SPATIAL VARIATION OF MAXIMUM SPHERULE SIZES IN DISTAL EJECTA LAYERS AROUND THE ARCHEAN-PROTEROZOIC BOUNDARY. David Kambhu and Bruce M. Simonson[1], [1]Geology Dept., Oberlin College, Oberlin, OH 44074 USA (dkambhu@oberlin.edu, bsimonso@oberlin.edu).

Introduction: Thanks to their broad (even global) distribution, layers rich in impact spherules -- roughly millimeter size glassy beads formed from vaporized rock during large impact events -- are among the most resilient pieces of evidence for ancient asteroid impacts [1,2]. These layers are especially important when studying impacts dating from the Archean, where subduction and other geologic processes have removed most other traces they would have left in the crust.

Numerous well preserved examples of spherule layers are found among strata in the Hamersley Basin of Western Australia and the Griqualand West Basin of South Africa. Such layers have been found and sampled within 8 stratigraphic units in these Basins, 5 in Australia and 3 in South Africa, almost all involving detrital reworking [2-5]. Based on their stratigraphic relationships, these layers represent a minimum of 4 large impacts, at least 3 of which probably deposited spherules on both continents. Three correlated pairings -- the Kuruman and Dales Gorge (~2.49 Ga); the Reivilo and Paraburdoo (~2.57 Ga); and the Monteville, Jeerinah, and Carawine spherule layers (2.63 Ga) -- are the focus of our analysis.

By making a comprehensive study of the largest spherules in these correlated layers, it should be possible to improve our understanding of the impacts that caused them and get a better picture of part of Earth's paleogeography around the Archean-Proterozoic Boundary (APB).

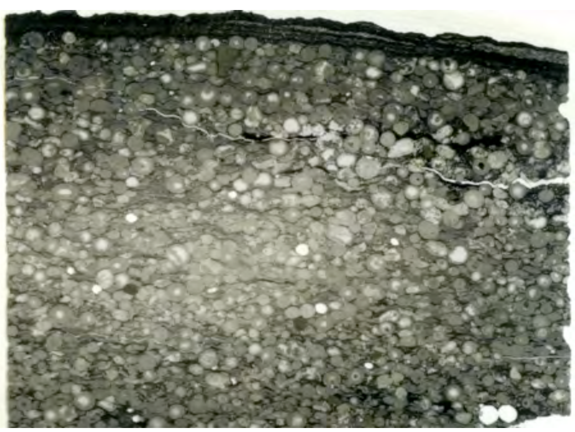

Fig 1. Scan of most of a typical thin section with abundant reworked spherules from the Monteville layer in South Africa; largest spherules are ~1.3 mm across and layer is capped by thinly laminated black shale.

Methods: We measured spherules in thin sections (Fig. 1) from each layer for as many sites as we could in each Basin. We selected the sample with the largest and most abundant spherule populations from each site, then measured the 50 largest spherules from a sample population of approximately 500. If a single thin section lacked sufficient spherules to reach the target population, we combined measurements from replicate thin sections from the same sample where possible. If a single thin section had substantially more than 500 spherules, we isolated a representative area with the right number and counted moving upward from the base. We measured both the long axis and the largest width normal to that axis of each spherule and approximated its cross-sectional area as either a circle or a regular ellipse. We used these numbers to estimate the maximum spherule size for each site, then averaged them for all sites available to obtain the maximum size of the whole layer throughout a given Basin.

Irregular particles -- more angular chunks that are frequently flow-banded -- are also present in samples from two layers. They were measured using the same methods, but compiled separately.

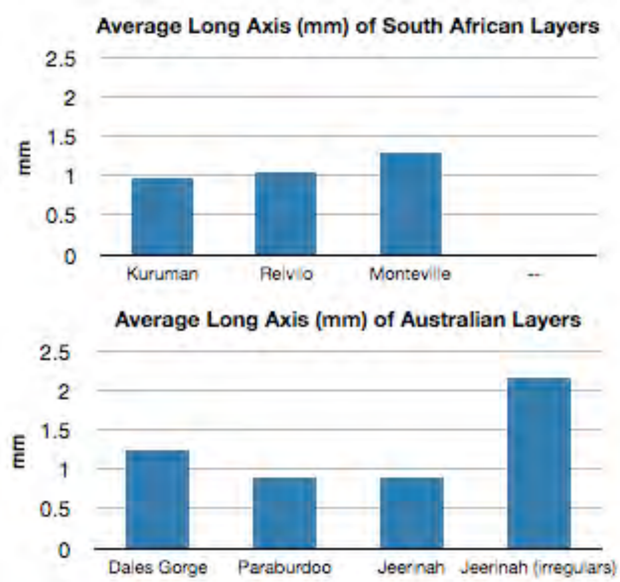

Fig 2. Average maximum spherule sizes of correlated layers in South Africa and Australia.

