Geophysical Research Abstracts
Vol. 20, EGU2018-10802-1, 2018
EGU General Assembly 2018

Cosmic-ray geology and hydrology: a scientist walking in circles

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Cosmic-ray particles and their products are used in many fields of geology and hydrology. Two common applications are dating of landforms with in-situ produced cosmogenic isotopes and measuring soil moisture and snow using cosmogenic neutrons. Unfortunately, despite the fact that both fields need a good understanding of neutrons, they developed separately, with scanty interactions between geologists and hydrologists. Cosmogenic dating came first, and it required the knowledge of the spatial and temporal variations in the cosmic-ray flux so that accurate production rates of isotopes could be determined. One of those isotopes, 36Cl, was found to be sensitive to water in minerals because one of its production mechanisms is activation by low-energy neutrons. That generated the idea that cosmogenic neutrons in air above the land surface can be used to measure soil moisture content, snow and other water stores at and near the surface. Scientific progress in the field of cosmogenic neutron moisture sensing has improved our understanding of neutrons, and some of that knowledge is now being transferred back to the field of cosmogenic isotope dating of landforms, for example to correct isotope production rates for the effects of water in minerals, soil and snow. An exciting new idea is measuring soil moisture and snow in the geological past by measuring in the same rocks in-situ isotopes that are produced by different mechanisms – one insensitive to environmental water (such as 10Be), the other sensitive (such as 36Cl). This is not possible yet, but continuing research in cosmic-ray geology and hydrology will enable this application, and thereby complete the circle from isotopes, through neutrons and back to isotopes.