Measurements of In-situ Produced ^{53}Mn in Rocks

A. Meier, T. Faestermann, G.F. Herzog [a], K. Knie, G. Korschinek, J. Masarik [b], M. Poutivtsev, G. Rugel, J. M. Schäfer [c], C. Schlüchter [d], F. Serefiddin [a], and G. Winckler [c]

[a] Rutgers Univ., Dept. of Chemistry and Chem. Biol., 610 Taylor Rd., Piscataway, NJ 08854-8087, USA
[b] Commenius University Bratislava, Dept. of Nuclear Sciences, Bratislava, Slovakia
[c] Lamont-Doherty Earth Observatory, Route 9W, Palisades, NY-10964, USA
[d] Universität Bern, Geologisches Institut, CH-3012 Bern, Switzerland

Terrestrial cosmogenic nuclides have become an indispensable tool in Earth sciences, particularly for studying the chronology of landforms. The ultra sensitive measurements of longliving radionuclides with AMS give time-dependent information over geological processes. There are some radionuclides like ^{10}Be and stable nuclides like ^{3}He and ^{21}Ne, which are produced in-situ in rocks by cosmic rays. Measuring their concentrations can reveal the exposure time of the rock to the cosmic rays. Now for the first time, it is possible to measure the in-situ produced radionuclide ^{53}Mn in terrestrial samples. The advantage of ^{53}Mn is the long half-life of 3.7 Myr. With this nuclide it is possible to date rocks about 10 Myr back. ^{53}Mn is produced exclusively by spallation of cosmic rays on iron, which is nearly in every rock.

In concert with other in-situ produced stable or unstable nuclides, it is also possible to get information on the periods of irradiations and shielding of the cosmic rays due to ice or other rocks. Also, it is possible to calculate a production rate of ^{53}Mn, which is altitude and latitude dependent.

We measured ^{53}Mn with AMS at the GAMS (gas-filled analyzing magnet system). Background of AMS measurements originate usually from the interfering stable isobar, in case of ^{53}Mn this is ^{53}Cr (10% isotopical abundance). Therefore it is necessary, to extract the manganese by efficient chemistry - and to get rid of the chromium. We developed a new chemical procedur to suppress chromium two orders of magnitudes more than was standard at the beginning of our tests (Fig. 1) [2]. The extraction of MnF^- instead of MnO^- from the ion source gives an additional suppression of a factor of six [2].

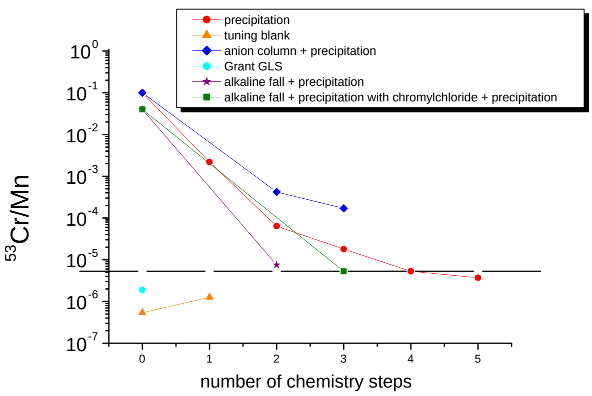

Fig. 1: Ratio of ^{53}Cr to Mn for different chemistry tests.

We measured 14 samples from different locations in Antarctica. The results are compared with the data of ^{3}He [3] in Fig. 2. A linear correlation between ^{3}He and ^{53}Mn can be seen. Adjusted for the duration of exposure, these results correlate well with the concentrations of cosmic-ray-produced ^{3}He in the same samples, implying that the ^{53}Mn is produced in-situ and retained quantitatively.

Our results show that the ^{53}Mn concentrations in bulk terrestrial rocks can be used for dating on time-scales exceeding 10 Myr.

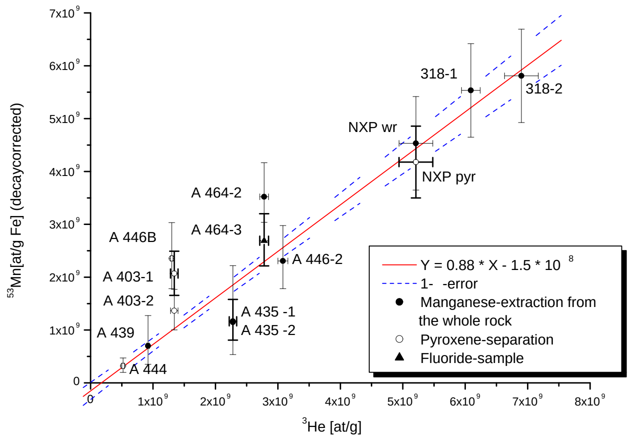

Fig. 2: Measured ^{53}Mn atoms per gram iron decaycorrected against the measured ^{3}He atoms per gram sample in the same rock. Decay-correction for ^{53}Mn concentrations are based on [1,2]
$^{53}\mathrm{Mn}_{decay-corr} = {}^{53}\mathrm{Mn}_{measured} * (\lambda \mathrm{T}/(1 - e^{-\lambda \mathrm{T}}))$,
where $\lambda = 0.187 * 10^{-6}$ yr^{-1} and T = ^{3}He-age [yr];

For comparison of the measurements, we simulated ^{53}Mn production in terrestrial rocks with a computer model based on two published codes [4,5]. The theoretical value for the production rate is 101 ± 12 atoms yr^{-1} (g Fe)$^{-1}$ at sea level and high latitudes (normalized to iron, because it is the only important target element). With the measurements we get a production rate of 95 ± 7 atoms yr^{-1} (gFe)$^{-1}$ which corresponds well to the calculated one.

References

[1] J. M. Schäfer *et al.* Earth and Planetary Science Letters **251** (2006) 334-345
[2] A. Meier, diploma thesis, TU München, 2006
[3] J. M. Schäfer *et al.* Earth and Planetary Science Letters **167** (1999) 215-226
[4] R. Brun GEANT3 User's guide. In Rep. DD/EE/84-1, pp. 584, Eur. Org. for Nucl. Res. 1987
[5] J. F. Briesmeister MCNP-A general Monte Carlo N-particle transport code version 4A. In LA-12625-M, pp. 693. Los Alamos National Laboratory, 1993