INSIGHT INTO ARCHEAN SPHERULE GROWTH FROM GEOCHEMISTRY AND 3D IMAGING. A. K. Davatzes[1] and G. R. Byerly[2], [1]Department of Earth and Environmental Science, Temple University (1901 N. 13th St. Philadelphia, PA. 19046. alix@temple.edu), [2]Department of Geology and Geophycis, LSU (glbyer@lsu.edu).

Introduction: After a large meteor impact, a plume forms by the vaporization of bolide and target rock. Condensed molten droplets within the plume ultimately crystallize or quench, forming spherules. The concentration of molten droplets and turbulence in the plume likely led to frequent collisions between particles at different stages of cooling. Agglutination or accretionary growth of spherules has been documented in the Eltanin spherules, Eocene cpx spherules, and the K/T spherules [1]. This accretionary growth may appear as small spherules attached to the outer margins of larger spherules, leading to odd-shaped particles. Others appear to be fully engulfed within larger droplets [1].

In Archean spherules from the Barberton greenstone belt, South Africa, odd-shaped or dumbbell-shaped spherules are rare (Fig. 1), and numerous small particles attached to larger spherules have not been documented [2]. One difficulty in determining the outer shape of these spherules is the fact that they are fully lithified in a silica cement and cannot be separated. Here we use microCT imaging of the spherules to create a 3D rendering of the spherules within the host rock. We also collected electron microprobe line scans of the spherules in thin section, focusing on spherules in which two compositionally distinct layers are present, marked by a Ti-oxide rim between the layers.

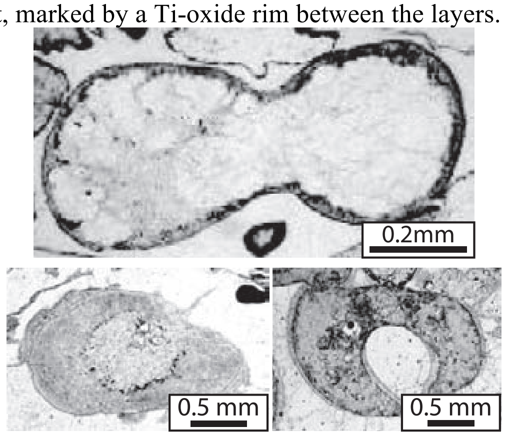

Figure 1: PPL photomicrographs of Barberton spherules showing the rare dumbbell-shaped spherule (top), phyllosilicate layered spherule (bottom left) and layered spherule with quartz core and phyllosilicates surrounding (bottom right) Images in [2, 3].

Although most of the primary mineralogy has been lost due to pervasive diagenetic alteration, geochemical differences in the resultant clays can indicate variability in the primary mineralogy. Currently, the mineralogy of the spherules includes secondary quartz, a variety of phyllosilicates, rutile, anatase, iron oxides and rarely carbonates, and primary Ni-rich chrome spinel. Infered primary mineralogy included glass, olivine, pyroxene, and feldspar, in addition to the spinel [2,3].

Geochemistry of spherule layers: Approximately 15% of the spherules are composed of multiple, compositionally distinct concentric layers [3]. There are generally only two or three distinct layers. Most commonly, there is a core of micro- or megacrystalline quartz surrounded by phyllosilicates in the outer ring that may have originally been a gas-filled core within the spherule. Also common are two layers of phyllosilicates, either with or without a central quartz core (Fig. 1, 2). Rarely there is a phyllosilicate core surrounded by quartz. The majority of the layered spherules are less than 2 mm and greater than 1 mm in diameter. The total distribution of spherule sizes throughout the bed ranges from 0.25 to 4 mm in diameter [3].

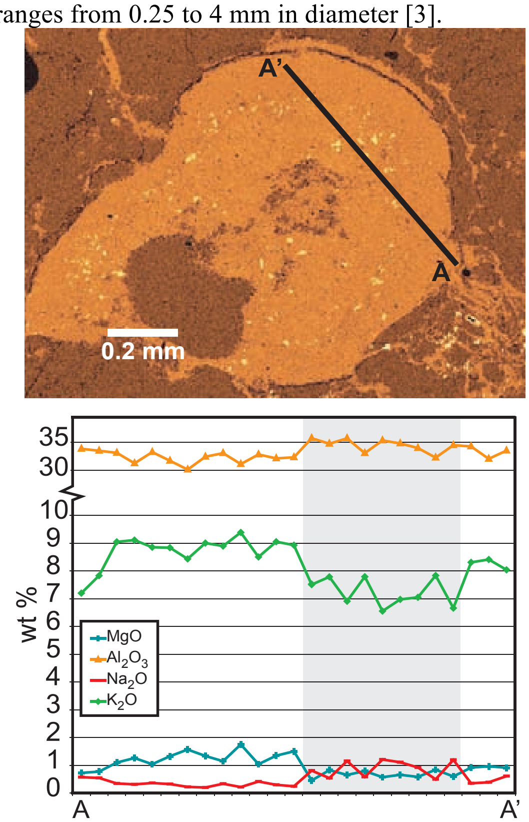

Figure 2: Backscatter electron photo of spherule with EMP line scans. The orange color is phyllosilicate material, the darker color is microquartz, and the bright yellow is TiO_2. Line scan shows that K_2O and MgO is slightly lower in the inner portion (marked by gray box) and Na_2O and Al_2O_3 is slightly higher.

