EXOTIC HEAVY MINERAL ASSEMBLAGE FROM A LARGE ARCHEAN IMPACT

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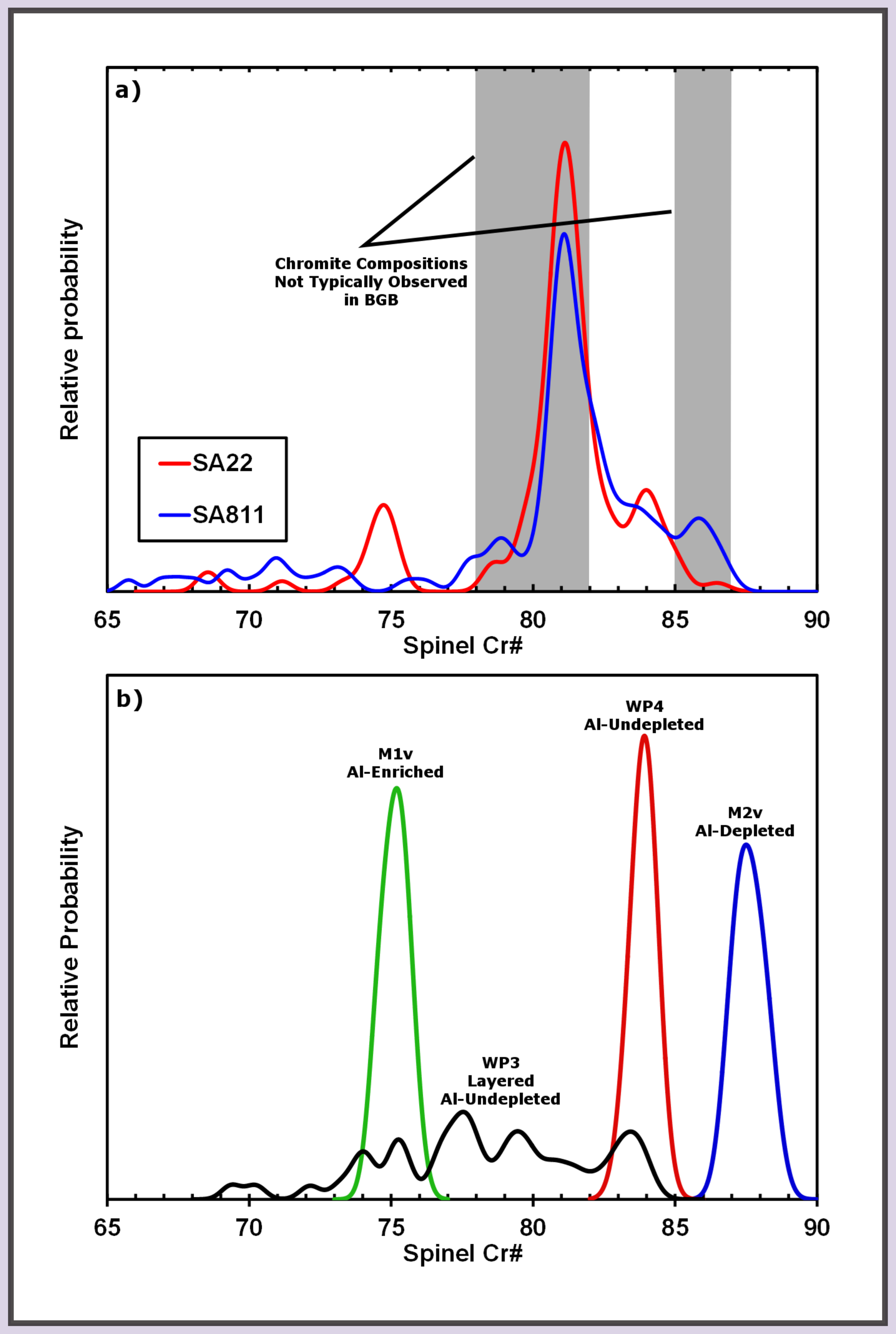
Introduction: The 3.55-3.22 Ga Barberton Greenstone Belt (BGB) provides evidence for at least eight large asteroidal impacts (S1-S8 in order of discovery, [1,2]). These high-energy events had profound effects on the surface environment such as evaporation of tens of meters of ocean water, generation of large tsunamis, and widespread disruption of crustal and upper mantle material (crater formation) [2,3]. Here we explore the effects of a large impact by examining a rare, heavy mineral-rich sandstone layer that lies above the 3.31 Ga S6 impact layer.

