70 Years History of Cosmogenic Nuclide Studies

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Cosmic rays populate the entire solar system, the galaxy, and likely the universe. The nuclear interaction of these cosmic rays with matter produces trace amounts of cosmogenic nuclides (CN). These secondary nuclides, both stable and radioactive, inhabit the entire universe.

V. Hess discovered cosmic rays in 1912. W. Libby predicted the production of radionuclides in the atmosphere by cosmic ray interactions 70 years ago, predictions that were followed by discovery of ^{14}C and development of radiocarbon dating. Early applications of terrestrial CNs were limited to a few heroic measurements, such as the first determination of *in situ* produced ^{36}Cl in phonolite collected at high elevation in 1955 and ^{26}Al in tens of kg of chert in 1968. The activities of these CNs were low, making counting difficult, so the first 30 years of terrestrial CN studies were limited to a few ^{10}Be measurements in deep sea sediments and ^{14}C dating for archeology.

Work in extraterrestrial materials followed a different trajectory. Cosmogenic ^{3}He in iron meteorites was discovered in 1952. Shortly after demonstrations of ^{3}H-^{3}He exposure age measurements of meteorites in 1957, more than 20 CNs, including ^{10}Be, ^{22}Na, ^{26}Al, ^{36}Cl, ^{53}Mn, ^{60}Co, and ^{59}Ni were measured in meteorites by low-level counting by the early 1960s. Although CN concentrations in extraterrestrial materials are higher than those of terrestrial materials, tens to hundreds gram of meteorites and lunar samples were required nonetheless to determine CN radionuclides. An exception is ^{53}Mn that can be measured with high sensitivity.

Advanced accelerator mass spectrometry (AMS) dramatically changed the detection limits of long-lived CNs and expanded the application of CN, especially those involving terrestrial materials. Terrestrial CN studies encompass a diverse range of applications, encompassing chronological studies and erosional process studies. While these studies have increased our knowledge of Earth surface processes the techniques are extensions of earlier extra-terrestrial studies. The collaborations between these two groups of researchers have jointly contributed to the growth of the field.

More recently, improved detection limits and reduced backgrounds in both AMS and noble gas mass spectrometry now allow the measurement of cosmogenic ^{10}Be, ^{21}Ne, and ^{26}Al in $\leq 1\ \mu g$ of extraterrestrial materials, such as returning samples of Hayabusa.