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TERRESTRIAL AND EXPOSURE HISTORIES OF ANTARCTIC METEORITES: K. Nishiizumi,

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Records of cosmogenic effects (noble gases, radionuclides, and cosmic ray tracks) have been studied in a large suite of Antarctic meteorites. The cosmogenic nuclide measurements together with cosmic ray track measurements (if possible) on Antarctic meteorites provide us with information such as exposure age, terrestrial age, size and depth in meteoroid or parent body, influx rate in the past, pairing, and so on. The first two ages are of special interest. The exposure age is the time period between meteorite ejection from its parent body and capture by the earth. The cosmogenic nuclides are produced during this period by interraction of cosmic rays in space. The terrestrial age is the time period between the fall of the meteorite on the earth and the present. To define both ages, two or more nuclides with different half-lives and possibly noble gas data are required.

In the present work, we emphasize the terrestrial age of Antarctic meteorites based on their cosmogenic radionuclides. The cosmogenic radionuclides for this study are ^{14}C ($t_{1/2}$ = 5740 years) [e.g. 1,2,3], ^{81}Kr (2.1×10^5 years) [e.g. 4,5], ^{36}Cl (3.0×10^5 years) [e.g. 6,7,8], ^{26}Al (7.05×10^5 years) [e.g. 9, 10], ^{10}Be (1.6×10^6 years) [e.g. 11,12], ^{53}Mn (3.7×10^6 years) [e.g.13,14,15] and ^{40}K (1.28×10^9 years) [e.g. 16].

Terrestrial age: Figure 1 is a histogram of terrestrial ages of Yamato, Allan Hills, and other Antarctic meteorites. The figure shows the average age for same fall (pair) meteorites and does not include the so-called 3.5×10^4 year peak for ^{14}C age [2]. This figure indicates several features. The terrestrial ages of Allan Hills meteorites are widely distributed between 1×10^4 and 7×10^5 years and clearly show longer ages than both Yamato and non-Allan Hills meteorites. This is expected because the meteorite surface density on the Allan Hills blue ice is much higher than that at the Yamato mountain area. All six Meteorite Hills meteorites which we have so far measured show terrestrial age less than 1×10^5 years. The shape of the two distributions is different. The terrestrial ages of Allan Hills meteorites show poisson distribution and others show exponential distribution. It is not clear that the difference is due to different accumulations mechanisms or sampling bias for measurements. For Allan Hills meteorites, there is no clear correlation between the terrestrial age and their weathering features. It may be that weathering is mainly dependent on exposure time at the ice surface. Meteorites found on the west and north part of the Allan Hills blue ice region have shorter terrestrial ages than meteorites found on the south and east part. This trend is similar to the flow direction of the surface ice. Figure 1 also indicates that the terrestrial ages of Allan Hills L-chondrites are widely distributed up to 7×10^5 years compared to other types of meteorites. We are not confident that this indicates a different influx rate of L-chondrites in the past, because of inadequate statistics and sampling artifacts which were the result of non-random selection of samples for measurement of terrestrial age determination. Additional studies are required to clarify this.

Cosmic ray exposure history: There is no distinguishable difference between Antarctic meteorites and non-Antarctic meteorites with regard to exposure age. The distribution of ^{21}Ne exposure ages of Antarctic meteorites [e.g. 17,18,19] is very similar to that of non-Antarctic meteorites [20]. Figures 2-a and 2-b show the histogram of ^{53}Mn results in L-chondrites (2-a) and H-chondrites (2-b) of both Antarctic and non-Antarctic meteorites. The

values have not been corrected for undersaturation. These two histograms for both classes of meteorites are surprisingly similar to each other. It is completely different from the histogram of nuclides with shorter half-lives, ^{26}Al [9,10] and ^{36}Cl. Figures 2-a and 2-b indicate that the terrestrial ages of the Antarctic meteorites are usually short compared to the half-life of ^{53}Mn, and also that the ^{53}Mn contents of Antarctic meteorites are useful for the study of meteorite exposure history. We found several interesting exposure histories among Antarctic meteorites, for example, two stage irradiations for ALHA 76008, Yamato 7301, 74028 and 74116 [6,14] and Solar Cosmic Ray effects for ALHA 77005 [unpublished]. These discussions will be described elsewhere. In general, we found no distinguishable differences between the average exposure histories for the two sources of meteorites.

New methods: We have started two new dating methods for measuring terrestrial ages of Antarctic meteorites and the history of the glacier. The cosmogenic nuclide ^{41}Ca with half-life of 1.0×10^5 years can fill the gap between ^{14}C and ^{81}Kr, also ^{36}Cl for measurements of the terrestrial age of Antarctic meteorites. The ^{41}Ca in the metal phase is produced by high energy spallation such as ^{36}Cl in the metal phase. The production rate of ^{41}Ca is insensitive to size and depth for a meteorite of normal size. The first accelerator mass spectrometry measurement of this nuclide in the Bogou iron meteorite [21] demonstrates that ^{41}Ca can be measured in 100-200 mg of meteoritic metal. The sample size will be reduced after improvements of the ion source of the accelerator. We also demonstrated in situ production of ^{10}Be and ^{26}Al in quartz samples [22]. The concentrations of both nuclides and the ratio show the erosion rate and cosmic ray exposure age of the quartz on the earth's surface [23]. The measurement of this pair in Antarctic quartz indicates that how long the quartz was exposed on ice or snow. The first measurements of ^{10}Be and ^{26}Al in a quartzite which was collected at the peak of Allan Hills shows that the top of Allan Hills was not covered by ice for the last 1 million years [22]. The measurements of ^{10}Be and ^{26}Al in other quartz collected at different locations are in progress.