Backscatter electron images of the spherules with multiple phyllosilicate-rich layers show a slightly brighter region in the inner layer of the spherules compared to the outer layer (Fig. 2). The inner phyllosilicate is generally lower in K_2O (averaging 7.3 wt % compared to 8.7 wt % in the outer layer) and MgO (0.7 wt % compared to 1.2 wt % in the outer layer) and higher in Na_2O (1.0 wt % compared to 0.4 wt % in the outer layer) and Al_2O_3 (34.7 wt % compared to 32.5 wt % in the outer layer) (Fig. 2).

MicroCT imaging: A 1-inch diameter round core of spherule bed S3 with a height of ½-inch was analyzed with the SkyScan 1172 desktop micro computed tomography (microCT) system with an image pixel size of 26.7 um. The raw data was thresholded to pull out the density contrast between the phyllosilicates and the quartz matrix (Fig. 3), as well as to pull out the Ti- and Fe-oxide rims, and the spinels within the spherules. Once thresholded, these were processed to create a 3D rendering of the spherules within the core (Fig. 3). All spherules show relatively smooth surface textures, with no agglutinated particles on the surface. This sample site was chosen for its excellent preservation of spherules without diagenetic flattening.

Implications: The presence of spherules with compositionally distinct layers suggests that these formed by the collision of two droplets within the impact plume, one more fully crystallized compared to the other. In all cases (though only 1 is shown here, >10 line scans were performed on different spherules), a similar pattern of aluminosillicate composition with more Na and Al was present in the interior portion, and the outer spherule contained more Mg and K.

Interestingly, these compositionally layered spherules tend to be concentrated in the middle part of spherule beds that were deposited as a complete fall sequence [4]. Below these layered spherules, we see a concentration of large spherules (generally >2 mm) with devitrification textures, implying an originally glassy composition and spherules containg high concentrations of spinels and iridium. Above the compositionally layered spherules there are mostly smaller quartz and phyllosilicate spherules, all less than 1 mm in size. This suggests an evolution of temperature and droplet concentration. Soon after impact, high concentrations and high temperatures may have resulted in spherule growth by collision, but all fully molten. By the end of the plume lifetime, lower concentrations of droplets in the plume, and therefore low collision rates, resulted in smaller spherules.

Based on trends observed in Eltanin, Eocene, and K/T impacts, the two controlling variables include the size of the impact (smaller impacts result in more accretion) and the proximity to the impact site (more accretion is observed close to the impact site) [1]. This is consistent with our observations of the Archean spherules, which formed by an impact significantly larger than the Phanerozoic impacts, and where the sample site is interpreted as distal to the site of impact.

References: [1] Kyte F. et al. (2010) *Meteoritics & Planet. Sci.* [2] Lowe D.R. et al. (2003) *Astrobiology*. [3] Krull-Davatzes A.E. et al. (2012) *Precambrian Research*. [4] Krull-Davatzes A.E. et al. (2006) *EPSL.*

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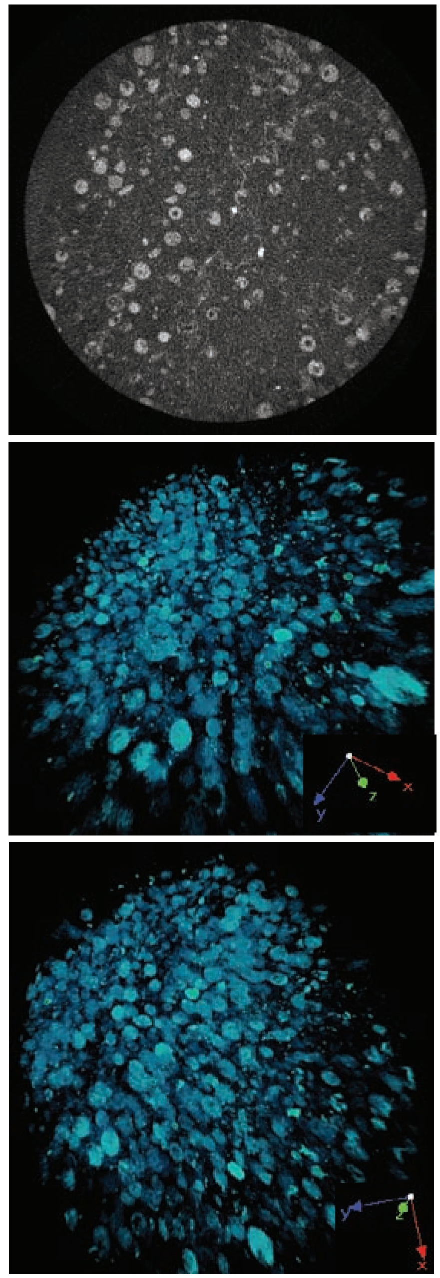

Figure 3: *MicroCT images of spherules from a core of the S3 bed. Image to the upper left shows a single raw image of the core. Diameter of the circle is 1 inch. The two other images show the thresholded and processed data rotated to three orientations (x, y, and z axis shown in lower right for each image).*