Surface Exposure Dating with ^{53}Mn: First Experimental Results

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Surface exposure dating (SED) by means of cosmogenic nuclides is an important tool in quantitative geomorphology. One of the main problems in surface exposure dating is the detection of multiple exposures. This problem can be addressed through the application of stable and radionuclides in concert. Although many studies of multiple exposures have appeared in the literature, few of them include the radionuclide ^{53}Mn, mainly produced in-situ by spallation reactions of cosmic radiation on iron. The steadily increasing sensitivity of AMS in the mass range $A \approx 60$ motivated us to re-visit the possible usefulness of ^{53}Mn for SED. The information that ^{53}Mn provides complements the information from other radionuclides:

(1) Because of its long half-life of 3.7 Myr, ^{53}Mn is better suited than ^{26}Al and ^{10}Be for the determination of exposure ages in the range from 3 Myr to 10 Myr.

(2) Again, because of its long half life, ^{53}Mn activities, if taken together with noble gas informationss, can record longer periods of burial ages than ^{26}Al or ^{10}Be.

(3) As elements heavier than Fe are rare in most terrestrial surface materials, ^{53}Mn is almost entirely produced from Fe, a fact that simplifies the estimation of its production rates.

(4) As a consequence of (3) ^{53}Mn offers the possibility for SED of hornblende, garnet or biotit.

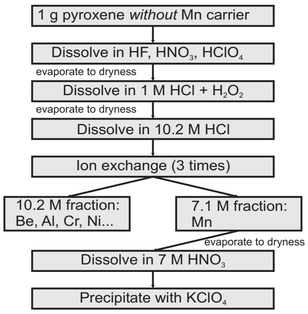

Fig. 1: Flow diagram of the manganese extraction and purification from the pyroxene sample.

For a first ^{53}Mn determination, we chose a pyroxene (NXP 93*52) separated from a rock collected from Mt. Feather, Antarctica; a detailed description of this very pure and ingrowth-free pyroxene is given in [1]. An extraordinarily high surface exposure age of 5.5 Myr, based on noble gas data, has been reported for this sample [1]. Both, He and Ne ages are in very good agreement.

After the determination of the Mn and Fe content with ICP-MS ([0.195 ± 0.007] % and [7.82 ± 0.10] %, respectively) from one gram of the pyroxene manganese has been extracted (see fig.1). In this sample the isotopic ratio ^{53}Mn/^{55}Mn has been measured via AMS at the GAMS setup [2] to $(1.06 \pm 0.07) \times 10^{-11}$. This value corresponds to a ^{53}Mn activity of 42 g^{-1} yr^{-1} or to 60 % of the estimated production rate P, which equals the saturation activity (see tab. 1).

For the build-up of an activity A it is $A(t) = [1-e^{-\lambda t}]P$, thus the ^{53}Mn exposure age can be calculated to (5.0±0.7) Myr, which is in perfect agreement with the cosmogenic noble gas exposure ages given in [1] (see also fig.2).

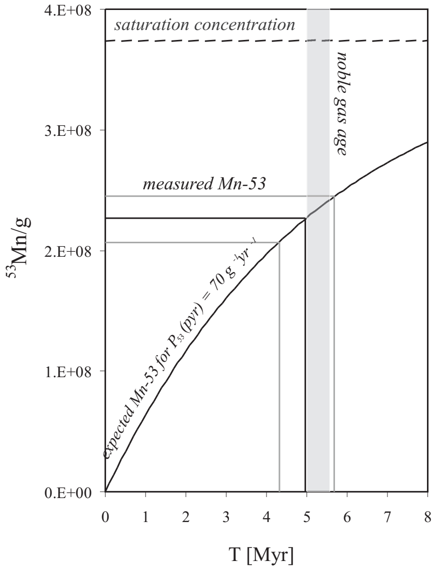

Fig. 2: ^{53}Mn concentration versus exposure time. The measured concentration of $(2.26 \pm 0.18) \times 10^8$ at g^{-1} corresponds to ≈ 60 % of the expected concentration in saturation (dashed line), or, to an cosmic ray exposure age of (5.0 ± 0.7) Myr. The exposure age deduced from cosmogenic noble gases is indicated by the shaded area.

target	product	P_i/P_{21}(Si) [a]	P_i(2555 m) [b] [at g^{-1} yr^{-1}]
Mg	^{21}Ne	4.34	1.6×10^3
Al	^{21}Ne	1.17	4.3×10^2
pyroxene	^{21}Ne	0.80	3.0×10^2
Fe	^{53}Mn	2.42	9.0×10^2
pyroxene	^{53}Mn	0.19	70

Table 1: [a] Calculated production rates P_i relative to the production rate P_{21}(Si) of ^{21}Ne on silicon [4].
[b] production rate P_i using 45 at g^{-1} yr^{-1} for P_{21}(Si) [3] for high geographical altitudes at sea level. The enhanced comic ray flux at the samples elevation of 2555 m is considered by a correction factor of 8.21 according to ref. [5].

References

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