IMPACT PLUME FRACTIONATION AS INDICATED BY SIZE AND MINERAL DIVERSITY IN ARCHEAN SPHERULES. A. E. Davatzes, Department of Earth and Environmental Science, Temple University (1901 N. 13th St. Philadelphia, PA 19122; alix@temple.edu).

Introduction: Hydrocode modeling of impacts provides most of our information as to how impact plumes form. These models focus largely on modeling the K/T boundary event [e.g. 1,2,3,4]. Models of impact plumes have calculated the amount of target rock that would be evaporated [2,5], the size of spherules produced by the condensation and crystallization of molten and vaporized rock [3], composition of spherules [1], and the effects of impact angle [4]. Unfortunately, all models to date have focused on the first few seconds after impact. Little is known about how the plume evolves temporally and spatially. In addition, field data to constrain these models is sparse because there are not abundant spherule layers in the geologic record and those that are present are often thin, incomplete, or bioturbated. The spherule beds in the Barberton greenstone belt (BGB) provide an ideal case to study and understand the evolution of an impact plume in time and space. The S3 spherule bed in the BGB is a particularly good candidate, because it is very thick, produced by a bolide approximately 30 km in diameter [6], it has not been bioturbated, primary spinel and some primary textures are preserved, and at least two outcrops preserve a fall sequence [7]. This study focuses on the total number and size distribution of spherules preserved in a full fall sequence from the Barite Syncline locality. Thin sections from the full stratigraphic height of the section were examined, and 1445 spherules were identified, classified, and measured to determine the volumetric abundance, size distribution and overall composition of the deposit.

Spherule Types: Five primary types of spherules are contained within the S3 spherule bed [7]. Each of the five types of spherules is observed in every section of S3 and represents the altered remnants of a diverse population of impact-produced spherules. The only primary minerals preserved are Ni-rich chromites [6,8,9].

Type 1 spherules are now composed entirely or largely of microcrystalline and megacrystalline quartz. They lack crystallites, and the largest of these spherules have a devitrification texture. Rims surrounding the spherules contain variable amounts of patchy phyllosilicate material, opaque oxides, and carbonaceous material.

Type 2 spherules are characterized by abundant patchy phyllosilicates, primarily sericite, that are well distributed within the spherules. The abundance of phyllosilicates in this population clearly sets them apart the large quartz spherules in which minor amounts of phyllosilicates occur either along the margins or as small, isolated patches within spherules. These spherules also commonly have rims similar to the Type 1 spherules.

Type 3 spherules are composed almost entirely of fine-grained phyllosilicates. These spherules also commonly have thin rims with abundant opaque material, including carbonaceous material and fine-grained Fe- and Ti-oxides.

Type 4 spherules are composed of multiple, compositionally distinct concentric layers. Most of these layered spherules have two or three distinct layers, excluding dark rims and diagenetic coatings. The most common layered spherules have a layer of fine-grained phyllosilicates surrounding a core of microcrystalline or coarsely crystalline quartz. Approximately 40% of the quartz-phyllosilicate layered spherules have relict fibroradial textures in the outer phyllosilicate layer. Other layered spherules are comprised of two layers of phyllosilicates, either with or without a central quartz core. Both quartz-phyllosilicate and phyllosilicate-phyllosilicate layered spherules commonly have a thin boundary layer between the outer layer and the core that is composed predominantly of fine-grained Ti-oxides, including both rutile and anatase. Fe-oxide and Ti-oxide-rich rims are also present along the outer margins of many of these spherules.

Type 5 spherules are now composed of quartz and have a relict barred texture or a microporphyritic needle-like texture, inferred to have been originally olivine [8].

Relative proportions of spherule types: Images of all thin sections were captured. Using image processing software, individual spherules were outlined, classified, and measured. The total volume for each group was estimated using the histogram tool. The results of these calculations are given in Table 1 and Figure 1.

	Quartz (type 1)	Mixed (type 2)	Phyllo (type 3)	Layered (type 4)	Barred (type 5)
Vol. %	22.1%	41.3%	17.4%	17.0%	2.3%
Abun. %	22.3%	29.0%	32.3%	15.2%	1.3%
Total #	322	419	466	219	19

Table 1: Volume estimate and abundances of spherules of each of the 5 types.

The barred spherules represent the smallest fraction of the total spherule population. The type 3 spherules composed almost entirely of phyllosilicate material do make up a large percentage of the total spherules in the section, but because these tend to be the smallest spherules, they make up less than 18% of the total volume. Within the thin sections, there are ghosts of spherules present in the matrix [7]. Much of the "matrix" is actually composed of the type 1 spherules that have been amalgamated into the microcrystalline quartz matrix. Therefore the type 1 abundance represents a minimum value, and is most likely a much larger component of the total.

