The parent body of the ca. 480 kyr-old Tunguska-like impact over Antarctica.

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Introduction:

Meteoritic ablation spheres (MAS) recently found on top of the Victoria Land Transantarctic Mountains (TAM) and in the EPICA Dome-C and Dome-Fuji ice core document the impact of a 10^8 kg (or larger) cosmic body in the Antarctic region ca. 480 kyr ago [1, 2, 3]. The exact nature of the impactor is unknown, and whether the impactor struck the Antarctic ice sheet or exploded in the atmosphere is matter of debate [1, 2, 4]. In order to address these questions, we discuss high-precision oxygen isotope compositions of two MAS aggregates from the TAM micrometeorite traps.

Methods:

The overall petrography of MAS samples #20c.25 (0.56 mg) and #20c.351 (0.3 mg), from the micrometeorite trap #20c, Miller Butte, Antarctica, was first studied with a Scanning Electron Microscope (SEM). Oxygen isotope compositions were determined using the IR-laser fluorination coupled with mass spectrometry (IRMS) technique adapted for the study of extraterrestrial materials following [5]. Two samples of the host granite detritus, namely "host granite" -which was cleaned from weathering product- and "host granite < 25 µm" -which was not cleaned- were also analysed to study the effect of weathering and bedrock contamination in the MAS aggregates.

Results:

SEM observations show that the aggregates consist of a myriad of microscopic MAS and that a larger amount of weathering products occurs in #20c.351 compared to #20c.25 (Fig. 1). Oxygen isotope compositions are $\delta^{18}O = 2.98$ and $\Delta^{17}O = -3.26$ for #20c.25, $\delta^{18}O = 6.50$ and $\Delta^{17}O = -0.54$ for #20c.351, $\delta^{18}O = 13.65$ and $\Delta^{17}O = 0.03$ for "host granite", and $\delta^{18}O = 4.97$ and $\Delta^{17}O = 0.09$ for "host granite < 25 µm" (analytical uncertainties are ±0.27‰ for $\delta^{18}O$ and ±0.07‰ for $\Delta^{17}O$).

Discussion:

Comparison of oxygen isotope compositions of MAS aggregates and host granites indicate that alteration broadly shifts the MAS aggregate composition toward those of host granite, with maximum alteration on the terrestrial fractionation line (Fig. 2). Pristine bulk oxygen isotope composition of the MAS, derived from modal composition of sample #20c.25 [1], is $\Delta^{17}O \approx -3.86$‰. This is consistent with a parentage with CV, CO and CK chondrites or with anhydrous silicates of short period comet 81P/Wild 2, within a context of a dominant mixing with atmospheric oxygen (Fig. 2). The oxygen isotopic composition of 17 individual dust particles from the EPICA-Dome C L2 layer vary widely with values ranging from $\delta^{18}O = -17.5$‰, $\delta^{17}O = -9.8$‰ to $\delta^{18}O = 20.1$‰, $\delta^{17}O = 8.2$‰ [4]. These values are consistent with the bulk oxygen isotopic composition of the paired Transantarctic Mountain ablation spheres determined in this work. The wide compositional scatter of L2 particles suggests that individual particles formed within an heterogeneous and turbulent plume characterized by variable contents - in space and time - of atmospheric and Antarctic ice oxygen. This strengthens previous conclusion by [1], who suggested that a Tunguska-like impact would explain the wide continental distribution of the impactor debris.

Conclusion:

MAS from the TAM, the EPICA Dome-C and Dome-Fuji ice cores are the debris of a high-altitude (>15 km) Tunguska-like airburst of a cosmic body several tens of meters in size or larger (i.e. at least 10^8 kg), which impacted Earth's atmosphere over Antarctica ca. 480 kyr ago. The impactor was most likely an asteroid of CV, CO or CK composition or a comet with composition similar to that of the short-period comet 81P/Wild 2.

References:

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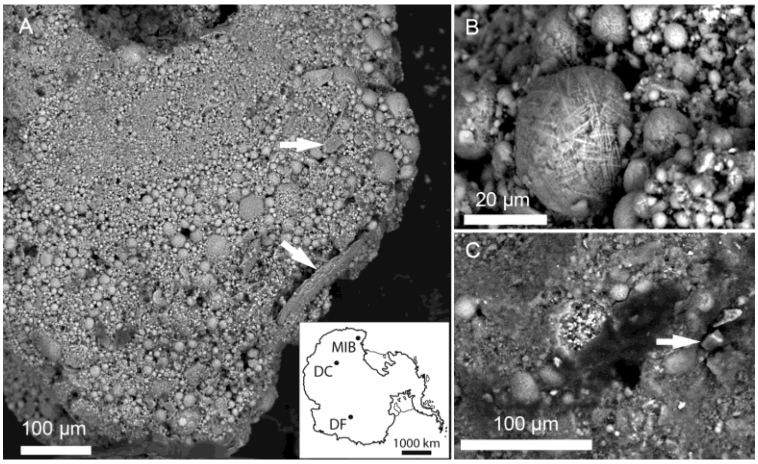

