Rae impact spherules: aftermath of a *ca.* 2.1 Ga exoplanet strike

J.A. PERCIVAL[1], W.J. DAVIS[1], D. PETTS[1], S. JACKSON[1], R.G. BERMAN[1], B. SHALCHI AMIRKHIZ[2], T.M. HARRISON[3] AND E.A. BELL[3]

[1]Geological Survey of Canada, 601 Booth St. Ottawa, ON K1A 0E8 *John.percival@canada.ca
[2]CANMET Materials, Hamilton ON L8P 0A5
[3]Earth, Planetary & Space Sciences, UCLA, CA 90095-1567

Remarkably well preserved *ca.* 700 µm spherules occur in a 5 cm thick mudstone bed within the Rae cover sequence, deposited between 2.19 and 2.045 Ga [1] and metamorphosed to *ca.* 3 kb, 300°C *ca.* 1.85 Ga. The bulk layer contains 0.5 and locally up to 50 ppb of Ir, supporting an origin as distal impact ejecta related to a large (>10 km) asteroid strike.

SEM and TEM-scale studies show the cryptocrystalline (200 nm - 200 µm grain size) spherules to be mineralogically and geochemically zoned, with potassic (phengite-rich) cores and calcic (prehnite-quartz) mantles. Phengite varies from <500 nm patches with 3.7 afu Si (70-80 kb equilibration P in terrestrial bulk compositions) to background domains with 3.3-3.5 afu Si, characterized by nanodomains with planar amorphous bands spaced at 3-6 nm, interpreted as shock-induced deformation lamellae.

Bulk compositions were obtained using LA-ICP-MS transects (110 µm spot size) across 40 spherules. Relative to bulk continental crust, the compositions are enriched in MgO and lithophile elements, and depleted in siderophile elements, Na_2O, and Sr. One of the most surprising attributes is super-chondritic Nb/Ta (24-35) and Zr/Hf (38-64), uncharacteristic of solar system materials [2]. Detailed analyses of phengite yield high Nb (22-48 ppm), Ta (1-2 ppm) and Nb/Ta (25-28).

Common lead measurements of silicates, determined on UCLA's RF-source SIMS show a range of values, including some low $^{206}Pb/^{204}Pb$ and $^{207}Pb/^{204}Pb$, and a few sub-primordial $^{208}Pb/^{204}Pb$ ratios. Sparse <20 µm zircon contains <1 µm galena spheres with >35% common lead component. 5 µm spots on zircon yielded U-Pb ages between 2.8 and 1.9 Ga, including several *ca.* 2.1 Ga.

The observations point to an origin for phengite at >200 km depths within a pre-solar planet. A >10 km fragment of the parental body collided with Earth *ca.* 2.1 Ga; some phengite survived the impact as shocked, sub-µm dust particles, then acted as nucleii during vapor cloud condensation. Phengite provides structural and compositional constraints on a planet with high volatile and refractory lithophile element content, and modest geotherm at *ca*. 200 km depths.

[1] Percival *et al.* (2017) *Can J Earth Sci* **54**, 512-528. [2] Münker *et al.* (2003) *Science* **301**, 84-87.

This abstract is too long to be accepted for publication. Please revise it so that it fits into the column on one page.