Unusual sources of fossil micrometeorites in sediments ~467 Ma old

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Fossil micrometeorites recovered from marine sedimentary rock are useful to determine changes in the sources of extraterrestrial materials to Earth [e.g., 1–4]. Although sediment diagenesis results in complete alteration of most phases, chromite and chrome spinel have been reported to be resistant [1] and can retain their original structural [5], chemical [1] and isotopic composition [6]. By analyzing the elemental and oxygen isotopic composition of these phases the micrometeorites can be classified and hence their sources determined. We have recently shown that about ~467 Ma ago an unusually large fraction of extraterrestrial chrome-spinel grains (>63 μm diameter) that arrived on Earth as coarse micrometeorites originated from differentiated asteroids [2]. Here, we present results from micrometeoritic relict chrome-spinel grains of a smaller size fraction (32–63 μm), representing a more comprehensive suite of coarse micrometeorites from the same sediments, with the goal to further investigate relative contributions of their sources.

Chrome-spinel grains were recovered from ~467 Ma old limestone in the Lynna River section near St. Petersburg, Russia [7] by acid dissolution. Polished grains in epoxy mounts were imaged and quantitatively analyzed for major and minor elements with SEM/EDS and EPMA/WDS. We used a Cameca IMS-1280 to analyze three oxygen isotopes with an established method [2,6,8]. The combined approach by using $\Delta^{17}O$ values, and TiO_2 and V_2O_3 concentrations allows classification of grains [2,6,8].

Abundances of different types of coarse micrometeorites were markedly different than today. We determine that the relative abundance of micrometeorites of HED achondritic type was about ≥4× higher than today, and of primitive and ungrouped achondrites about ≥75× higher. The relative abundance of ordinary chondrites was less than 56%, with LL chondrites being about ~2× more abundant than today. We attribute as plausible sources of the LL chondrites the Flora family formation event ~1 Ga ago [9] and of the HED samples the Rheasilvia-basin forming event on Vesta ~1 Ga ago [10]. This implies that the sediments sampled products of these collisions ~500 Ma past the peak flux but still higher up in the tail of the decaying impact rate function than today. The source of the ungrouped and primitive achondrites is unknown but likely also the result of a collisional event on their (partially) differentiated parent asteroids. In addition, we found rare chrome-spinel with positive $\delta^{17}O$ and $\delta^{18}O$ values on or close to the 1:1 line in three-oxygen-isotopic space (Fig. 1). Such a composition is not observed in chrome spinel from any known meteorite group, however, it has been observed in hydrous alteration phases such as magnetite in unequilibrated chondrites [e.g., 11,12]. In contrast to magnetite, chrome spinel is a product of thermal metamorphism and should not be affected by aqueous alteration. Similar compositions were also found in comet dust crater residue from the Stardust mission [13] but are likely also unrelated due to the absence of coarse chromite in Wild 2 comet dust. A small fraction of recently fallen Antarctic micrometeorites revealed $\Delta^{17}O$ values compositions that are similar to our unusual samples and have been possibly attributed to R chondrites (Group IV in [14]). While the $\Delta^{17}O$ values of our samples would be consistent with an R chondrite origin, the TiO_2 compositions are lower (<0.5 wt%) than what is known as typical for chrome spinel from R chondrites (>4 wt%; [15]). The origin of these grains needs to be further scrutinized.

Our study confirms that the composition of the micrometeorite flux ~467 Ma ago was remarkably different than today with a high abundance of achondritic material. Furthermore, we find rare chrome-spinel of unusual oxygen isotopic composition that is not seen in known meteorite groups and thus may represent a previously unknown class of meteorites.

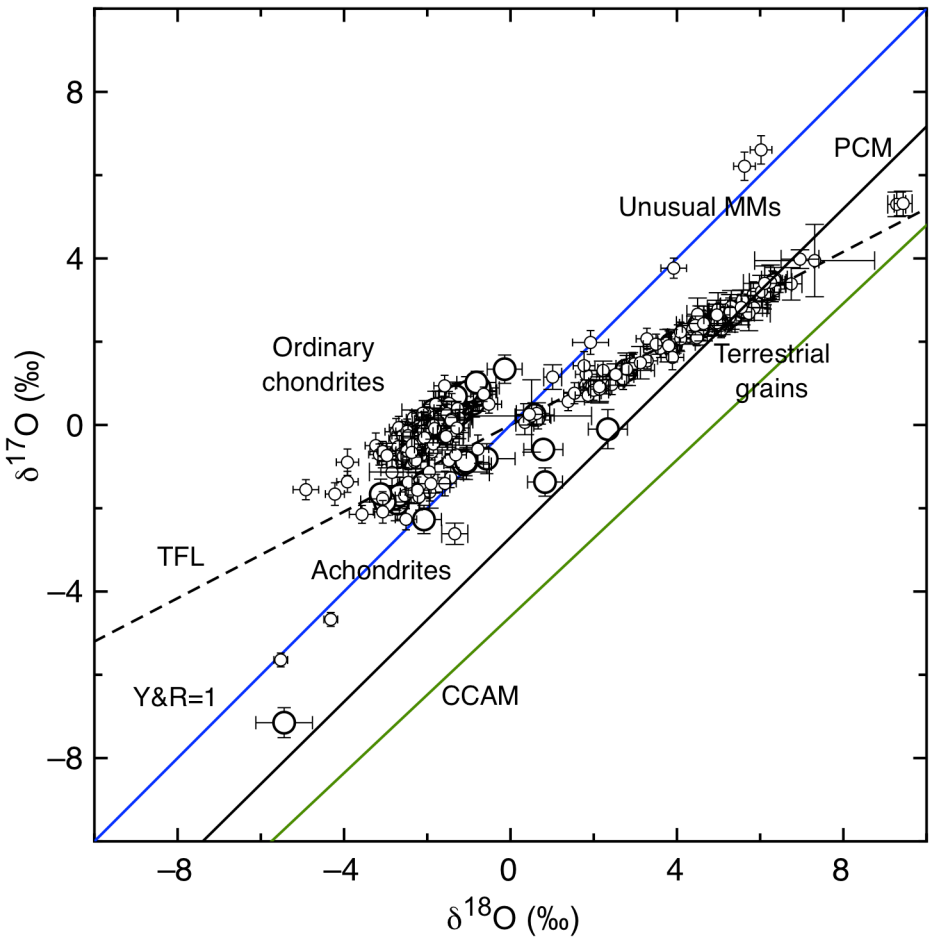

Figure 1: Three oxygen isotope diagram. Small symbols is data obtained from 32-63 μm chrome spinel; large symbols from >63 μm chrome spinel. TFL=Terrestrial Fraction Line; Y&R=Young & Russell line [16]; PCM=Primitive Chondrule Minerals line [17]; CCAM Carbonaceous Chondrite Anhydrous Minerals line [18]. Error bars are 2σ.

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