Results: The sizes of the spherules change from continent to continent in each correlated pair of layers (Fig. 2). In the Kuruman-Dales Gorge pair, the average spherule long axis is larger in Australia (1.24 mm) than in South Africa (0.98 mm). In the Reivilo-Paraburdoo pair, the larger spherules are in South Africa (1.05 mm) instead of Australia (0.89 mm). The Jeerinah-Monteville pair also has its largest average in South Africa (1.28 mm) rather than Australia (1.18 mm). The irregular particles in this layer are larger than the associated spherules (2.17 mm), but they are only found in samples from Australia

Discussion: We apply our new data to three important questions: constraining the locations of the impact craters responsible for the correlated layers, testing a new model for calculating impactor size [6], and assessing the paleogeographic proximity of the two Basins at the times of the impacts.

Locations of impact sites. Spherules typically decrease in size the further they are from their source craters [2]. Hence, the larger Australian spherules from the Kuruman-Dales Gorge pair suggest an impact site closer to the Hamersley Basin than the Griqualand West Basin. Conversely, the larger spherules in South Africa for the Reivilo-Paraburdoo pair suggest an impact site closer to the Griqualand West Basin.

The Jeerinah-Monteville layer is more difficult to analyze thanks to the presence of irregular particles. The larger spherules in South Africa suggest an impact closer to the Griquland West Basin, but the restriction of irregulars -- which represent more proximal ejecta [7,8] -- to the Hamersley Basin suggests an impact closer to Australia. Perhaps this counterintuitive distribution is best explained by the South African Basin being closer to the impact site (accounting for the larger spherules) but with the Australian Basin being hit by a ray of proximal-intermediate ejecta (resulting in the presence of irregular particles) despite its being further from the crater.

Estimating impactor sizes. One of the methods used to estimate impactor size is based, at least partially, on maximum spherule size [e.g. 6]. This method rests heavily on the constant size of the largest spherules in distal parts of the K-Pg ejecta layer [9]. If the proposed correlations of the APB layers [2-5] are correct, the impactor for each of the pairs we studied has to be the same size. However, different estimates of projectile sizes have been proposed for individual APB impacts [5], due in part to differences in spherule sizes in the two Basins. For the Jeerinah-Monteville pair, one problem in [5] was the inclusion in the size estimates of irregular particles that are proximal ejecta rather than part of the global layer. For the Kuruman-Dales Gorge pair, there are no irregular particles to complicate the issue, but the small size of the sample population of spherules available from the Kuruman layer casts doubt on the legitimcy of the size difference we obtained. Another possibility is that the assumption of a global layer in which the spherules are all the same size is incorrect. Yet another possibility is that the relative positions of the Hamersley and Griqualand West Basins changed through time, but this seems unlikely (see next item).

Paleogeographic implications. There has been a debate about whether the Hamersley and Griqualand West formed separately or as a large unified Basin [10, 11, and refs. therein]. We find possible support for the separate basins hypothesis in a consistent change in the percent-difference of spherule sizes between correlated layer pairs over time. Dividing the smaller maximum spherule size by the larger one yields a size difference of 8% for Jeerinah-Monteville, 15% for Reivilo-Paraburdoo, and 21% for Kuruman-Dales Gorge. This increase in the amount of difference could be explained by the Hamersley and Griqualand West Basins slowly drifting apart on separate continents, being closest around 2.63 Ga and farthest at ~2.49 Ga. However, even a slow but steady spreading rate of 5 cm/year would put a distance of 7,000 km between the Basins during the 140 million years when the APB impacts happened. This distance seems unreasonably large and not in keeping with the close stratigraphic similarity of the two basins, which makes it unlikely that the two basins were on separate continents during these impacts [10, 11]. Since it is likely that the Hamersley and Griqualand West Basins were on the same continent during deposition of the layers, the differences we observed in maximum spherule size probably reflect factors such as detrital reworking and selective sampling more than large differences in their locations relative to the original points of impact.

References:

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