LARGE PLATINUM ANOMALY IN THE GISP2 ICE CORE: EVIDENCE FOR A CATACLYSM AT THE BØLLING-ALLERØD/YOUNGER DRYAS BOUNDARY? Michail I. Petaev[1,2], Shichun Huang[1], Stein B. Jacobsen[1], Alan Zindler[1]. [1]Department of Earth & Planetary Sciences, Harvard University Cambridge, MA 02138; [2]Solar, Stellar, & Planetary Sciences, Harvard-Smithsonian CfA, Cambridge, MA 02138; mpetaev@fas.harvard.edu

Introduction: The Younger Dryas (YD), a millennium-long cooling period amidst post-glacial warming, is well documented in the Greenland ice cores [*e.g.*,1-2] but apparently missing in Antarctica [*e.g.*,3]. It is thought to result from an abrupt change in atmospheric and oceanic circulation, but the cause of such a change remains controversial.

Among other causes, the Younger Dryas impact hypothesis [4] is based on observations and is testable. A C-rich layer, exposed in many sites in North America and Europe at or near the YD boundary, is enriched in magnetic grains with Ir, magnetic microspherules, charcoal, soot, carbon spherules, glass-like carbon with nanodiamonds, and fullerenes with extraterrestrial He. This has been interpreted as evidence for an impact or aerial blast at ~12,900 years ago. Subsequent studies both cast doubt on [5-12] and found new support for [13-14] the petrographic evidence. However, the invoked markers have never been supported by a geochemical impact signature such as a sharp increase in Ir or other PGE concentrations.

Here we report trace and major element concentrations in ice samples from the GISP2 ice core across the Bølling-Allerød/YD boundary (depth of 1709-1720 m, 12279-13064 years old) with a spatial resolution of ~12.5 cm (time resolution of 2.5-4.6 years) and discuss its implications for the YD impact hypothesis.

Ice Sampling: The eleven ice samples (~2 cm × 3 cm × 1 m each) provided by the National Ice Core Laboratory were processed in our clean lab at room temperature. The ice 'sticks' packed in plastic sleeves arrived partially broken into smaller pieces. Before sampling, broken 'sticks' were carefully aligned in the original sleeve and then split into eight samples, each ~ 12.5 cm long, using a metal bar wrapped in aluminum and plastic foils. Subsequently, each sample was extracted from a sleeve, carefully washed with ultra-pure DI water to remove possible surface contamination, and placed in a tall 300-ml polypropylene container, precleaned in 1:1 HCl and then 1:1 HNO_3 for several days. Small ice fragments and water left in a sleeve were collected as 'waste' samples and were used to develop and test analytical protocols. 'Wastes' from several sleeves were combined to get total weight comparable to the real ice samples. Overall, 88 ice samples, ranging from 38.42 to 68.90 g, and 5 'waste' samples were collected and processed. The empty and filled containers were weighed with a precision of ±0.01 g.

Preparing Analytical Solutions: The ice samples were melted at room temperature in closed containers and the water was slowly evaporated on a hot plate down to 1-2 ml. The remaining water was transferred into pre-cleaned (boiled in 1:1 HCl and then 1:1 HNO_3) 6-ml, PFA teflon beakers. Each ice container was then washed at least twice with 1-2 ml ultra-pure DI water, and the washes were collected and added to the corresponding samples.

The 93 samples along with 2 procedure blanks were (1) dried down on a hot plate; (2) treated with 1 ml of 1:1 mixture of conc. HF and conc. HNO_3 at 150°C; (3) dried down again; (4) re-dissolved in 0.4 ml of aqua regia; and, (5) finally diluted with 1 ml of ultrapure DI water to yield analytical samples of ~1.45 g each. Both empty and filled PFA beakers were weighed with a precision of ±0.0001 g.

Analytical Technique: The samples were analyzed in two analytical sessions, first for Ir, Pt, Lu, and Hf and then for Mg, Al, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Zn, Zr, Ru, Rh, Pd, Ag, Ba, La, Ce, and Au using a GV Instruments Platform ICP-MS equipped with an Apex inlet system in order to increase sensitivity and reduce oxide interferences. Ratios of LuO/Lu (<0.01) and HfO/Hf (<0.05), measured in a Lu-Hf solution together with ice samples, were used to correct for LuO and HfO interferences on ^{191}Ir and ^{194,195,196}Pt, respectively. The oxide corrections were typically <5%. For calibration, we used a 10 ppb Pt-Ir solution made from 1000 ppm HPS single element standards. The BHVO-1 standard was used for major and trace elements calibrations.

Results: The major result of this study is the lack of Ir anomaly in the ice samples studied (Fig. 1A). Instead, we found a large Pt anomaly in the middle of the YD boundary (Fig 1B), with Pt concentrations gradually rising by at least 100× over 25 years and dropping back during the subsequent 7 years. This Pt anomaly is accompanied by extremely high Pt/Ir and Pt/Al ratios (Fig. 2), indicative of a highly unusual source of Pt in the ice.

