On the Possibility of a Late Pleistocene Extraterrestrial Impact: LA-ICP-MS Analysis of the Black Mat and Usselo Horizon Samples

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INTRODUCTION

A dark thin layer of the organic-rich material contemporaneous with the abrupt onset of the Younger Dryas (YD) cooling (12.9 ka) has been identified in North America (black mat; BM) and Western Europe (Usselo Horizon; UH). Most BM sequences contain a thin (2-5 cm) basal pitch-black layer likely corresponding to the lower YD boundary LYDB (Fig. 1). The UH sequences are represented by charcoal-rich and/or peat layers within aeolian sands (Fig. 2).

There is no consensus on the origin of the layer, and the main hypotheses include a) formation by water-transported organic material; b) heavy deposition of algae in a shallow fresh-water reservoir; c) formation in response to periods of spring-flood stream activation when groundwater oxidized organic material; d) wood fires and decomposition of charred wood. Recently another hypothesis has emerged that suggests e) the impact of a comet or asteroid [1-3].

ANALYTICAL METHODS

Trace element concentrations in the BM (USS Arizona) and UH (the Netherlands and France) samples were studied using a CETAC LXS-213 Nd*YAG laser coupled with Finnigan Element2 ICP-MS (Fig. 3). Analyses were conducted in low resolution mode. In order to obtain a composition as close to bulk sample as possible, the laser beam was focused onto the sample surface with wide spots of 200 μm. During the analytical runs, the laser was operated at full energy, 20 Hz frequency, and 700-1000 shots (according to each chunk size) with the He flow of ~700 mL/min.

RESULTS

Trace element compositions of the LYDB material and the BM itself are different: the BM displays a trace element concentrations similar to those of the average continental crust (ACC), while the LYDB is strongly enriched in REE (up to 800x chondrite) and relatively depleted in Ta, Nb, Zr, and Hf (down to 30x CI chondrite) (Fig. 4a). UH samples display similar patterns to the LYDB trace element features (Fig. 4b).

All studied samples display 2-5 times higher PGE concentrations than the sediments underlying SE Arizona BM sequences (Figs. 4c, d). LYDB samples display a positive correlation between Ni and Ir (Fig. 5a) with a slope of about 30,500 that is very close to the chondrite values, accompanied by an Os – Ir ratio of 1:1 (Fig. 5d) and overall high concentrations of both Os and Ir. Samples of BM itself do not display any correlation between Ni and Ir (Fig. 5b), and have an Os-to-Ir ratio of 1:2, which is more typical for terrestrial sediments [5]. Fingerprints of the trend with Os-to-Ir ratio of 1:1 can, however, also be seen in BM samples (Fig. 5a).

Overall, UH samples display PGE features which are a mixture between those typical of the BM and the LYDB. However, UH samples do not display any correlation between either Ni and Ir (similarly to BM samples) or Os and Ir (Figs. 5c, f).

DISCUSSION

A difference in trace element compositions between the LYDB and BM can point to a sharp change in the conditions of sedimentation just before the onset of the YD cooling. On the other hand, a similarity between trace element features of the LYDB and UH samples (which are enriched in charcoal) could suggest that enrichment of sediments in REE accompanied by depletion in Ta-Nb and Zr-Hf (Figs. 4a, b) might be due to the process of biomass burning. As a result of an ET impact, extensive fire and configurations may have been triggered that resulted in a generation of a large amount of the BM and UH. We suggest that elements such as Zr, Hf, Ta, Nb could be vaporized during the extensive biomass burning whereas REE were preferentially accumulated in the resulting ash leading, therefore, to REE enrichment (Figs. 4a, b). Another suggested explanation for the observed geochemical features is an introduction of the matter enriched simultaneously in REE, PGE and N. If we invoke an ET object (Fig. 4), a positive correlation between Ni and Ir for the LYDB (Fig. 5a) is explainable since a lot of meteorites display just exactly such composition. However, in order to explain additional REE enrichment, we still need to involve terrestrial processes such as configuration which could enrich resultant material in REE (F).

CONCLUSIONS

1. The distributions of the trace elements in the Lower Younger Dryas Boundary, Black Mat and Usselo Horizon samples point to an event which changed abruptly conditions of sedimentation just before the onset of the Younger Dryas cooling 12.9 ka.

2. Trace element distributions and relations observed for Lower Younger Dryas Boundary samples may be consistent with incorporation of the material of ET origin shortly before the beginning of the Younger Dryas cooling.

3. The Black Mat itself was formed by sheared terrestrial processes in response to a climatic change and displays the trace element composition similar to that of the ACC.

4. Impact-related material could be delivered as airborne particles as far west as Western Europe where it could participate in the generation of the Usselo Horizon resulting particularly in elevated PGE concentrations.

5. The study of PGE distributions across the sediments of the appropriate age could be of the highest priority in further studies of the problem of the possible ET Late Pleistocene impact.

REFERENCES