^{26}Al in a Manganese Crust: Indication for a Constant Cosmic Ray Flux during the Last Million Years

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Manganese crusts are growing very slowly (few mm/Myr) on the ground of the oceans. They are mobilizing there elements from the ocean water, i.e. they preserve the ocean water's isotopic composition for millions of years. Therefore, manganese crusts are an important reservoir for paleoceanographic, paleoclimatic and even paleoastronomic studies (see also [1,2]).

Fig. 1: The manganese crust 237KD.

To date layers of a certain depth in the crust radiological methods are used. The radionuclide ^{10}Be ($T_{1/2} = 1.51$ Myr) is produced in the atmosphere by spallation of cosmic rays on nitrogen or oxygen. After a relatively short time it is washed out of the atmosphere, can get dissolved in the ocean and might finally be incorporated into the crust. Assuming a constant ^{10}Be flux into the crust, one can easily use the ^{10}Be concentration for dating crust layers of a certain depth: If a layer is deeper and therefore, older, its ^{10}Be content will be low due to radioactive decay. A similar attempt is made with ^{53}Mn [1], which is a cosmogenic isotope as well, thus the same assumption of a constant cosmic ray flux has to be made.

However, for the radionuclide ^{26}Al ($T_{1/2} = 0.72$ Myr) the production is substantially different. The main fraction is not mobilized from the ocean water, but produced in-situ. α particles from natural radioactivity produce ^{26}Al in a compound reaction with ^{23}Na in the crust (see figure 2).

The expected depth (or time) profile of ^{26}Al depends on the half-life of the α emitter:

- **^{230}Th** ($T_{1/2} = 75$ kyr): Relative to the crust's age the half-life is very short. ^{230}Th from the ocean water is adsorbed at the crust's surface. Here it decays "instantaneously" and produces ^{26}Al with a certain probability. Similar to ^{10}Be or ^{53}Mn, one expects an exponential decrease of the ^{26}Al concentration with the layer's age (or depth) due to radioactive decay.

- **^{232}Th** ($T_{1/2} = 14$ Gyr) and **^{238}U** ($T_{1/2} = 4.5$ Gyr): Relative to the crust's age the half-lifes are very long. ^{26}Al is produced with a constant rate. A saturation level is reached when ^{26}Al's decay rate equals the production rate.

In figure 3 the results of a depth profile measured with AMS at the GAMS setup is compared with the estimated profile. Using ^{10}Be ages for the layers [4] an excellent agreement between theory and experiment can be observed. The dating of the crust with the cosmogenic nuclide (^{10}Be) is fully compatible with the dating by the radiogenic nuclide ^{26}Al. This supports a long term constancy of the galactic cosmic ray flux.

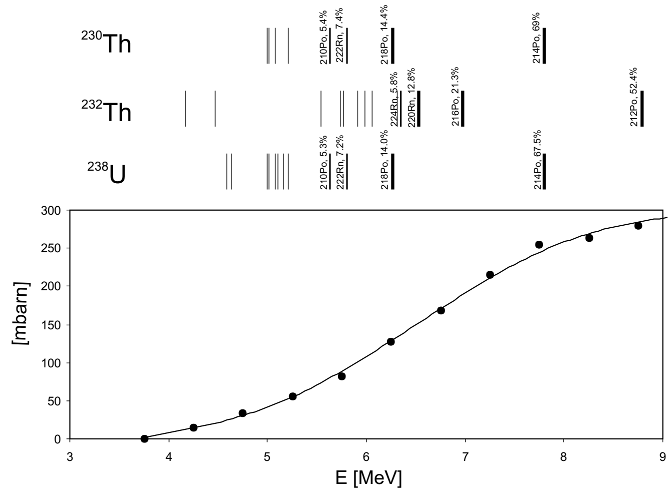

Fig. 2: Cross section for the ^{23}Na(α,n)^{26}Al reaction [3]. The α energies of the different decay chains are indicated above. The main fraction of ^{26}Al is produced by only few, high energetic α particles (bold indications).

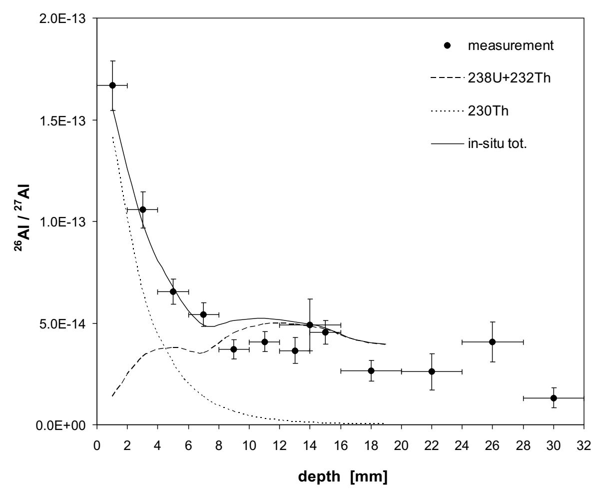

Fig. 3: Measured ^{26}Al/^{27}Al ratio versus the depth of the layer. The dotted (dashed) line shows the expected ^{26}Al profile due to production with α particles from the ^{230}Th (^{232}Th and ^{238}U) chain. The dip in the dashed line reflects a reduced ^{232}Th and ^{238}U concentration in the 6-8 mm layer. The sum of both signals is given by the solid line.

References

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[2] K. Knie *et al.*, 24
[3] E.B. Norman *et al.*, Nucl. Phys. A **390** (1982) 561
[4] M. Segl *et al.*, Nature **309** (1984) 540