COMPOSITIONAL GRADING IN AN IMPACT-PRODUCED SPHERULE BED, BARBERTON GREENSTONE BELT, SOUTH AFRICA: A KEY TO CONDENSATION HISTORY OF ROCK VAPOR CLOUDS. A. E. Krull[1], D. R. Lowe[1] and G. R. Byerly[2], [1]Department of Geological and Environmental Science, Stanford University, Stanford, CA 94305-2115, [2]Department of Geology and Geophysics, Louisiana State University, Baton Rouge, LA 70803-4101.

Introduction: The chemical and physical processes by which spherules form during the condensation of impact-produced rock vapor clouds are poorly understood. Although efforts have been made to model the processes of spherule formation, there is presently a paucity of field data to constrain the resulting theoretical models. The present study examines the vertical compositional variability in a single early Archean spherule bed in the Barberton Greenstone Belt (BGB), South Africa, in order to better identify the process by which impact vapor clouds condense and spherules form and accumulate. The BGB spherule beds are suitable for this type of study because of their great thickness, often exceeding 25cm of pure spherules, due to the massive sizes of the impactors. Based on spherule size, Ir fluence and deposit thickness, the bolides that produced at least two of the four known BGB beds are estimated to have been about 20-50km in diameter [1].

Vertical compositional variability in fall-deposited spherule beds may reflect hydrodynamic separation of spherules during fallout and accumulation or sequential production of spherules having different compositions within an evolving rock vapor cloud. These interpretations are strongly dependent on the beds being fall deposits with no reworking after initial deposition. Two main problems complicate analysis of vertical compositional variability of graded spherule beds: (1) differential settling of particles in both the vapor and water column due to density and size differences and (2) turbulence within the vapor cloud. The present study compares sections of spherule bed S3 from four different depositional environments in the Barberton Greenstone Belt: (1) The Sheba Mine section (SAF-381) was deposited under fairly low energy conditions in deep water, providing a nice fallout sequence, and also has abundant Ni-rich spinels; (2) Jay's Chert section (SAF-380) was deposited in subaerial to shallow-water conditions with extensive post-depositional reworking by currents. The spherules also have preserved spinels; (3) the Loop Road section (loc. SAF-295; samp. KSA-7) was moderately reworked and has only rare preservation of spinels; and (4) the shallow-water Barite Syncline section (loc. SAF-206; samp KSA-1) has few to no spinels preserved and is not reworked. Although all of the spherule beds have been altered by silica diagenesis and K-metasomatism, most of the compositional differences between these sections appear to reflect their diagenetic histories, possibly related to their differing depositional environments. Sulfate diagenesis in the Barite Syncline and Loop road sections may account for the loss of spinels.

Geologic Setting: The Swaziland Supergroup of the BGB is composed of three major lithostratigraphic units deposited between 3.2 and 3.55 Ga. These three units, from lowermost to uppermost are the Onverwacht, the Fig Tree, and the Moodies Groups. Four spherule beds have been described from the Onverwacht and Fig Tree Groups, termed from oldest to youngest S1 through S4 [2,3]. The focus of this study is bed S3, which occurs at the base of the Fig Tree Group in northern sections of the BGB. S3 has been dated by single zircon U-Pb techniques from adjacent tuffs at 3243 Ma [4].

Methods: Petrographic thin sections through S3 in each section were point counted to identify textural and compositional variability in the spherule beds. Bulk analyses of major, trace and rare earth elements (REE) were performed at the Washington State University analytical lab using XRF and ICP-MS. Microprobe analyses of individual spinels were completed on the LSU JEOL JXA-733A Superprobe at 15 keV accelerating voltage and 10na beam current for 80s and the Stanford JEOL JXA-733A Superprobe at 15 keV accelerating voltage and 15 na beam current for 50s.

Results and Discussion: Major stratigraphic changes in spherule composition and texture in S3 are based on selected bulk chemical analyses, petrographic observations and microprobe analyses on primary minerals.

Bulk Geochemistry. REE plots (Fig. 1a) from Barite Syncline demonstrate a trend from near chondritic values at the base to about 10 times chondritic levels at the top. This section has shown very little reworking, and was deposited in a protected shallow water environment. It is therefore as close to a pure fallout sequence as has been discovered to date in the BGB. The section is capped by a massive sandstone unit, and it appears that the top of S3 in this section may have been eroded. The Loop Road section (Fig. 1b) has been reworked, and the REE values tend to be more homogenous. Ongoing work at this point includes analysis of S3 at the other two localities for bulk geochemistry.

