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CR-TYPE CHONDRITE FOR AIRBURST EVENT OVER EAST ANTARCTICA 430 KA AGO

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Introduction: The geological record contains scarce evidence for airbursts, the most common type of hypervelocity impact events. During airbursts, impactors of 50 to 150 m in size are fragmented and vaporized during atmospheric entry, as exemplified by the Tunguska and Chelyabinsk events [1]. In recent years, meteoritic debris resulting from such low-altitude airbursts has been found on various locations across Antarctica (cf. summary in [2]). Fine-grained (<100 μm) particles recovered from Miller Butte (Northern Victoria Land), Dome Concordia (C), and Dome Fuji (F) were likely produced by a Tunguska-like event 481 ka ago [2]. More recently, larger (~100 to 500 μm) extraterrestrial spherical and spherulitic particles correlated to similar particles in the Dome C and Dome F ice cores, dated to ca. 430 ka, have been recovered from sedimentary deposits near the Walnumfjellet (WN) summit in the Sør Rondane Mts., East Antarctica (S72°07'11", E24°12'30"). The unique properties of the recovered particles attest to an unusual type of touchdown event, likely intermediate between an airburst and a crater-forming impact, during which a high-velocity vapor jet produced by the disruption of a projectile reached the Antarctic ice sheet [2]. Using additional petrographic, geochemical, and isotopic data, we refine the nature of the impactor, the location of the touchdown, and thermodynamic conditions under which the vapor jet interacted with the Antarctic ice.

Samples and methods: The studied particles were extracted from glacial sediment on top of WN during the 2017-2018 BELAM (Belgian Antarctic Meteorites) expedition. Igneous spherical to spherulitic particles exhibiting unusual structures and textures were extracted from the deposits. The nature of the extracted particles was confirmed using scanning electron microscopy (SEM) at the VUB. The most pristine particles were selected for further chemical and isotopic analysis. For Cr and Ti isotopic analysis, 75 particles were combined, digested, and processed using established procedures [3]. For Mg, Fe, and K isotopic analysis, 22 particles were digested together, after which the target elements were isolated and the isotopic measurement performed according to [4,5]. In total, 9 particles were prepared for bulk oxygen isotope analysis following [6]. Results were obtained for 2 particles, while 7 other particles are being processed. $\Delta^{17}O$ values were calculated using the linearized format with $\lambda = 0.5247$ [7].

Results: The combined particles yield a $\varepsilon^{54}Cr$ value of 1.57±0.15 and $\varepsilon^{50}Ti$ value of 1.59±0.25 (2SE), while $\delta^{25}Mg_{DSM-3}$ is -0.11±0.04 ‰ (2SD) and $\delta^{56}Fe_{IRMM524-A}$ is 0.23±0.10 ‰ (2SD). Two particles show $\delta^{18}O$ values of -43.7 to -39.7 ±0.4‰ and $\Delta^{17}O$ values of -0.19 to -0.17 ±0.04‰ (2SD).

Discussion and conclusions: A touchdown airburst scenario for the WN particles is proposed mainly based on their unique petrologic features (incl. spinel chemistry) and oxygen isotope ratios [2]. The $\delta^{18}O$ values fall close to those of Antarctic inland ice, while the $\Delta^{17}O$ values are all below the terrestrial fractionation line (TFL), both at the bulk scale and for individual phases [2]. The negative $\Delta^{17}O$ value for the WN particles likely results from mixing of Antarctic ice and/or air to a precursor composition with an even lower $\Delta^{17}O$. This implies a carbonaceous chondritic impactor rather than an ordinary chondrite body. The measured $\varepsilon^{54}Cr$ and $\varepsilon^{50}Ti$ values overlap with CR-type or CI-type carbonaceous chondrites, although the latter type can likely be excluded based on the negative $\Delta^{17}O$. Such composition is supported by the $\delta^{25}Mg$ value [8], while the $\delta^{56}Fe$ value is distinct from those reported for chondrites [9], probably due to thermal processing or oxidation in the touchdown plume. Recent spectral analysis by NASA's OSIRIS-REx spacecraft revealed that asteroid (101955) Bennu may be comprised of CR1(-like) material [10]. If confirmed after sample-return, these particles would highlight the importance of (CR-type) carbonaceous chondritic materials among Near-Earth asteroids. The effects of airburst and touchdown events remain poorly studied to date. However, if such a touchdown impact event occurs above a densely populated area, it would be a major hazard resulting in millions of casualties and damage over distances of up to hundreds of kilometers [2].

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