WHEN DID THE AVERAGE COSMIC RAY FLUX INCREASE?

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Abstract

We developed a new 129I-129Xe method to obtain cosmic ray exposure ages and to study the average cosmic ray flux on a 10^{7}-10^{8} year time-scale. The method is based on secondary neutron reactions on Te in troilite and the subsequent decay of 129I, the reaction product to stable 129Xe. We report the first measurements of 129I and 129Xe in aliquot samples of a Cape York troilite sample.

Introduction

Several investigations were carried out regarding possible variations of cosmic ray intensity in the past. Cosmic ray produced 14C in trees provides one of the most reliable records for the cosmic ray intensity in the past 10^{4} years in spite of some uncertainties in the carbon cycle and/or past geomagnetic field variation [eg. 1]. For longer periods 10Be (t1/2 = 1.6x10^{6} years) and/or 36Cl (3.0x10^{5} years) concentrations in ice cores or deep sea sediment cores may provide additional information on the cosmic ray flux in the past. However, there are many uncertainties in past climates, in precipitation and sedimentation rates, in geomagnetic fields, because the terrestrial environment is rather complex. On the other hand, the study of cosmogenic radionuclides in extraterrestrial matter provides key information for the history of cosmic rays. Kohl et al (1978) found that the average solar cosmic ray (SCR) flux changed relatively little over the last 1-10 million years, based on a study of cosmogenic 53Mn (t1/2 = 3.7x10^{6} years) and 26Al (7.05x10^{5} years) in several lunar rocks [2]. The average SCR flux during the last few million years was similar to that measured during the last few decades by detectors on satellites. However, 14C (t1/2 = 5740 years) [3] and 81Kr (2.1x10^{5} years) [4] activities in lunar samples indicate that the average SCR flux during the last 10^{4} - 10^{5} years was somewhat higher than the recent average flux. Very useful records on the galactic cosmic ray (GCR) flux were observed in meteoritic detectors. Nishiizumi et al (1980) carried out systematic studies on cosmogenic nuclides of various half-lives such as 22Na (t1/2 = 2.6 years), Kr, 26Al, and 53Mn in chondrites as a test for possible variation of the GCR flux during the last ~10 million years [5]. All sets of nuclides, with the possible exception of 26Al indicate that the averaged GCR flux was constant within ~15%, at least during the last 5 million years. More recently, Moniot et al (1983) confirmed this result using Be as the monitor [6]. On the other hand, the records of spallation K and Ar observed in iron meteorites reflect ~33% smaller average GCR fluxes on the 10^{8}-10^{9} year timescale [7, 8]. This suggests a cosmic ray flux increase ~2x10^{8} years ago.
**129I-129Xe Method:**

An investigation for possible intensity changes of GCR flux between 10^7 and 10^8 years is required. The half-life of 129I (1.57x10^7 years) makes this an appropriate nuclide for such a study. The 129I in extraterrestrial materials is produced by cosmic ray secondary neutron reactions on Te, 130Te (n,2n,β) 129I and 128Te (n,γ β)129I, and by high energy spallation reactions on Ba and the Rare Earth elements. Troilite inclusions in iron meteorites are ideal monitors among extraterrestrial materials because of their long cosmic ray exposure ages (10^8 to 10^9 years) their relatively high Te contents (~ ppm) and their low abundances of Ba and Rare Earth elements. The 129I decays to stable 129Xe. 129Xe is not directly produced by cosmic ray secondary neutrons, yielding a fractional isobaric production ratio P (129I)/P(129I + 129Xe) ~ 1 [9]. The simultaneous determination of cosmogenic 129I and 129Xe in the same troilite phase is the basic concept of the new method of determining 129I-129Xe exposure ages. This exposure age can be obtained without any shielding and target element corrections for a constant exposure geometry. The exposure age T can be calculated from the equation:

\[
\frac{-\lambda_{129I}T - 1 + e}{1 - e} = \frac{129}{129}Xe_{Te}
\]

where \(\lambda_{129I}\) is decay constant of 129I, 129I is 129I content (atom/sample), and 129Xe, is cosmogenic 129Xe content (atom/sample) produced from Te after subtraction of other components. The comparison of 129I-129Xe exposure ages and with those obtained by methods such as 46K-41Ar, 26Al-21Ne, and 36Cl-36Ar could indicate either a complex exposure history of the meteorite or a change in cosmic ray flux intensity. We developed the experimental techniques and measured both 129I and 129Xe in the same troilite sample of the large Cape York iron meteorite. The 129I measurement was carried out by accelerator mass spectrometry using the University of Rochester MP tandem van de Graaff accelerator [see 10], while the 129Xe measurement was performed by static mass spectrometry.

**Discussion:**

The Cape York iron meteorite contains (8.3±1.3)x10^6 atoms 129I/g troilite and (2.6±0.3)x10^7 atoms 129Xe, troilite. The 129I-129Xe exposure age of Cape York is calculated from the above equation as T = 93 ±18 million years. This is the first determination of a cosmic ray exposure age of Cape York. The inferred Ar production rate P (38Ar) ~ 200 atoms/g Fe x year [11] is one order of magnitude smaller than that corresponding to the most shielded location for which P(38Ar) data are available. This result documents (a) the extremely heavily shielded location of our sample and (b) that secondary cosmic ray neutrons are very useful in unravelling exposure histories and geometries. The Cape York results, however, do not allow an evaluation of the average cosmic ray flux over the 93 million year exposure period, since no other
information on the exposure age is available. Therefore, we are now applying the $^{129}$I-$^{129}$Xe dating method to meteorites for which independent exposure age information is either available, or can be obtained.

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References