Late Eocene impact layers in the Southern Ocean:

A geochemical and geochronological archive of the Popigai impact event

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1) Introduction

During the Late Eocene, the two largest impact structures, **Popigai** (Russia; ~100 km, 36.63±0.92 Ma [1]) and **Chesapeake Bay** (USA; ~85 km, 34.86±0.32 Ma [2]) are thought to have formed as a result of nearly simultaneous impact events [3–5] (Fig. 1). Although chronologically insufficiently documented, these events may have caused biotic disruptions and significantly altered climate conditions on a global scale during a time before the expansion of the Antarctic ice cap [4,6]. A more detailed assessment of impact-induced effects and chronology of these events, however, requires high-resolution stratigraphic correlation and more accurate age data than currently available (Fig. 2).

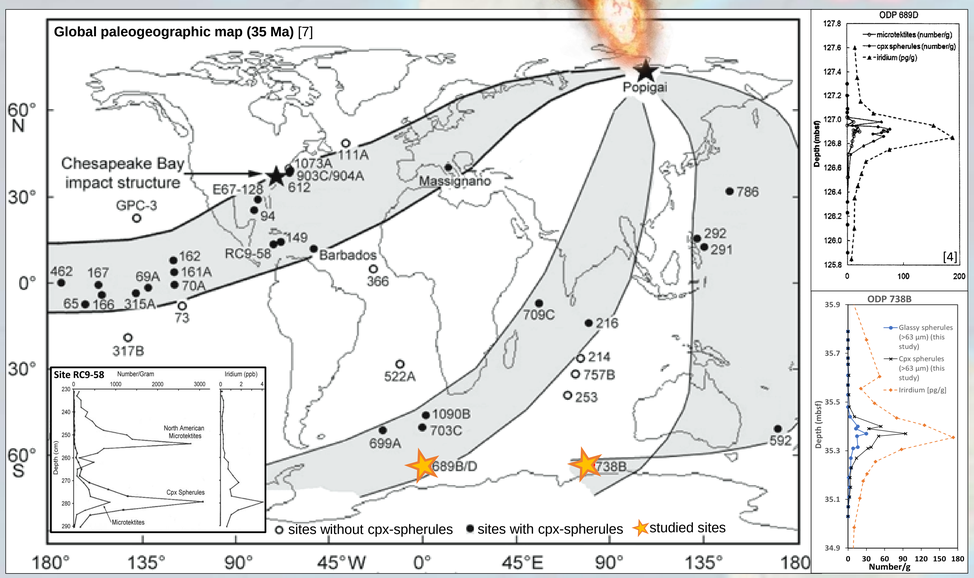
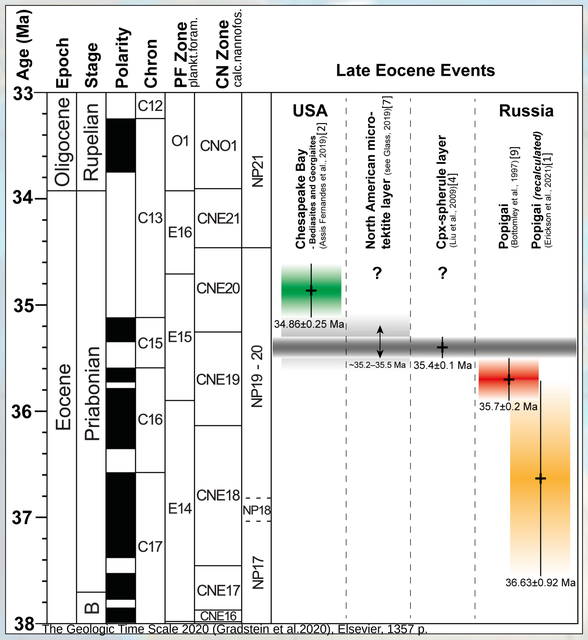


Fig. 1: Geographic distribution and stratigraphic positions of N.Am. tektites and cpx-spherules in different drill core sites.



The Geologic Time Scale 2020 (Gradstein et al.2020). Elsevier, 1357 p.

Fig. 2: Stratigraphic framework for the Late Eocene–Early Oligocene.

3) Methods

Spherules were picked under the microscope from sieved <150µm and >150µm sediment fractions after disintegrating ≤20g drill core samples from international core repositories (689D: GCR, 738B: KCC). BSE-imaging (Fig. 3) and EPMA analyses of major oxides (Fig. 4) were performed at the Institute of Earth Sciences in Heidelberg.

4) Results

A total of ~1500 and ~2200 cpx-spherules and ~640 and ~830 microtektites (>63 µm) were documented for ODP sites 689 and 738, respectively (Fig. 1).

- 689 peak abundances of ~60 cpx-spherules/g and ~24 microtektites/g agree with [4].
- Cpx-spherules and numerous microtektite are recorded for the first time at site 738.
- Optical differences of cpx-spherules (opaque dark to light) and microtektites (transparent colorless to yellowish) are also distinct in BSE-images (Fig. 3).
- Major oxide compositions for 689 and 738 samples (Fig. 4) are in agreement with previously reported data for the cpx-spherule layer distinguishing cpx-spherules and microtektites [4, 8] and confirm their provenance from the **Popigai** impact.