Such a source is unlikely to be lab contamination because: (1) all samples defining the anomaly are from the same ice 'stick' (Fig. 3) sampled with the same set of tools including a pair of latex gloves; (2) three peak samples (#62-64) are from a single continuous chunk; and, (3) the samples were analyzed randomly in different sessions.

Discussion: Our results could be explained by the impact of an iron meteorite with low Ir and high Pt concentrations like Sikhote-Alin (IIAB) or Grant (IIIAB)

[e.g.,15]; the former is a large crater-forming meteorite shower. If the Pt peak is caused by an iron meteorite impact, then the observed gradual ingrowth of the Pt concentration in ice over ~25 years requires lifting impactor's material above the stratosphere and formation of a ring around the Earth. The decay of the Pt signal is consistent with ~5-years lifetime of the dust in the stratosphere. Such an impact could result in a global Pt anomaly. An anomalous 50 cm thick ice layer with 100 ppt Pt would require a sub-km-size iron meteorite to account for the Pt mass-balance.

The huge Cape York IIIAB iron meteorite shower from West Greenland is thought to have fallen at about the time of the YD (~10,000 years ago), but it has comparable concentrations of Ir and Pt that cannot account for the very high Pt/Ir ratio found in the ice core.

Finding a terrestrial source of Pt is more difficult. The Laacher See supervolcano exploded ~12,900 years ago and spread tephra over Western Europe and Greenland, but this material is not expected to be Pt-rich. Some island arc volcanoes can apparently fractionate PGEs [e.g.,16], but whether a volcanic eruption could produce such a large Pt anomaly remains to be studied.

Concluding remark: The main conclusion of our study is the detection of an unusual event during the Bølling-Allerød - YD transition period that resulted in deposition of a large amount of Pt to the Greenland ice. The nature of the event remains uncertain, but our results clearly rule out an impact or airburst of a chondritic bolide. If an impact was involved, the impactor had a very unusual composition deriving from a highly fractionated portion of a proto-planetary core.

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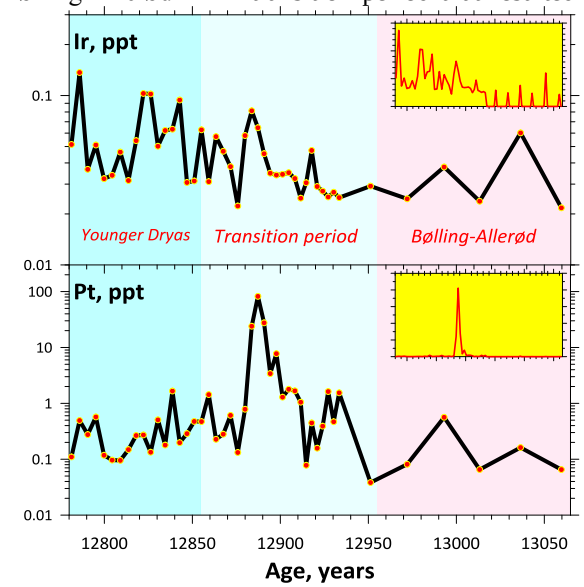

Fig. 1. Ir and Pt variations in the GISP2 ice samples. Yellow inserts show the same plots on linear scale. The peak Pt concentration is in the sample #63.

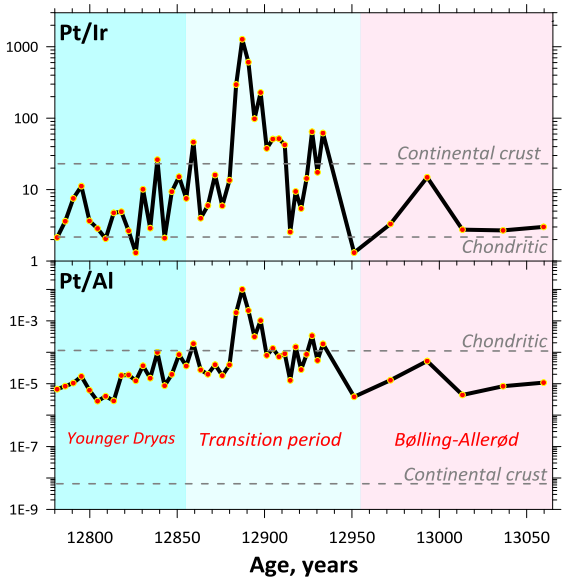

Fig. 2. Pt/Ir and Pt/Al variations in the GISP2 ice samples.

Fig. 3. Photo-mosaic of the ice 'stick' F containing anomalous samples identified by green numbers. Red dashes mark sample boundaries; some look non-parallel due to the tilting and displacement of individual images. Green arrows show breaks in the 'stick'. The original markings and labels are in black.