More than rates or dates: The power of amalgamation when tracing landscape-scale processes with ^{10}Be

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Boulder dates and bedrock erosion rates have been the bread and butter of cosmogenic nuclide science for more than a decade. Isotopes of He, Be, Ne, Al, and Cl illuminate the dark geochronologic recesses of the Pleistocene beyond the radiocarbon timescale, when luminescence dating fails, and where racimized shells are absent. But cosmogenic nuclides can do much more than constrain the history of points on Earth's surface. By exploiting the power of amalgamation, cosmogenic nuclides can help us understand landscape-scale processes and overcome the sometimes devastating spatial variability in nuclide concentration. This talk will review amalgamation techniques and results, and present new data.

Rivers-nature's amalgamators. A handful of river sand contains thousands of quartz grains, each of which has a unique and unknowable history. Yet, together these grains tell a coherent story of landscape erosion and sediment production. Numerous isotopic studies demonstrate efficient fluvial mixing down drainage networks. Regression analysis of river-sediment ^{10}Be data sets from around the world suggests tectonic setting and slope as overriding controls on erosion rate. Grain-size specific nuclide analysis allows process inference. In humid regions, with deep soil cover and extended periods of near-surface weathering, grain size is inversely related to ^{10}Be concentration reflecting differing sources and exposure histories. In arid regions, dominated by rock slopes and thin soil, grain size, and nuclide concentration are unrelated suggesting more uniform exposure histories.

Throwing dirt in a bag—geologists extend nature's work. Sometimes nature does not do enough amalgamation and geoscientists need to help out. On both low-gradient, grussy, desert piedmonts in the Mojave Desert and also on steep, soil-mantled slopes in the Great Smoky Mountains, samples amalgamated from 7 to 20 soil pits dug along slope-parallel transects reveal soil processes including stirring, erosion, and deposition. Everywhere, we find an active layer, where transported sediment is well mixed. In the desert, sediment is stirred dm by episodic surface flow. On humid slopes, soil is stirred more deeply, primarily by tree-throw. In contrast to river networks, ^{10}Be concentration in soil generally increases downslope as sediment is dosed during slow, creeping transport. Average rates of downslope transport can be inferred from these data. Pebbles are washed down gentle desert piedmonts at cms to dms per year. Soil creeps down steeper mountain slopes at similar rates.

doi:10.1016/j.gca.2006.06.208

Chronometers and ages in early solar system materials

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Recent instrumentation and improvements of existing techniques have largely extended the use of radio chronometers in the study of the early steps of planet formation. Among the long-lived or absolute chronometers, still only U–Pb has sufficient direct resolution to resolve some of the stages one from another. Among the numerous proven extinct radio activities there is a choice of temporal scales which should allow to address also the shorter episodes but with the drawback of being only relative chronometers. However, a solid interconnection among these and to an absolute scale has still largely to be achieved. Normally this would be done on common well behaved primitive objects. Even when this is apparently the case as on the coupled chronometers Sm-147/Nd-143 and Sm-146/Nd-142, inconsistencies may appear (Prinzhofer et al., 1992). It turns out that the figure of planet formation is extensively blurred by a rather long list of features which complicates the understanding of the connection between the physico-chemical processes leading to the present day planetary bodies.

Various levels of disturbance affecting differentially the various chronometers, may result from reheating, shock, aqueous alteration, exposure to galactic cosmic rays and finally secondary effects of the residence time on the terrestrial surface. The initial isotopic homogeneity which is a prerequisite to radiometric dating may also be questioned in primitive object displaying isotopic heterogeneity but this can be addressed on neighbouring isotopes of the same element if these exist like for Cr (Trinquier, 2005). It appears necessary to make a sometimes subtle distinction between "date" and "age" as pointed out in a recent review of Y. Amelin Amelin (2006) in the case of U–Pb dating.

Fortunately with the ongoing production of high precision isotopic results on an extended number of meteorites, abundant crosschecking of the data from the different chronometers should solve some of the most annoying inconsistencies. Nevertheless most results show that much of the history of the planets is written early in a very few million years and one of the most striking recent result is the evidence for almost simultaneous onset of magmatic differentiation at the My level with the production of the primitive refractory constituents.

References

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doi:10.1016/j.gca.2006.06.209