EXOTIC HEAVY MINERAL ASSEMBLAGE FROM A LARGE ARCHEAN IMPACT. B. L. Byerly1, D. R. Lowe2 and G. R. Byerly1,2, 1Department of Geology and Geophysics, Louisiana State University, Baton Rouge, Louisiana, 2Department of Geological Sciences, Stanford University, Stanford, California).

Introduction: The 3.55-3.22 Ga Barberton Greenstone Belt (BGB) provides evidence for at least eight large asteroidal impacts (S1-S8 in order of discovery, [1,2]). These high-energy events had profound effects on the surface environment such as evaporation of tens of meters of ocean water, generation of large tsunamis, and widespread disruption of crustal and upper mantle material (crater formation) [2,3]. Furthermore, it is possible that one or more very large impacts could have had long-lasting geodynamic effects that dramatically shaped Earth’s tectonic evolution as has been proposed for other terrestrial bodies. Much like studies of the Lunar regolith, studies of large impacts on early Earth may provide evidence of crustal materials representing a broad sampling of planetary lithologies not previously observed.

M3c – Green Sandstone: Impact layer S6 lies within member M3c of the Mendon Formation [4,5], an 8-m-thick cherty unit between thick volcanic flow units M3v (below) and M4v (above). Near the top, M3c includes spherule bed S6 and a very locally developed overlying ash layer of either impact or volcanic origin. Both are about 50 cm thick. The ash layer is overlain by 2-m of banded black-and-white chert that is succeeded by a graded bed, 3-4 m thick, of coarse- to very coarse-grained, pale greenish, current-deposited lithic sandstone that contains an unusual assemblage of spinel, zircon, and rutile. Heavy minerals from the green sandstone have been examined in detail from two structural blocks (samples SA22 and SA 811) separated by faults of unknown off-set, but possibly 10’s kms. We argue below that these heavy minerals were not derived from the greenstone belt itself, but rather from distal portions of the Earth’s crust at 3.3 Ga, the age of the S6 impact.

Spinel: Komatiites of each stratigraphic unit of the BGB have distinctive bulk compositions and mineral chemistry. Komatiites and their constituent spinels fall within three compositional (and petrogenetic) groups: Al-depleted (bulk Al/Ti < 15, spinel Cr# > 87), Al-undepleted (bulk Al/Ti 15-30, Cr# 82-85), and Al-enriched (bulk Al/Ti > 30, Cr# < 78). The BGB is dominated by Al-depleted (Komatiti Fm.) and Al-enriched (Mendon Fm.) komatiites [5,6, and this study].

Major element compositions were measured for spinels (chromite) from SA 22 (n = 124) and SA 811 (n = 116). Most have low Fe# (< 30) indicative of minimal secondary alteration. Some chromites have Cr# that overlap with those typically observed in the BGB (Figure 1). However, the majority of chromites in the green sandstone do not represent materials that could have been derived by erosion of surficial volcanic rock of the BGB. The only flow with approximately the observed Cr# of the green sandstone is a rare chemical type about 5 km down section. There is no geological evidence in the BGB to support such a dramatic uplift and erosion associated with S6. Minor Cr# peaks do suggest some chromite may have been derived from local erosion of 10-100s m at the time of the impact.

![Figure 1](image-url) Chromites from S6 impact green sandstone (a) and komatiitic units of similar age from the Barberton Greenstone Belt (b).

Zircon: The green sandstone above impact layer S6 is notable for its abundance of zircon within an otherwise komatiitic sequence of lithologies. The youngest zircon (3.31 ± 0.01 Ga) is considered to represent the age of the deposit (Figure 2). In both samples a majority of the zircons have an age of ~3.40 Ga, an age that does...
not correspond with any of the known felsic volcanic or plutonic units of the BGB and surrounding plutons. The oldest zircons are 3.70-3.80 Ga, much older than sources within the BGB or even the Kaapvaal Craton. The overall age distribution of zircons amongst SA 22 and SA 811 are broadly similar.

**Figure 2.** SHRIMP single zircon Pb-Pb age spectrum derived from 66 zircons at SA22 and 33 at SA811.

**Rutile:** Detrital rutile is a minor component of the heavy mineral assemblage of the S6 green sandstone. The honey-yellow crystals have two sets of pyramidal polysynthetic twins and distinct parting planes that yield only broken prismatic pieces 25-75 microns in diameter. Pb-Pb ages from four crystals with low common Pb are 3.31 ± 0.01 Ga, consistent with the age of deposition of M3c. Two rutiles have an age of 3.41 ± 0.01 similar to the unusual zircon age reported above. The Zr-in-rutile temperatures 800-1200°C suggest an eclogitic source, again one not known from the BGB nor Kaapvaal Craton (other than what is found as xenoliths in younger kimberlites). Cr/Nb > 1 suggest that these eclogites were mafic in composition.

**Provenance and Transport:** The heavy minerals from the green sandstone are also unusual in size and morphological traits. Mean diameters for spinel are 75 ± 40 microns and for zircon 85 ± 30 microns. About half of the spinel and zircon display extreme rounding and polishing (Figure 3), some show significant corrosion, and yet significant numbers remain euhedral with little abrasion or corrosion. None of the heavy minerals display internal or external PDFs that might support direct involvement with the impact target.

Fine grain size (coarse silt to fine sand) and extreme rounding and polishing of exotic heavy minerals suggest a short-lived and highly dynamic episode of atmospheric transport. Corrosion may be related to the hot impact vapor cloud, though subsequent diagenetic corrosion cannot be ruled out. The unusual compositional traits of the chromite, zircon, and rutile suggest great transport distances, likely related to the impact and subsequent events, including severe events in Earth’s atmosphere and hydrosphere, as well as crater formation and uplift which reached upper mantle depths.

**Figure 3.** SEM photomicrographs display extreme rounding, polishing, and corrosion of zircon (A, B) and chromite (C, D). Scale bar for all is 10 microns.

**Significance:** 1) Spinel, zircon, and rutile from the green sand above impact layer S6 are largely derived from outside the depositional setting of the Barberton Greenstone Belt, and likely outside the crustal components that now make up the Kaapvaal Craton of southern Africa. 2) The fine size distribution, rounding and polishing of heavy mineral grains suggest an extreme atmospheric transport event independent of the initial rainout of condensed silicate droplets of the impact layer, but likely during the later stages of surface cooldown following a giant asteroidal impact. 3) The lack of heavy minerals associated with continental crust (e.g., garnet, kyanite, or staurolite) is consistent with other aspects of S1-S8 impacts and suggests a paucity of such materials at the Earth’s surface 3.5-3.2 Ga.