^{26}Al-^{53}Mn Exposure Ages of Lodranites and Acapulcoites

K. Knie, A. Arazi, T. Faestermann, G.F. Herzog [a], G. Korschinek, P. Ma [a], G. Rugel, and A. Wallner
[a] Department of Chemistry, Rutgers University, Piscataway, NJ, USA

Both Lodranites and Acapulcoites are very uncommon subgroups of the meteorite group of the primitive achondrites. They presently comprises only eleven and twelve members, respectively. Cosmic-ray exposure (CRE) ages[1] (mainly deduced from noble gas data) for most lodranites and acapulcoites fall between 5 and 10 Myr [1,2,3]. Because of uncertainties, it remains unclear how tightly they cluster around 7-8 Myr, the most common CRE ages for H chondrites, which would point to a common origin in one collision with the parent body. Examined in detail, however, the noble gas ages show some dispersion. Therefore, the measurement of cosmogenic radionuclides would improve these ages in two ways:

i) directly, by providing independent ages, when the half life is comparable to the CRE age (which is especially the case for cosmogenic ^{53}Mn with a half life of 3.7 Myr as shown in fig.1); and

ii) indirectly, by indicating shielding (when combined with another cosmogenic radionuclide of different half life, as in our case ^{26}Al with $T_{1/2} = 0.72$ Myr).

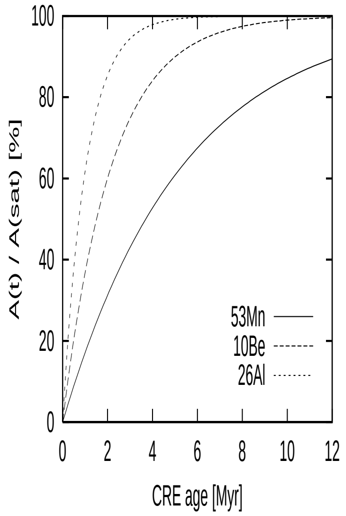

Fig. 1: Build-up of the activity of cosmogenic radionuclides relative to their saturation activity A(sat).

To a good approximation the ^{26}Al production rate P_{26} (in dpm/(kg Si)) depends linearly to the ^{53}Mn production rate P_{53} (in dpm/(kg Fe) for meteoroids with radii less than 50 cm [4]: $P_{26} = \mathrm{a} + \mathrm{b}P_{53}$. Thus, for most meteorites, it is possible to obtain a ^{26}Al-^{53}Mn exposure age by solving the equation

$$\frac{A_{26}}{1-\mathrm{e}^{-\lambda_{26}t}} = \mathrm{a} + \mathrm{b}\frac{A_{53}}{1-\mathrm{e}^{-\lambda_{53}t}} \qquad (1)$$

with the activities A_i and the decay rates λ_i.

Samples from three lodranites (GRA 95209, EET 84302, and MAC 88177) and four acapulcoites (ALH 81261, ALH 81187, ALH 84190[2], and Acapulco) were separated into metal- and silicate-rich phases. According to [5] ^{53}Mn was extracted from the metal phase after adding a known amount of stable ^{55}Mn carrier.

For these samples ^{53}Mn/^{55}Mn ratios were determined by accelerator mass spectrometry at the Munich Tandem. To obtain the required sensitivity the ions were accelerated to ≈ 150 MeV and the interfering stable isobar ^{53}Cr was separated at the gas-filled analyzing magnet system GAMS [6]. The resulting ^{53}Mn activities are given in table 1. For each meteorite the P_{53} and P_{26} were calculated for various depths and sizes from elemental compositions [2,7] and elemental production rates [4]. The values for a and b were derived from fitting these production rates. ^{26}Al-^{53}Mn exposure ages, T_{26-53}, calculated with A_{53} from this work and A_{26} from [1] are given in table 1. Uncertainties include contributions from ^{53}Mn, ^{26}Al, and the elemental compositions.

For each meteorite T_{26-53} is slightly older than, but agrees within the uncertainties with the noble gas CRE ages given by [2,3].Comparisons of measured ^{26}Al with calculated P_{26} indicate that all of these meteorites had preatmospheric radii of less than 25 cm, MAC88177, ALH81261, ALH84190, and ALH81187 of even less than 5 cm. A size so small suggests that solar cosmic-ray produced nuclides are probably present in some of these meteorites.

T_{26-53} from six of seven samples cluster in the range between 6.5 and 8.5 Myr, supporting the hypothesis, that a single collision on a parent body produced all lodranites and acapulcoites. The result for GRA95209 ($T_{26-53} = 10 \pm 3.4$ Myr) is compatible within the error bars.

Meteorite	A_{53} dpm/(kg Fe)	T_{26-53} Myr	T_3 Myr	T_{21} Myr
Lodranites				
GRA 95209	293 ± 28	10.0 ± 3.4	6.9	6.7
EET 84302	221 ± 19	6.9 ± 1.6	6.0	6.6
MAC 88177	121 ± 9	6.8 ± 1.5		8.2
Acapulcoites				
ALH 81261	135 ± 16	7.3 ± 2.3	5.9	6.2
ALH 81187	150 ± 30	8.6 ± 5.2	7.3	7.5
ALH 84190	162 ± 13	8.5 ± 3.2	7.2	7.3
Acapulco	281 ± 23	8.1 ± 4.1	7.5	7.6

Table 1: ^{53}Mn activities (A_{53}), measured at GAMS, and the resulting ^{26}Al-^{53}Mn exposure ages (T_{26-53}) according to eq. (1). For comparison, the noble gas ages T_3 (deduced from ^{3}He) and T_{21} (deduced from ^{21}Ne and ^{22}Ne) are given [2,3].

References

[1] S. Xue *et al.*, Proc. Lun. Planet. Sci. Conf. XXV (1994) 1523
[2] A. Weigel, Geochim. Cosmochim. Acta **63** (1999) 175
[3] D. Terribilini *et al.*, Meteoritics & Planet. Sci. **35** (2000) 1043
[4] I. Leya *et al.*, Meteoritics & Planet. Sci. **35** (2000) 259
[5] C. Schnabel *et al.*, Proc. Lun. Planet. Sci. Conf. **XXXII** (2001) 1357
[6] K. Knie *et al.*, Nucl. Instr. Meth. B **172** (2000) 717
[7] J. Zipfel and H. Palme, Proc. Lun. Planet. Sci. Conf. **XXV** (1994) 1563

[1] Cosmic-ray exposure age means the time, during which high energy cosmic particles had interacted with the meteoroid, i.e. the time from the impact on the meteoroid's parent body to the meteoroid's entrance into the Earth's atmosphere. During this time, the so-called cosmogenic isotopes (e.g. ^{53}Mn) had been produced by nuclear reactions.

[2] ALH 84190 is paired with ALH 81187, i.e. it originates from the same meteoroid, which was broken up in the Earth's atmosphere