The incoming particles include a variety of atomic nuclei and originate from unknown sources elsewhere in our Milky Way galaxy. Mechanisms not yet well understood channel

them toward the solar system. Some of the incoming particles cause nuclear reactions in the atmosphere, giving off secondary particles. These secondaries plus many of the primary particles penetrate the surface of rocks and soils, They cause nuclear reactions that Create a variety of So-called cosmogenic byproducts. Some of these byproducts are stable forms of various elements, such as helium-3. Many axe radioactive, such as beryllium-10, and decay at known rates. Soils and sediments may also pick up cosmogenic elements formed in the atmosphere that are washed out by rain.

The essence of cosmogenic dating is to count the number of atoms of one or more of these elements per gram of rock, sediment, or soil. Since geochemists know the rate at which cosmic rays produce cosmogenic atoms they can date how long the or soil surface has been exposed to the cosmic radiation. What makes this technique feasible is the fact that, over the past 10 years, instruments for identifying such tracer elements have become so sensitive they can identify one target atom among 1,000 trillion other atoms.

For example, Dr. Gosse explains that helium-3 is produced at a rate of 100 atoms per gram of quartz per year on an Arctic beach. If a rock sample has 100,000 of these atoms per gram, simple division of 100,000 by the 100 yearly production rate gives an exposure age of 1,000 years. Helium-3 is stable. If one or more radioactive elements were used as tracers, the age calculation would have to take account of loss of some tracer atoms through radioactive decay. Geochemists also have to consider possible loss of tracer atoms through erosion.

Such calculations are muddied by uncertainty over how the flux of incoming cosmic rays - and hence the production rate of the cosmogenic atoms - has varied over time. There may also be uncertainty about how much of the tracer elements the rock or soil samples had to begin with. Gosse said, however, that all uncertainties combined probably don't introduce an error of more than 25 percent in the age estimates. The concentration of these cosmogenic atoms can also indicate how fast a rock surface is eroding. Again, there is an uncertainty of about 25 percent.

Gosse has used these techniques to gauge erosion rates at Yucca Mountain. Well-established radioactive dating methods can tell how old a boulder is. But they can't tell how long it has been since the boulder eroded from the mountainside and lay exposed on the ground. Nor can they tell how fast exposed bedrock on the is eroding.

Gosse says studies he and his colleagues have made at Yucca Mountain indicate that the mountain is old but has not eroded much. The planned nuclear-waste repository would be about 200 meters or more below the mountain's surface. Gosse's measurements indicate a maximum erosion rate for that surface of only 0.14 centimeters per thousand years.

Meanwhile, Paul Bierman is adapting cosmogenic dating to estimate histories of alluvial fans - erosion deposited sediments - built up off the Sierra Nevada Mountains. He notes that, "previously, they really defied dating." Geologists had a sense of relative ages - of what stage preceded what - in the development of these fans. But they had no idea of when events happened. "Now we start to have some idea of the timing of deposition. We can begin to think about linking that to other records of Earth's surface response to changing climate," Bierman explains.

A suite of cosmogenic elements can also. give a characteristic "fingerprint" to soils. Milan Pavich of the US Geological Survey has used such "fingerprints" to identify sediments in Chesapeake Bay. He can match those sediments to locations and known events in the past.

"We were actually successful in showing that, during the two main agricultural periods in the middle-eighteenth century and then [in] the beginning of the nineteenth century, there were pulses of soil erosion." He adds that if scientists can understand such erosion - where the dirt comes from and where it goes -"maybe [we] can help come up with controls on erosion."

PHOTO (COLOR): YUCCA MOUNTAIN: Cosmic rays help scientists determine the erosion rate of this potential high-level nuclear-waste repository in Nevada. It is exceptionally slow.

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By Robert C. Cowen

Special to The Christian Science Monitor
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