# Calculations of Cosmogenic Radionuclides in the Moon and Comparison with Apollo Measurements*

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Calculations have been carried out to determine the time and spatial dependence of the reproduction of various radionuclides in the moon from solar and galactic proton bombardment. The calculational method utilizes Monte Carlo techniques to obtain a detailed description of the induced nucleon-meson cascade. All required spallation cross-sections are computed using the intra-nuclear-cascade-evaporation model, the calculated depths dependence of $^{26}Al$ and $^{22}Na$ is in good agreement with Apollo 11 and 12 measurements. The depths-dependent neutron spectra are also directly available from the calculations. The calculated thermal neutron flux is in good agreement with the flux obtained from measured $^{60}Co$ concentrations. Irradiation ages obtained from the calculated thermal flux and the thermal fluence based on measured gadolinium concentrations are consistent with the ages determined by other methods.

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# Spallogenic $^{53}Mn$ ($T \approx 2 \times 10^6 a$) and Search for Re Isotopic Anomalies in Lunar Surface Material by Means of Neutron Bombardment.

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## Preliminary Abstract.

Because of their possible usefulness for the determination of exposure ages long term flux variations and profiles especially the production rates of the longer lived spallation nuclides deserve interest.Cosmic ray produced radionuclides in the lunar surface were detected only in the range of up to about 100 dpm/kg, so that for "low level" measurements the necessary amounts of material are exceeding 100 grams. The scarcity of extraterrestrial material in mind a highly economic and sensitive method for the exact determination of $^{53}Mn$ via an intense neutron activation was developed, transforming the K-emitting $^{53}Mn$ into the $\gamma$-radiating $^{54}Mn$ ($T = 300$ d). Hence rising the activity rate by a factor of $\sim 10^4$. In this way, eleven rock and soil samples as small as 0.6 to 1 gram were successfully analyzed, especially of stone No.10017, cut from different depths. Their $^{53}Mn$-disintegration rates were compared with those of the Grant, Peace River and Sichote Alin meteorites. The chemistry was controlled by a "carrier-free" $^{52}Mn$ tracer, additionally by $^{56}Mn$ using ion exchange and destillation techniques.- Attention had to be paid to the interfering (n,2n)reaction, which contributed to about 50% of the $^{54}Mn$-activity. Whereas the interference of the $^{54}Fe(n,p)^{54}Mn$ -reaction proved to be smaller by a factor of 10. The irradiation conditions during the 8 weeks of high flux bombardment were carefully examined by several independent standards. This study should be regarded as part of a more comprehensive investigation following the line and in co-operation with J.R. Arnold and his group, Science 167, 576, verging for

improved informations on the flux and rigidity of past ($\gtrsim 10^6$ a) solar events. We established further the Re-content of several lunar rock samples in the ppb range by neutron activation techniques. The low energetic natural ß-emitting $^{187}$Re deserves interest because recently a possible temperature dependent decay has been discussed. The induced $^{186}$Re:$^{188}$Re activity ratios were checked and upper limits were set for a suspected isotope abundance anomaly of solar wind affected Re. Miscellaneous studies on thermoluminescence behaviour and trace element composition were shortly mentioned.