M3c – Green Sandstone: Member M3c of the Mendon Formation is an 8m-thick cherty unit between thick komatiite flow units [4,5]. Near its top, M3c includes spherule bed S6 and a very locally devloped ash layer of either impact or volcanic origin. Each are ~50 cm thick. Above the ash is 2 m of banded black and white chert that is succeded 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. Samples of this sandstone were collected from two structural blocks of unknown offset.



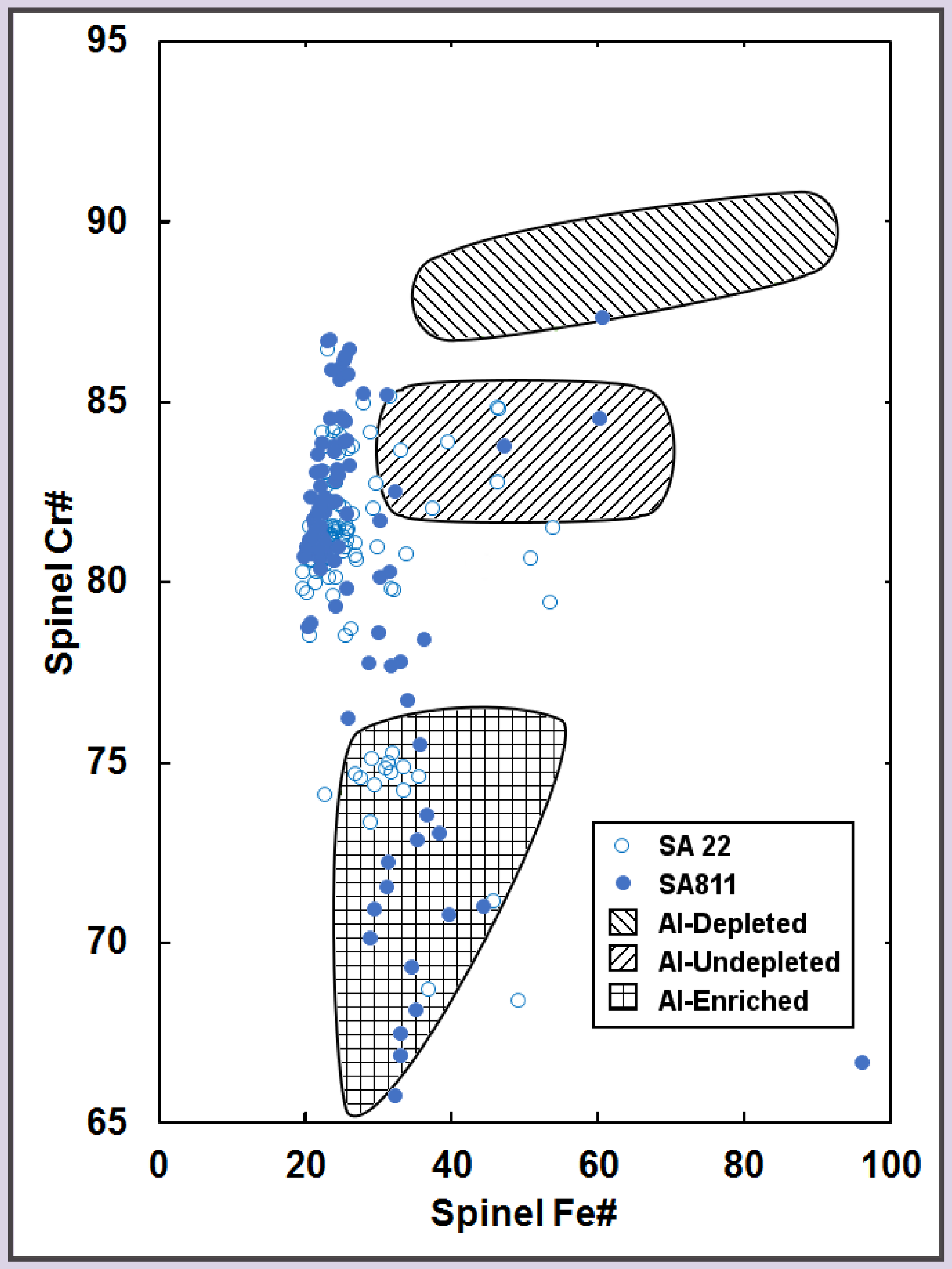
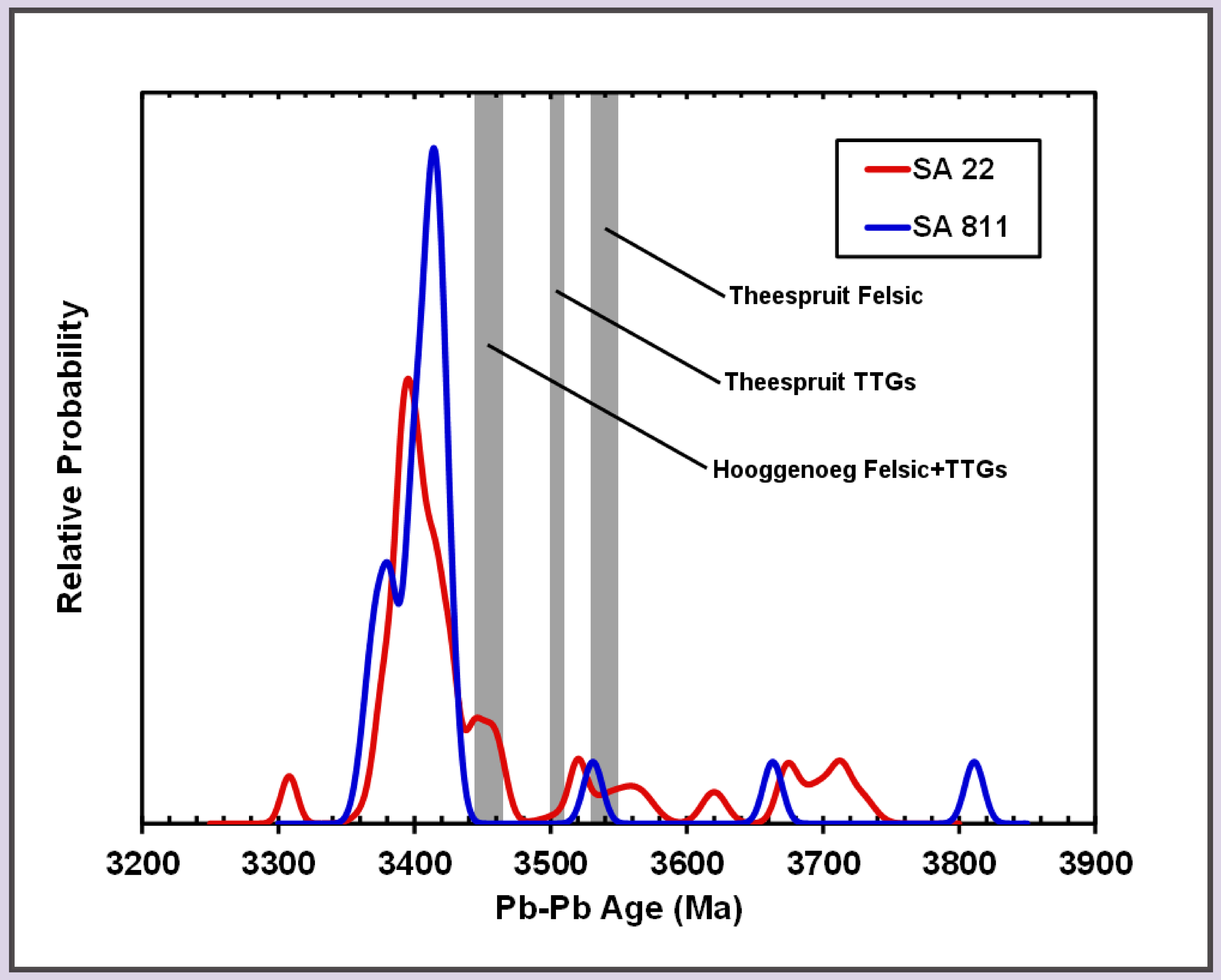


