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1 Compositional evidence for multiple source areas of the 4 kyr BP distal impact-ejecta.

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The identification of diagnostic criteria relevant for determining the provenance of precursor materials that generated distal impact-ejecta are critical for attempting to locate the original impact area. The fallout of impact-produced debris dated at around 4 kyr BP has been traced in marine and terrestrial depositional settings across the two hemispheres. The related debris-rich strata contain a similar exotic assemblage that is formed of four types of finely-imbricated components: (i) vesicular silicate glass; (ii) carbonaceous materials associated to metallic particles; (iii) sedimentary clasts; & (iv) igneous-like rock clasts. A similar morphological diversity has been encountered (with variable proportions at all spatial scales) of angular fragments, glazed vesicular beads, spherules and filaments. A wide spectrum of particle-sizes has always been

observed ranging from nano-sized particles to fist-sized blocks. Fallout of the exotic debris in terrestrial settings locally induced ignition, heating, and partial melting of the host materials.

The evidence for phase transformation specific to impact processes has allowed to explain this intriguing assemblage as having resulted from surface pulverization of hot debris that traces the widespread dispersion of distal impact ejecta. The impact indicators comprise: (1) lechatelierite schlieren within compositionally heterogeneous Ca-rich flow glass that are characteristic of rapidly-quenched impact materials formed from incomplete melting under high pressure of silicate and carbonate fine-textured sediments; (2) blue glass with a microspheroidal pattern similar to the Zhamanshite impactite resulting from shock-induced liquid immiscibility; (3) diaplectic glass, ballen-textured quartz and crystal anomalies of quartz typical of high pressure transformation; & (4) silt-sized baddeleyite clusters produced from impact-linked thermal decomposition of sand-sized zircons with high-pressure shock defects. The presence within flow glass and mineral clasts of nano-sized clusters consisting of detonation-diamond, graphite, amorphous carbon, and polycyclic aromatic hydrocarbons (PAHs) indicates shock-induced formation of a kerogene-derived volatile phase that interacted before quenching with fluid condensates and solid debris within the impact-ejecta. Identification in the kerogene volatile-component of a sulphur phase with an isotopic anomaly indicating mass independent fractionation due to photolytic transformation suggests launching at great heights, beyond the O^2-O^3 UV shield. The occurrence of carbide carbon, carbyne species and graphitic nano-tubes in a vesicular green fibrous carbonaceous material derived from marine algae suggests shock-induced pyrolitic transformation of a fresh carbonaceous precursor.

The identification in the coarse debris of sediment clasts with fresh radiolaria and foraminifera of distinctive origin allows to elucidate the compositional complexity of the impact ejecta materials. At present three sources of marine materials are identified: silico-clastic marine calcareous mud from a polar region, a volcano-clastic marine fine sand from a sub-polar region, and metal-rich marine carbonaceous materials of algae origin with a hydrothermal component. The provenance diversity of the target terrains suggests a low-angle impact that might not have produced deep craters, but possibly large-scale propagation of a blast wave resulting in a giant tsunami. Incomplete melting of the heterogeneous impact ejecta and its erratic, but worldwide, dispersion would possibly express effects of a fragmented projectile along the impacted sub-surface sea trajectory. Identifying the exact location of the 4 kyr BP impact is one objective of ongoing research.