Petrography. All of the sections show spherule variation in size, texture, and composition stratigraphically within S3. Spinels in the greatly thickened, current-deposited Jay's Chert section tend to be concentrated at the base (Fig. 2A). However, in the Sheba Mine section, spinels are concentrated at the top of the section (Fig. 2B). This correlates strongly with previous Cr and Ir analyses [5, also plotted in Fig. 2]. Trends in spherule size, overall composition, and texture vary, although most beds show a larger proportion of large silica spherules at the base and abundant smaller aluminous spherules near the top of the bed.

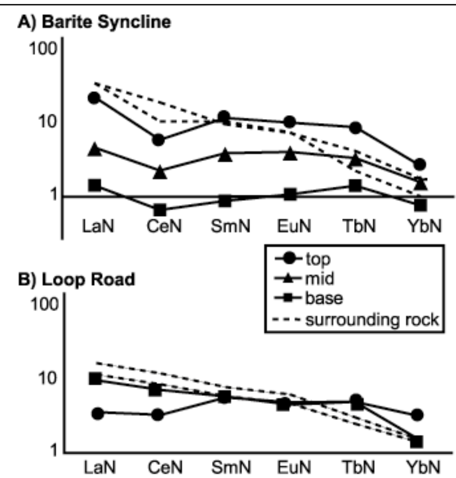

Figure 1: Chondrite normalized bulk rock REE results. A) This figure shows the REE data from sections at the base, middle and top of the spherule bed at Barite Syncline. B) REE data for the Loop Road location. This shows the values at the base and the top of the section are more homogenous due to reworking.

Microprobe analyses. Microprobe analyses of spinels show no variability with stratigraphic position. The impact spinels are significantly more oxidized than the detrital spinels of komatiitic origin found in the same section. The Fe^{+3}/Fe^{T} values in the Ni-rich impact spinels are about 0.5 whereas the detrital spinels have Fe^{+3}/Fe^{T} values between 0.0 and 0.25. In the low O_2 environment of the Archean, this suggests that the vapor cloud was more oxidizing than the ambient Archean atmosphere. It is estimated that an impact of this size would have evaporated between 0.3 and 3 meters of ocean water globally [6], and this abundance of water vapor in the impact cloud may account for the increased oxidation of the spinels.

Preliminary Findings: (1) The fallout deposit in the Sheba Mine section shows an increase in Ir and Cr [5] as well as an increased abundance of spinels at the top of the spherule layer. These data suggest that the fallout of the meteoritic component of the rock vapor occurs at the end of the fallout from the vapor cloud. (2) The REE pattern of the Barite Syncline section, however, suggests that more of the chondritic or komatiitic component is concentrated at the base and more of the basaltic target rock is mixed at the top of the section. Ir values are low in this section (<5 ppb) [5], perhaps reflecting sulfate diagenesis. However, given the eroded surface and capping sandstone, this may represent only the base of the fallout deposit. The high Ir and spinel-rich top may have been eroded. (3) Oxidized Ni-rich spinels in the spherule beds may indicate transient oxidizing conditions within the vapor cloud and terrestrial atmosphere due to the abundance of water vapor after the impact.

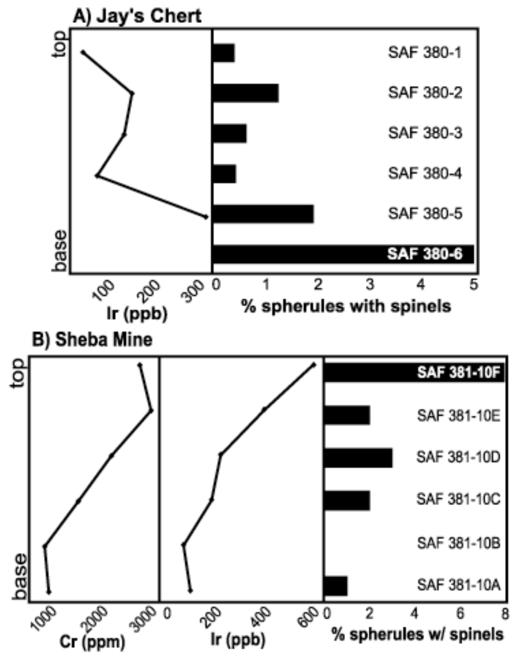

Figure 2: Ir content trends strongly with abundance of spinels. A) Data from Jay's Chert. On the left are data from [5], showing Ir abundance as a function of stratigraphic height. Sample SAF 380-6, the lowermost sample, was not analyzed. On the right are point-count results of the abundance of spinels as a function of strat. height. Ir and spinel-rich spherules were hydrodynamically heavier and were deposited first after reworking. B) Data from Sheba Mine section. Ir and Cr values are from [5]. In this section, spinel abundance correlates with Ir and Cr concentration, however, the Ir, Cr and spinel-rich spherules were deposited at the end. Because this is more representative of a fallout deposit, it suggests that much of the meteoritic component comes out of the vapor cloud late.

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