Figure 1. (left) Chromites from the M3c Green Sand (a) and from typical komatiite units of similar age from the Barberton greenstone belt (b). Note the narrow range in Cr# (molar Cr/(Cr+Al) × 100) for single undifferentiated flows (M1v, WP4, M2v). Chromite from both structural blocks have broadly overlapping compositions. **Figure 2.** (right) Some M3c Green Sand chromites have compositions that overlap with Al-Enriched komatiites which are the dominant komatiite type of the Mendon formation [6].

Spinel: M3c Green Sand chromite compositions broadly resemble those of chromites found in komatiites. Some chromite compositions overlap those found in underlying komatiites in the Mendon formation (Figures 1 and 2). However, most do not have compositions that like those sourced from komatiites from the anywhere within the BGB. Low Fe# (molar Fe/(Fe+Mg) × 100) suggests minimal alteration in the presence of olivine (i.e. erosion occurred shortly after deposition).

References: [1] Lowe, D.R. and Byerly, G.R. (1986) Geology, 14, 83-86. [2] Lowe, D.R., Byerly, G.R., and Kyte, F.T. (2014) Geology, 42, 747-750. [3] Krull-Davatzes et. al. (2014) Geology, 42, 635-638. [4] Lowe, D.R. and Byerly, G.R. (1999) GSA Special Paper 329, 1-36. [5] Byerly, G.R. (1999) GSA Special Paper 329, 189-211. [6] Decker, et al. (2015) Precamb Res, 261, 54-74.

Zircon: The abundance of zircon in the M3c Green Sand is rare in an otherwise komatiitic sequence of lithologies. Zircon Pb-Pb ages range from 3.31 Ga (assumed age of S6 impact) to 3.8 Ga (~0.3 Ga older than BGB; Figure 3). The majority of zircons have of ~3.40 Ga, an age that does not correspond with any of the known felsic or plutonic units of the BGB or surrounding areas.