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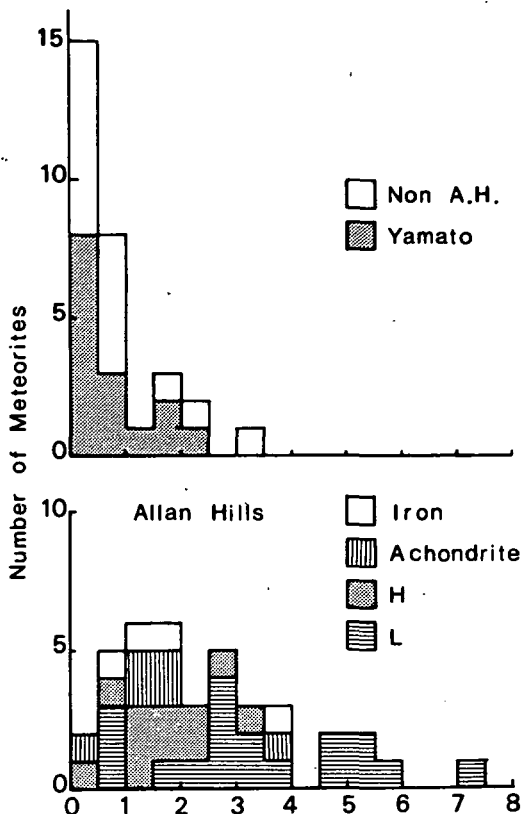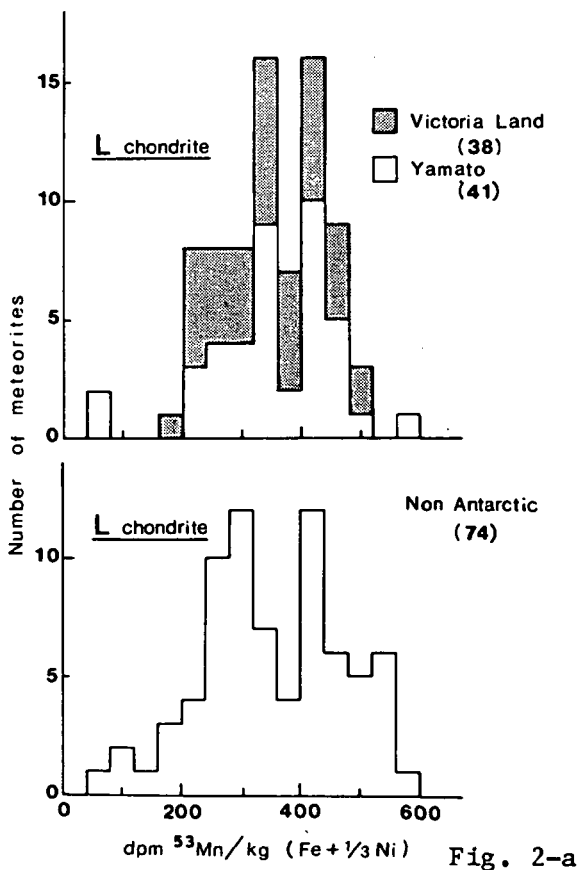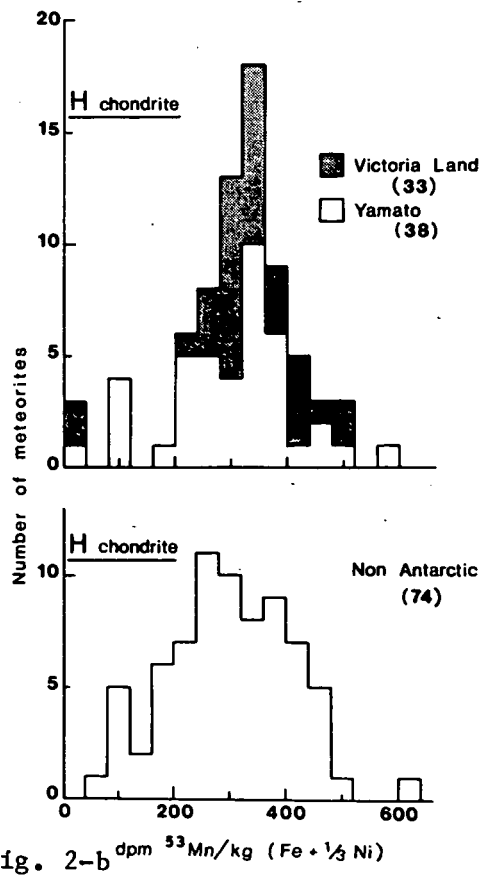
Fig. 1 Terrestrial Age (10^5y)

Fig. 2-a

Fig. 2-b dpm ^{53}Mn/kg (Fe + ⅓ Ni)