Fig. 1: Back scattered electron image of the aggregates of meteoritic ablation spheres from Miller Butte, Victoria Land Transantarctic Mountains studied in this work (obvious bedrock crystals embedded in the aggregates are arrowed). A) Sample #20c.25. B) Close-up of sample #20c.25 showing spherules with dendritic textures. C) Sample #20c.351. Inset: sketch map of Antarctica showing the location of Miller Butte (MIB), and Dome C and Dome Fuji where similar spheres were found in ice cores [2, 3].

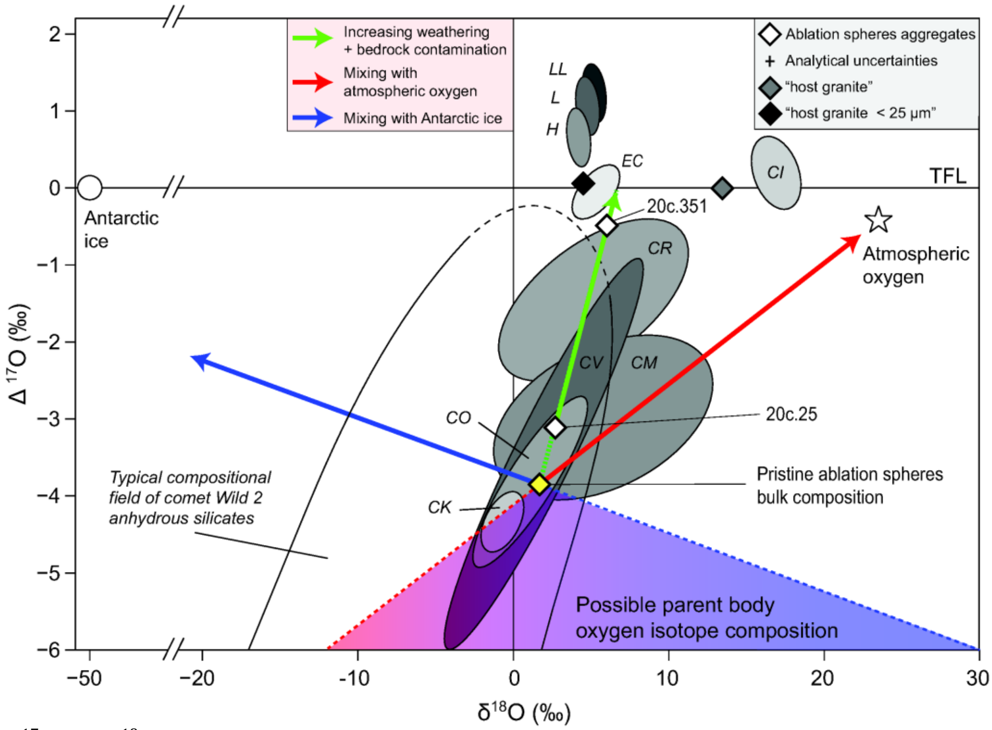

Fig. 2: $\Delta^{17}O$ vs. $\delta^{18}O$ values (in ‰ vs. V-SMOW) of aggregates of meteoritic ablation spheres from the Transantarctic Mountains and of the host granite measured by IRMS (analytical uncertainties are ±0.27‰ for $\delta^{18}O$, ±0.07‰ for $\Delta^{17}O$). Mixing models show the evolution of the oxygen isotope composition of sample #20c.25 with increasing terrestrial weathering + bedrock contamination during storage in the micrometeorite trap (green arrow). Models also show the evolution of bulk isotope composition of pristine ablation spheres with increasing mixing with atmospheric oxygen during atmospheric entry heating and melting (red arrow) and mixing with Antarctic ice (blue arrow). The red and blue shaded compositional field represents the possible oxygen isotope compositions of the parent body of the meteoritic ablation spheres assuming prevalent mixing with atmospheric oxygen (red area) or prevalent mixing with Antarctic ice (blue area). The isotopic composition of atmospheric oxygen is $\delta^{18}O$=23.5‰, $\Delta^{17}O$=−0.4‰ [6], that of Antarctic ice is $\delta^{18}O$≈−50‰ [7]. Bulk isotopic compositions of meteorites including CO, CV, CM, CR and CI carbonaceous chondrites, H, L and LL ordinary chondrites, and enstatite chondrites (EC) are shown for comparison [8, 9, 10]. The isotopic compositional field of anhydrous silicates from short-period comet 81P/Wild 2 is also displayed [11, 12].