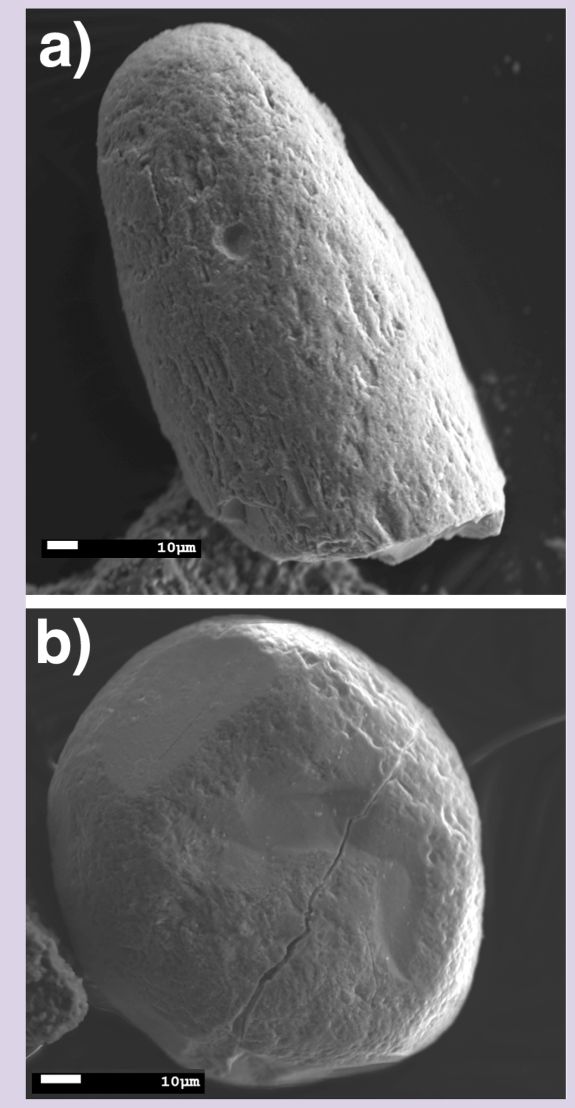


Figure 3 (left). Zircon Pb-Pb ages from the two M3c Green Sand structural blocks. As with chromite compositions, the age distributions are broadly similar. **Figure 4** (right) SEM photomicrographs of rounded zircon grains.

Rutile: Detrital rutile is a minor component of the heavy mineral assemblage. 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. Zr-in-rutile temperatures of 800-1200°C and Cr/Nb > 1 suggest an eclogitic source, again one not known from the BGB nor Kaapvaal Craton (other than what is found as xenoliths in younger kimberlites).

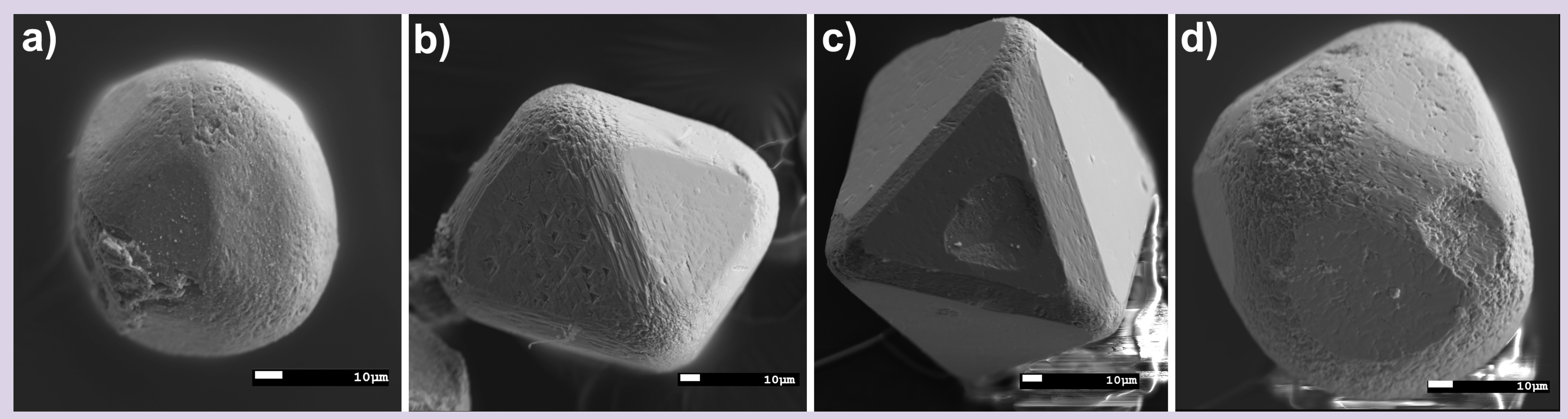


Figure 5. SEM Photomicrographs of chromites from the M3c Green Sand illustrate the range of rounding and etching. There is no apparent compositional different between rounded and euhedral grains.

Provenance and Transport: About half of the spinel and zircon display extreme rounding and polishing (Figures 4 and 5), some show significant corrosion. None of the heavy minerals display internal or external PDFs that might support direct involvement with the impact target. These characteristics 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.

Significance: The unusual compositional traits of the chromite, zircon, and rutile suggest great transport distances, likely related to an impact and the subsequent events in Earth's atmosphere and hydrosphere, as well as crater formation and uplift that reached upper mantle depths.