Comparative analysis of micrograins from asteroid 25143 (Itokawa) and Chelyabinsk meteorite

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We compared data concerning major, minor and trace mineral phases in rock particles from Chelyabinsk meteorite and Itokawa dust grains. General geochemical compositions of olivine, (Mg, Fe, Ca)-pyroxenes, feldspar and Fe-Ti-Cr oxides in both cases are very similar. The oxygen three-isotope ratios of minerals in Itokawa particles are nearly identical with the average value of $\Delta^{17}O$ and $\delta^{18}O$ of Chelyabinsk, too. There are small but significant differences in the relative abundances of the refractory siderophile (Ir and others) and chalkophile (Zn and others). Comparing Ir/Ni and Zn/Ni ratios of the Itokawa and Chelyabinsk samples, we are likely to assume that the materials comprising theirs parent bodies were formed in areas with similar heliocentric distances not far from the formation place of the main part LL chondrites.

Parent body of Chelyabinsk meteorite has a complex history of collisions. Sm-Nd and Rb-Sr isotope systems analysis provided two isochrones with ages 4,56 Ga and 290 Ma (million years) [2]. The last event likely indicator of the impact that caused extensive melting (lithology B) and destruction of the parent body. Alternative, phosphate U-Pb age as 4,452 ± 21 Ma and a significant thermal and/or collision resetting event at 115 ± 21 Ma after formation of the Solar System were defined. As a group, LL chondrites have a typically cosmic ray exposure (CRE) age as 5-50 Ma with a peak in the CRE age histogram at ~15 Ma. Chelyabinsk, as assumed, was exposed only since ~1.2 Ma after being ejected from the resonance, due to breakup from either thermal stresses, rotational spin-up, or from tidal forces in terrestrial planet encounters.

Irradiation history of Itokawa grains was deduced from noble gases analysis [3]. The upper limit of CRE ages based on the Ne isotopic composition was obtained as ~3 Ma, if the grain remained in the uppermost regolith layer, and at most ~8 Ma, if the grain remained several centimeters below the surface. From the other side, M. Meier with collaborators determined CRE age for individual olivine particles, using cosmic-ray produced ^{3}He and ^{21}Ne . It was shown, that for any original burial depth larger than 1 cm, solar wind contributions is negligible, and the CRE age is consistent with 1.5 Ma over the rest of the depth range. In any case, a likely CRE age for the surface of Itokawa is very short compared to the CRE ages of most LL chrondrites as in case of the Chelyabinsk meteorite.

It seems unlikely that Chelyabinsk would derive directly from Itokawa, but both materials might derive from the related LL type asteroids belonging to the Flora family that experienced a number of collisions. Surface resetting events ~1.2 - 8 Ma ago ejected some material into Earth crossing orbits and in the main asteroid belt. The rest of that chunks and rubble could still be part of the near-Earth object population.

[1] S. A.Voropaev, V. S. Sevastyanov, A. A. Eliseev, D. I. Petukhov (2013) Raman Identification of Calcite Grains in the Chelyabinsk Meteorite. Geochemistry International 51(7): 593-598.

[2] E. M. Galimov et al. (2013) Analytical results for the material of the Chelyabinsk meteorite. Geochemistry International 51(7): 522-539.

[3] K. Nagao et al. (2011) Irradiation history of Itokawa regolith material deduced from noble gases in the Hayabusa samples. Science 333: 1128-1131.