A 3.46 Ga impact tsunami breccia/conglomerate and geochemical meteoritic signatures of Archaean impact clusters, Pilbara Craton, Western Australia

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Pioneering research of asteroid impact fallout units in the Pilbara Craton (Lowe and Byerly, 1986; Byerly et al., 2002; Simonson, 1992; Simonson and Hassler, 1997; Simonson et al., 1998, 2000a,b; Hassler et al., 2000; Hassler and Simonson, 2001) identified microkrystite (impact vapor-condensate) spherules and microtektite (impact melt fragments and droplets)-rich units, including (a) bands, lenses and dispersed microspherules in ~3.46 Ga chert/arenite intercalations in the Apex Basalt, Warrawoona Group (Figure 1); (b) >2.63 Ga spherule lenses and spherule-bearing intraclast conglomerate (JIL) associated with the transition from the Jeerinah Formation to the Marra Mamba Iron Member; (c) stratigraphically consistent spherule beds in the 2.56 Ga shale/carbonate Bee Gorge Member, Wittenoom Formation (SMB) and in probably contemporaneous tsunami-disrupted carbonates of the Carawine Dolomite (STM), and (d) thick (<80 cm) spherule-rich units in 2.49 Ga S4 Macroband of Dales Gorge Member (S4M), Brockman iron Formation.

New observations (Glikson and Vickers, in preparation) include (1) identification of microkrystite-bearing conglomerate located stratigraphically about 200 m below the original impact fallout unit of the Apex Basalt and microkrystite-bearing chert pebbles, indicating multiple impacts and intermittent volcanism; (2) suggested multiple impacts in the SMB, Wittenoom Formation, based on consistent undisturbed intermediate sediments; (3) observation of Ni-rich Fe oxides in the JIL and S4M, and of Ni metal, oxide, sulphide, and arsenide micron-scale particles in the S4M; (4) identification of high Ni/Co, Ni/Cr, Ni/Mg and Ni/Fe ratios in microkrystites, consistent with meteoritic contributions (Figure 2); (5) identification of low Pd/Ir and Pt/Ir ratios in microkrystites, interpreted in terms of loss of volatile PGE (Pd, Au) relative to more refractory PGE (Ir, Pt) upon microkrystite condensation. Complete gradations are observed between vapor condensate products (microkrystite spherules) and meta-glass particles (fragmental microtektites), attesting to melt/volatile fractionation in the vapor cloud. The domination of pseudomorphs of quench crystallites (after olivine? and pyroxene?) and of chlorite in spherules and the apparent absence of shocked PDF-bearing quartz grains support the suggestion by Simonson et al. (1998) of oceanic impact sites.

The dominance of K-feldspar shells in microkrystites and microlitic K-feldspar in microtektites is attributed to resorption of potassium from sea water into settling glass droplets and fragments, followed by devitrification represented by characteristic inward-radiating K-feldspar crystal fans first described by Simonson (1992). Preservation of Ni metal particles and quench ilmenite within the K-feldspar places limits on subsequent deuteric/burial alteration. Attempts at determining the K-Ar and O isotopes of the K-feldspars (Uysal and Golding, in progress) may clarify temperature and age parameters.

Regional mapping of the microkrystite and microtektite-bearing tsunami mega-breccia marker unit (STM) of the lower Carawine Dolomite in the East Pilbara (Rippon Hills and Warrie Warrie Creek area) indicates a distribution over an area in excess of 100 km N-S. The chaotic-structured megabreccia is interpreted in terms of autochthonous to subautochthonous tsunami disruption of the sea bed, including excavation of consolidated sedimentary substratum, attested by meter-scale blocks and near-absence of imbricated mass-flow structures. Deformed semi-ductile blocks are present. Field relations indicate injection of liquefied microkrystite-rich muds/microbreccia into fractures in the substratum under hydraulic pressures in excess of friction/grinding pressures, evidenced by near-perfect preservation of impact spherules and microtektites within breccia and microbreccia veins. The correlation of Pb-Pb whole rock carbonate age of the STM with the 2.56 Ga age of the SMB (Woodhead et al., 1998) supports their contemporaneity and a propagation of the tsunami wave from NE to SW suggested by Simonson and Hassler (1997) and Hassler and Simonson (2001). Meter-size chert and BIF boulders within the S4M impact fallout unit are interpreted as erratic tsunami-transported blocks.

