Mugenic nuclides: A method for dating rapidly eroding landforms

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Landforms are in principle datable using cosmogenic nuclides only until erosion has reached a depth comparable to the e-fold attenuation length of the production with depth. For deeper erosion, the cosmogenic nuclide inventory will become a function of the erosion rate alone and will no longer depend on the exposure age. For spallation-produced nuclides in resistant bedrock the time to approach this erosional limit is typically on the order of 200 to 500 kyr. However, landforms composed of unconsolidated material (e.g., moraines, marine terraces, alluvial fan surfaces) erode roughly an order of magnitude more rapidly and may reach erosional equilibrium in 20 to <100 kyr. This precludes many applications of geological interest. One approach to circumventing this problem is to employ cosmogenic nuclides produced by muons rather than spallation reactions. The attenuation length for muon production is ~1,500 g cm^2, about an order of magnitude greater than for spallation production, and thus potentially capable of compensating for the higher erosion rate. However, none of the commonly-measured cosmogenic nuclides are produced only by muons, and as a result measurements on near-surface samples will be dominated by spallation production. The solution to this dilemma is to measure depth profiles. Preliminary results from depth profiles measured in the Sierra Nevada (California, USA) indicate that this approach may be practical, if samples can be obtained at sufficient depth.

Are the rare gases within MORB contained within melt-inclusion-like bubbles that preserve a record of the underlying melting column?

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While melt inclusion studies continue to suggest that the melts formed beneath ridges and hotspots reflect strong local source heterogeneity, rare-gas observations are still commonly interpreted in terms of homogeneous, layered mantle reservoirs. Rare gas elemental ratios are known to vary within individual basalts. For example, the extremely volatile-rich 'popping rock' basalt is known to have different sub-regions whose He/Ar ratio varies between 1.4 and >2. However, local He/Ar variations could be produced by preferential helium mobility with respect to argon. In this same popping rock, measured Ar- and Xe-isotope ratios released by step-heating measurements of the rock range over practically the entire range recorded in oceanic basalts. The trapped $^{40}Ar/^{36}Ar$ measured in individual vesicles of the popping rock spans an even larger range than that found from step-heating measurements, ranging from airlike to ~60,000. These variations cannot be produced by diffusion, which would tend to reduce rather than enhance the isotopic variation of a single element. The EMORB and MORB basalts erupted along the Shona-Discovery SMAR ridge segments exhibit similarly striking variability between the Ne-, Ar-, and Xe- ratios of the trapped rare gases released at different step-heating levels of 700°C, 1200°, and 1700°C. While one cannot rule out the chance that this effect is entirely due to a very mysterious form of atmospheric contamination, the Xe-isotope variations found within individual diamonds strongly suggest that it is not. In several diamonds, the core of the diamond has an 'atmosphere-like' $^{129}Xe/^{130}Xe$ and $^{136}Xe/^{130}Xe$, while the diamonds coat (apparently a later overgrowth) is more radiogenic. How can a diamond's interior become contaminated while its near-surface is not?

I suggest that MORB rare gas observations may in fact contain strong signals of source heterogeneity that are imperfectly measured using conventional step-heating techniques, but which may be capable of much better measurement by applying laser-zapping techniques to measure the rare gases contained within individual vesicles. A basalt's bubbles (vesicles) may behave much like melt inclusions, both in trapping the rare gases from the heterogeneous melts that pool to contribute to a given basalt, and in effectively isolating these rare gases from each other during the rapid ~1000yr time of ascent and eruption. Here I will discuss the basic physics of this trapping process, and demonstrate that it is possible for CO_2-rich bubbles to behave essentially like melt-inclusions for rare-gases if melts are as rapidly transported towards the surface as is suggested by radioisotope disequilibria studies.