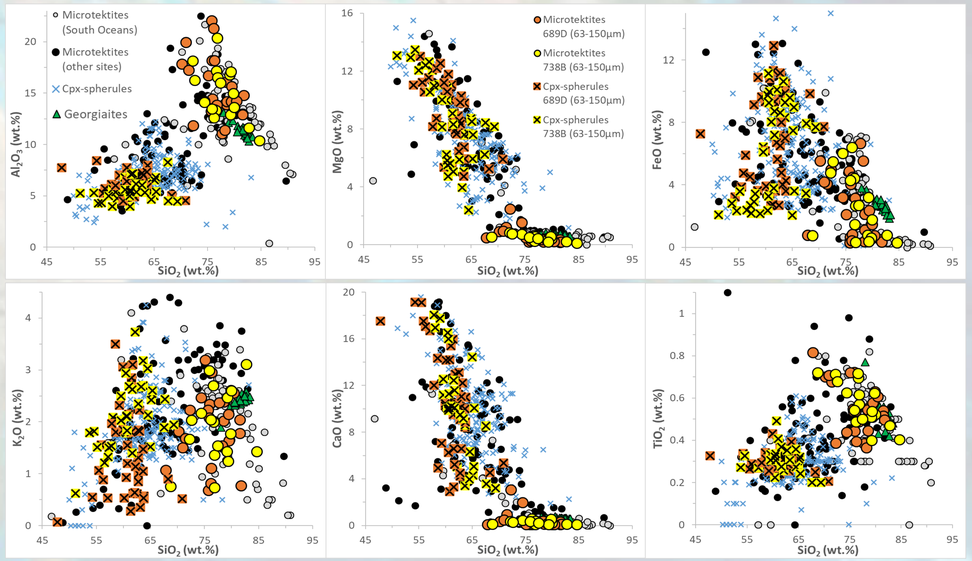


Fig. 4: Major oxide compositions of cpx-spherules and microtektites vs. N.Am. tektites compared to literature data [4,8].

2) Late Eocene impact layers in the Southern Ocean

The two Late Eocene impacts have been associated with two distinct impact layers identified in contemporaneous deposits around the globe (Fig. 1) [3–5]:

(a) the Chesapeake Bay impact with the **North American tektite (NAT) layer**, dated with $^{40}Ar/^{39}Ar$ to ~35.2–35.5 Ma [7].

(b) the Popigai impact with the stratigraphically slightly older **clinopyroxene (cpx)-bearing spherule layer**, bio- and magnetostratigraphically dated to ~35.4±0.1 Ma [4].

Cpx-spherules, occurring at several Southern Ocean sites drilled by the Ocean Drilling Program (ODP), were previously correlated with an Ir-anomaly and the Popigai impact [4]. However, a lack of geochemical data at some sites hitherto prevented rigorous verification that recovered spherules derived from the same or possibly multiple events.

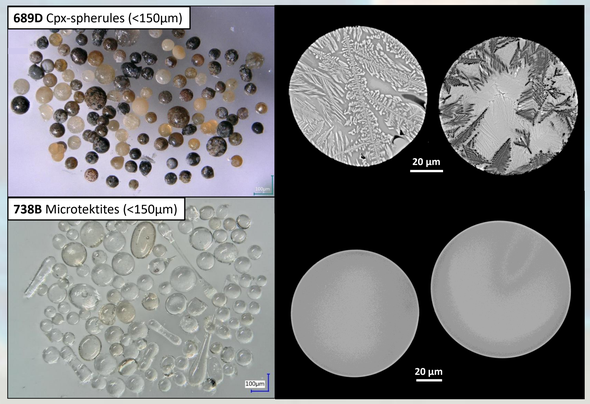


Fig. 3: Optical and BSE-images: Cpx-spherules and microtektites <150 µm

5) Future work

The cpx-spherule layer and associated tektites have never been radiometrically dated.

- Stratigraphic age [4] agrees with age of Popigai [9]

HOWEVER

- disagrees with recently re-evaluated age [1] (Fig. 2).

Glassy microtektites (>150µm in sizes, Fig. 5) are currently prepared for high-precision $^{40}Ar/^{39}Ar$ dating. This will potentially yield first radiometric ages of the cpx-layer and provide a new framework for assessing the timing and effects of Late Eocene impact events.

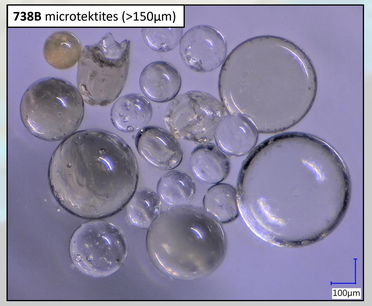


Fig. 5: Optical image: Microtektites >150 µm

References: **[1]** Erickson et al. (2021) *GCA* **304**, 68-82. **[2]** Assis Fernandes et al. (2019) *GCA* **255**, 289-308. **[3]** Koeberl, C. (2009), in: Koeberl, C. and Montanari, A. (Eds.), *GSA Special Paper* **452**, pp. 17-26. **[4]** Liu et al. (2009), in: Koeberl, C. and Montanari, A. (Eds.), *GSA Special Paper* **452**, pp. 37-70. **[5]** Glass & Simonson (2013) Distal Impact Ejecta Layers, Springer Berlin, Heidelberg. **[6]** Vonhof et al. (2000) *Geology* **28**, 687-690. **[7]** Glass (2019), in: Koeberl, C. and Bice, D.M. (Eds.), *GSA Special Paper* **542**, pp. 369-382. **[8]** Glass et al. (2004) *GCA* **68**, 3971-4006. **[9]** Bottomley et al. (1997) *Nature* **388**, 365-368.

Background from [3]