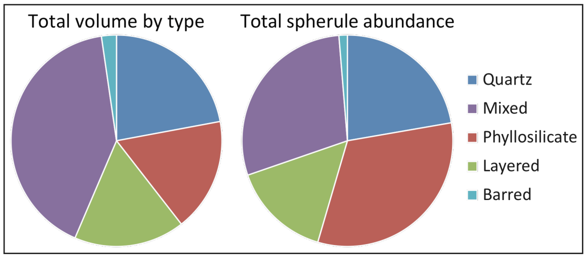

Figure 1: Volume and abundance distribution of the spherule types.

Size distribution: The overall size distribution of the spherules suggests that the majority of the spherules are approximately 1mm in size, but display a range of sizes from just under 0.25mm to nearly 4mm in diameter. The largest size fraction, from 2-4mm in size, comprises 0.9% of the total fraction; 0.8% of the spherules are between 1.75 and 2mm in diameter; 4.8% of the spherules are between 1.5 and 1.75mm; 17.3% are between 1.25 and 1.5mm; 25.5% are between 1.0 and 1.25mm; 23.9% are between 0.75 and 1.0mm; 19.7% are between 0.5 and 0.75mm; 6.8% are between 0.25 and 0.5mm; and less than 0.2% are smaller than 0.25 mm in diameter. These sizes do represent the minimum values as thin sections do not always cut through the center of the grain. Unfortunately because these spherules are enclosed in a chert cement, they cannot be separated.

The size distribution does depend on the spherule type, however. The pure phyllosilicate spherules are the smallest in size. The narrowest size distribution is observed in the type 5 barred spherules because these most represent a very specific composition. The spherules that have diagenetically altered to quartz have the largest range in sizes, though some original compositional differences are apparent among this size distribution. The largest group (d≥2mm) are uniquely microcrystalline quartz in composition now, and have devitrification textures indicating these were largely or entirely glassy in composition.

Discussion: Most of the Type 1, 2, and 3 spherules do not contain pseudomorph crystallites and may have been originally composed of glass [7]. There are two primary types of glassy spherules, one group of large quartz-rich spherules and another group of small aluminous spherules, representing endmembers with a range of intermediate spherules, represented by the mottled quartz-phyllosilicate mixed spherules. A large proportion of the layered spherules and all of the barred spherules contain pseudomorphs of plagioclase, pyroxene and/or olivine and are therefore unique in their composition.

Size of the melt droplet formed within an impact plume is dependent on the surface tension and velocity of the droplet and the surrounding vapor [3]. These will be affected by the temperature of the droplet, the viscosity of the material, and the expansion velocity of the plume. Therefore, it is not surprising that spherules of different compositions have this significantly large range in spherule diameters. As the plume cools and material is removed, the spherule composition will change and surface tension will likely increase, leading to the overall production of smaller spherules of differing composition due to this fractionation process.

This diversity of spherule types and crystalline textures most likely represents a range of cooling rates, from near-instantaneous, causing quenching of glass phases, to very rapid, forming dendritic spinels (present in many of the S3 sections but not discussed here) [9], to potentially fairly slow, even as low as 5°C/hour for some crystallites. This supports the idea that the impact plume was heterogeneous in temperature and cooling rate and resulted in fractionation within the plume.

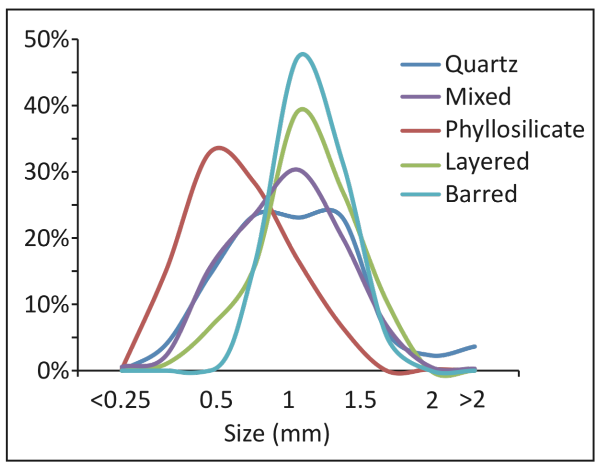

Figure 2: Size distribution by spherule type.

References: [1] Ebel D. S. and Grossman L. (2005) *Geology* 33, 293-296. [2] Melosh H. J. et al. (1997) *LPSC*, 935-936. [3] Melosh H. J. and Vickery A. M. (1991) *Nature* 350, 494-497. [4] Pierazzo E. and Melosh H. J. (1999) *EPSL* 165, 163-176. [5] Melosh H. J. (1982) GSA *Special Paper 190*, pp. 121-127. [6] Byerly G. R. and Lowe D. R. (1994) *Geochim. et Cosmochim. Acta* 58, 3469-3486. [7] Krull-Davatzes A. et al. (2006) *J. of So. Af. Geology* 109, 233-244. [8] Lowe D. R. et al. (2003) *Astrobiology* 3, 7-48. [9] Krull-Davatzes A. et al. (2010) *EPSL* 296, 319-328.