New Age Estimation of the Monturaqui Impact Crater ◇

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The Monturaqui impact crater is the only meteorite impact related structure yet found in Chile. It is localized in the second region, 200 km south-east of Antofagasta and at 3 015 m altitude in the precordillera near the southern end of Salar de Atacama. It corresponds to a simple crater of ∼400 m diameter and ∼34 m of depth [1], first referred as an impact crater by Sanchez and Cassidy [2]. The age of the crater was estimated as older than 0.1 Ma by Buchwald [3] by thermoluminescence analysis, but with an appreciable error.

Fig. 1: Monturaqui impact crater.

We are aiming for reporting the first absolute ages of the Monturaqui impact crater following two approaches: a) the terrestrial age of the impactor by measuring the residual activities of ^{10}Be, ^{26}Al, ^{36}Cl, ^{41}Ca, ^{59}Ni, ^{60}Fe, and ^{53}Mn in selected iron shale samples, which correspond to the remaining altered fragments of the impactor, inferred to be an iron meteorite: a coarse octahedrite of group I deduced from analyses of the Fe-Ni spherules found in impact melt ejecta [3,4], and b) in-situ ages obtained through the use of long-lived terrestrial cosmogenic radionuclides ^{10}Be and ^{26}Al in the granite outcrops exposed to cosmic radiation starting after the impact. Chemical preparation of targets suitable for accelerator mass spectrometry (AMS) have been performed after Merchel and Herpers (for the iron meteorite sample) [5] and a combination of slight modifications of [5] and [6] (for the granite samples). AMS measurements of ^{10}Be and ^{26}Al took place at the French 5 MV-AMS facility ASTER, ^{36}Cl at CAMS, USA, and ^{53}Mn at the MLL. Further AMS measurements of other nuclides are foreseen for the near future. Under the justified assumption – from the size of the crater – that any analyzed sample has been irradiated in space in a near 2π-geometry, we can compare our measured radioactivities with depth-depending production rates from sophisticated theoretical Monte-Carlo calculations [priv.com. I. Leya]. As these production rates are a function of the chemical composition (of the impactor in space), remaining fragments are highly altered and precise chemical analyses could not yet be achieved, certain further assumptions are influencing the following discussion of our, thus preliminary, data. The longest-lived radionuclide ^{53}Mn ($t_{1/2}$=3.7 Ma), normalized to a fully corroded Fe_2O_3-sample, is the least sensitive nuclide to a varying terrestrial age, thus, providing us with a shielding depth of 62-71 cm. The best fit of the measured shortest-lived radionuclide ^{36}Cl ($t_{1/2}$=0.301 Ma) with theoretical production rate at that depths is for a terrestrial age of 500-600 ka. The ^{26}Al-activity ($t_{1/2}$=0.7 Ma) goes along with that age. Though, the measured ^{10}Be-concentration is far too high in comparison to the theoretical production rate, which are based on an average carbon-content of 0.1% (as Canyon Diablo). As earlier studies [7,8] demonstrated the great influence of inhomogeneous distributed trace elements like C, S, and P on the production rates of lighter cosmogenic radionuclides in iron meteorite samples. Finally, under the contrary assumption of no corrosion of the impactor, the whole discussion changes only slightly: Deeper shielding position (66-80 cm), but as production rates of ^{53}Mn and ^{36}Cl are influenced the same way, the terrestrial age will not change. Our second approach using terrestrial cosmogenic radionuclides leads to concordant results for ^{10}Be only: The minimum in-situ exposure age of two samples from the crater wall could be calculated from ^{10}Be-concentrations in quartz to 200-250 ka. A larger age of excavation is very likely due to the subsequent erosion of the crater walls. However, the determined ^{26}Al-concentrations are probably erroneous. Paleomagnetic measurements carried out on several samples of the granite within the crater revealed a reverse magnetic field polarity suggesting an age older than 780 ka for the remagnetization of the granite. This magnetization may be related to the impact although we cannot exclude that it was produced by the earlier emplacement of the Pliocene ignimbritic sheet upon the preimpact surface. Up to now, we have to conclude that the most likely terrestrial age of the Monturaqui impact crater is in the range of 500-780 ka. We are looking forward to measurements of the most sensible ^{41}Ca($t_{1/2}$=0.104 ka) that might improve the accuracy of this age. However the expected ratios are as low as the $7{\times}10^{-14}$ ^{41}Ca/Ca and, thus, challenging to measure in the chemical form of CaF_2 even with the very sophisticated AMS set-up at the MLL.

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