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The effect of a giant 3.26 Ga meteorite impact on the early surface environment and life

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Meteorite impacts significantly influenced early Earth's habitability. At least 16 major impact events (>10 km bolide diameter) are recorded in Archean rocks. Though unlikely to cause total ecosystem annihilation, these impacts had severe environmental effects. We studied the sedimentology, petrography, and geochemistry across the 3.26 Ga S2 impact event (bolide diameter 37–58 km) in both shelfal and shallow-water sections to assess its environmental impact and potential effects on early life.

Both sections exhibit similar sedimentary transitions: (1) Below the S2 spherule layer, black-and-white banded cherts reflect background sedimentation (Fig. 1A). (2) A conglomerate containing impact-derived spherules marks the impact event and the passage of an impact-initiated tsunami (Fig. 1B). (3) A ~1-meter-thick, normally graded black chert bed above it represents settling of fine particles post-tsunami and contains evaporite pseudomorphs, indicating partial ocean evaporation (Fig. 1C). In both sections, abrupt increases in grain size and/or Al_2O_3 content suggest prolonged detrital input after the tsunami. (4) Lastly, the sections transition from black chert to iron-bearing cherts (FeO* up to 7.4 wt%). The FeO* increase does not correlate with deepening, provenance shifts, volcanic activity, or hydrothermal input. Hence, the increase likely resulted from tsunami-induced water column mixing, introducing Fe^{2+}-rich deep waters into Fe^{2+}-poor shallow environments (Fig. 1C).

Meteorite impacts are often viewed as catastrophic events. The S2 impact undoubtedly had short-term devastating effects on the early biosphere, decimating phototrophic microbes in shallow waters and life on land's surface. However, in the medium term, ocean mixing would have made Fe^{2+} available in the photic zone, a potential electron donor for microbial life. Additionally, tsunami-driven erosion and intense post-impact weathering in a hothouse climate may have introduced nutrients like phosphorus into the nutrient-starved Archean oceans (Fig. 1D). Thus, meteorite impacts may have provided transient benefits to early life.