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Cosmogenic Clues to the Tempo of Environmental Change

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Introduction

Many scientists have suggested that human activity may affect the global environment in a variety of ways. Unfortunately, the Earth is a complex system in which predicting and detecting environmental change is a difficult task; generations may pass before such human-induced changes and their impacts are sufficient to be measured.

Geologists have a unique perspective on the Earth and on past environmental changes, the perspective of time. By examining the response of Earth's surface, the landscape, to past changes in climate or human activity, we can begin to understand how our environment might respond to changes in the future.

Until recently, geologists could do no better than establish the relative age of landscape features, many of which are relicts from times in which the climate was quite different than that of today. The development of ^{14}C dating in the 1950s revolutionized our understanding of Earth's surface and of the changes it had seen over the past 40,000 years. A similar revolution has begun in the 1990s, catalyzed by advances in physics, chemistry and analytical instrumentation.

Cosmogenic Isotopes

The Earth's surface is constantly bombarded by low levels of cosmic radiation, primarily neutrons, uncharged particles identical to those found in the nucleus of every atom except hydrogen. These neutrons interact with the uppermost meter or two of soil and rock to produce a variety of very rare isotopes such as ^{10}Be, ^{26}Al and ^{36}Cl. In the 1950s, scientists proposed that measurement of these isotopes could be used to estimate the amount of time that a rock had been exposed on Earth's surface or the rate at which the surface was eroding. Now, forty years later, we can measure these isotopes and the results are revolutionizing the study of Earth's surface.

My students at the University of Vermont and I have been collecting samples from around the world and making measurements of "cosmogenic" isotopes in collaboration with scientists at the Center for Accelerator Mass Spectrometry, Lawrence Livermore National Laboratory. Our work has been funded by the National Science Foundation, the Army Research Office, and the University of Vermont. Below, I provide a summary of some of our research, that most directly applicable to understanding how Earth has or might respond to a changing climate.

Rates of Bedrock Erosion *(Figure 1)*

Bedrock is exposed over much of Earth's surface; yet, until recently measuring the rate at which exposed rock eroded was not possible except in rather unique circumstances. Although geomorphologists had hypothesized that rates of bedrock erosion would be proportional to the amount of rainfall, little quantitative data could be mustered to test this idea.

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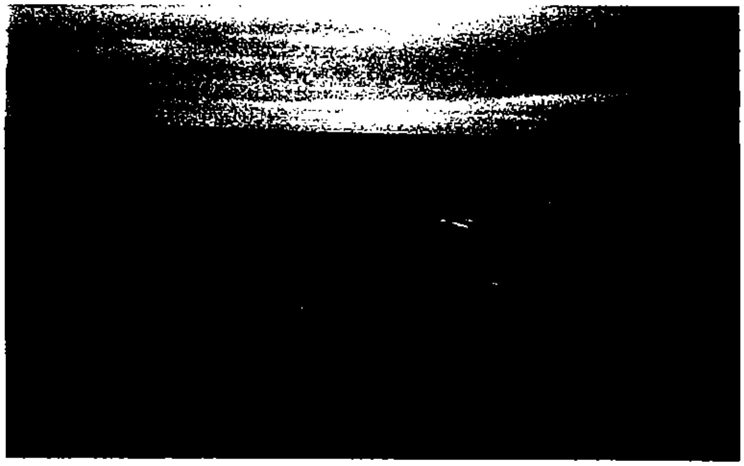

Figure 1. Bedrock outcrop on the Eyre Peninsula of southeastern Australia. Isotopic measurements show that the surface of this outcrop is exceptionally stable eroding only 40-50 cm every million years.

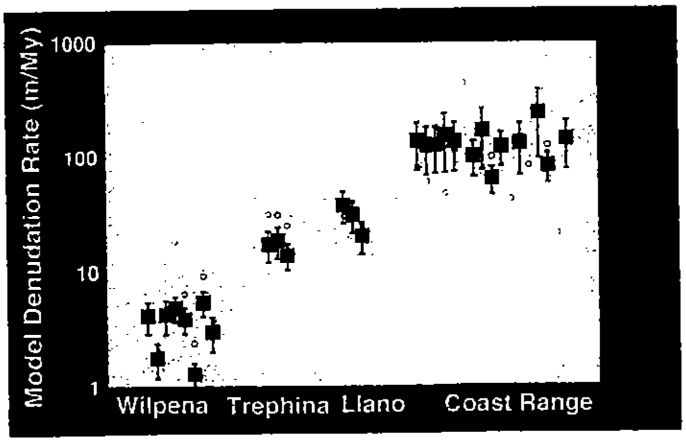

Figure 2. Sediment-based isotopic erosion rate estimates for Wilpena Pound (south Australia), Trephina Creek (central Australia), Llano Uplift (central Texas) and the Coast Range (Oregon).

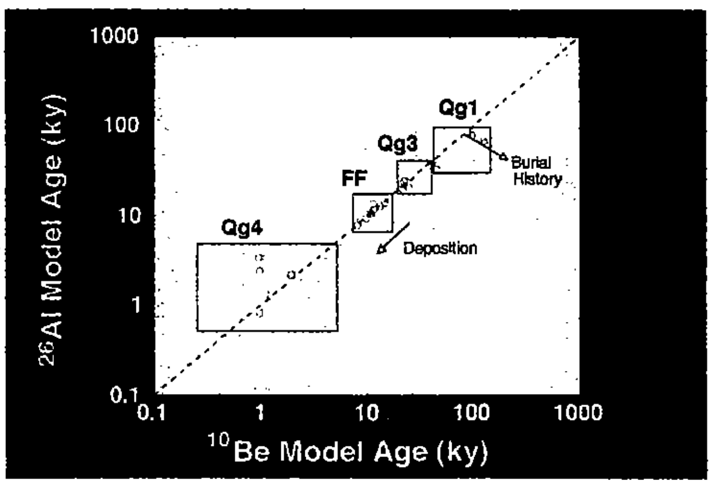

Figure 3. Isotopic age estimates for alluvial fans flanking the Sierra Nevada mountains in southern California.

Figure 4. Pangnirtung Fjord on Baffin Island where isotopic data suggest that the last glaciers left less than 10,000 yeas ago.