Giant submarine impact basins: Proliferation of life after a deadly impact

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The 1.85 Ga Sudbury basin is the oldest, best preserved and most accessible giant impact crater on Earth. The exceptional exposure of the basin fill sequence provides a unique opportunity to study the environment that developed within this submarine crater after the impact, and may indicate whether the conditions were suitable for the re-establishment of life. Here we report on field, petrographic, chemical and stable isotope data.

Grid survey transects through the basin fill strata revealed that lithic clasts decreased in abundance up section while the ash proportion increased, concomitant with a decrease in glass shard sizes. A total of 394 samples were taken and inspected petrographically for extent of alteration. Based on this screening, 71 ash matrix separates were obtained by diligent hand-picking to avoid mixed signals from lithic clasts and alteration products, for analysis of major elements, high-precision trace elements using ICP-MS, and C- isotopes.

Our data reveal that the lithophile elements are most variable in the lower fill, where the largest clast heterogeneity was also identified, reflecting the fall-back of impact-melted target rocks, whereas the upper fill varies on a finer scale. The lithophile elements suggest that the ash source progressed from average continental crust to more mafic up stratigraphy. In contrast, the metals with high volatility are conspicuously depleted in the lower fill, which may be interpreted as volatile loss related to extreme temperatures upon impact.

The Y/Ho ratio is consistently higher than chondrite, requiring submarine eruption of ash, and suggesting the crater was filled with saline water. There is a trend of increasing biogenic C content up section as well as an increase in pyrite, indicating an anoxic water column that supported life. Redox-sensitive elements such as Mo show interesting chemo-stratigraphies, with episodes of euxinia and possible reservoir effects in the basin. The crater wall collapse is clearly revealed by the chemistry across the overlying black shale.

These observations are consistent with a model in which the crater rim enclosed a basin of seawater, in which explosive volcanism persisted during sedimentation. The basin fill was dominated by lithic clasts and impact melt in the lower portion, grading into reworked impact melt and mafic melt, and a C-rich sediment. Life proliferated in the basin and the accumulation of reduced C led to anoxia and euxinia, providing a variety of ecologic niches.