Estimates of projectile diameters based on Ir mass balance calculations and on thermodynamic modeling of melt/vapor atmospheric fractionation of the ejecta (Melosh and Vickery, 1991) indicate JIL and SMB projectiles in the order of ~ 10 km and a Dales-S4 projectile several tens of km large. The few hundred micron-scale of Warrawoona Group microkrystites, with ensuing difficulty in field identification, suggests possible wider occurrence and encourages further field search. The close similarity in appearance between S4M-type impact fallout units and fine volcanic ash likewise justifies further investigation of the Brockman Iron Formation and similar units. Considering the methodological difficulties in field recognition of new impact fallout units, impact signatures may be more common in Archaean terrains than hitherto recognized, with significant implications for the understanding of the origin of the early terrestrial crust.

Figure 1 Chert conglomerate, boulder breccia, and microkrystite spherules within sedimentary chert/arenite intercalation of the 3.46 Ga Apex Basalt, North Pole dome, central Pilbara Craton, Western Australia.

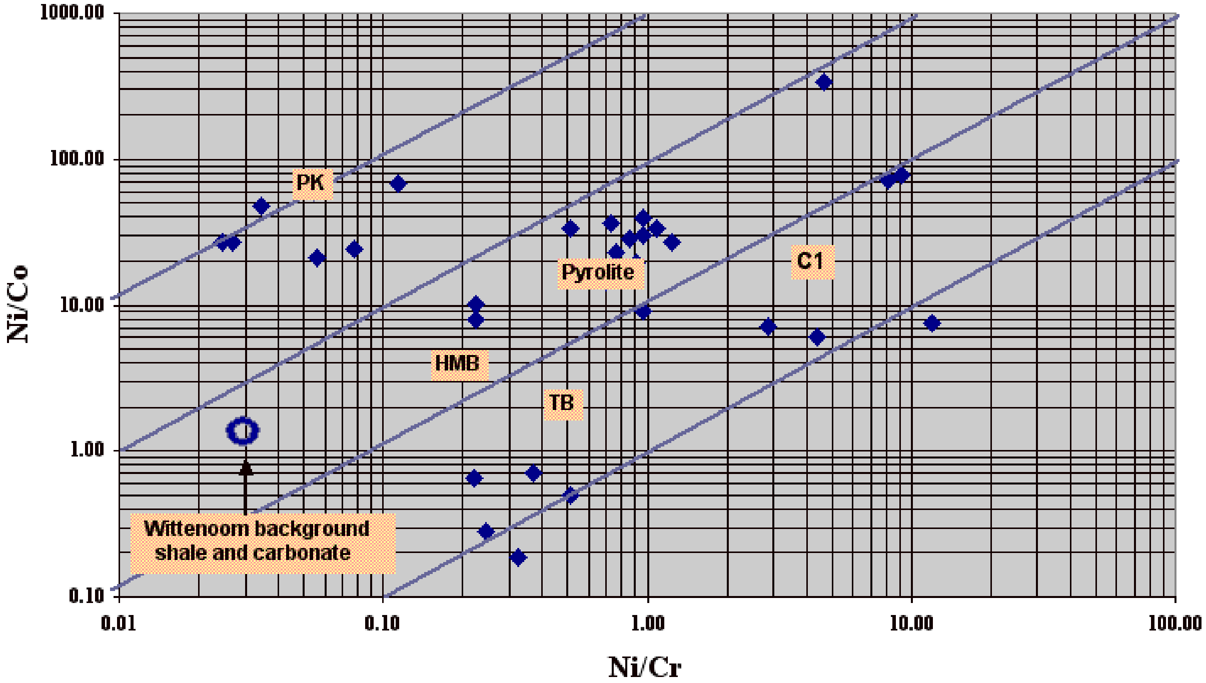

Figure 2: Ni/Co - Ni/Cr relations in Pilbara and Hamersley microkrystite impact condensate spherules (diamond symbols) compared to the mean composition of Archaean Pilbara volcanics. TB - tholeiitic basalt; HMB - high Mg basalt; PK - peridotitic basalt; C1 - C1 chondrite; Pyrolite - model mantle peridotite; Circle - average composition of Hamersley basin shales and carbonates