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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-fed 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].

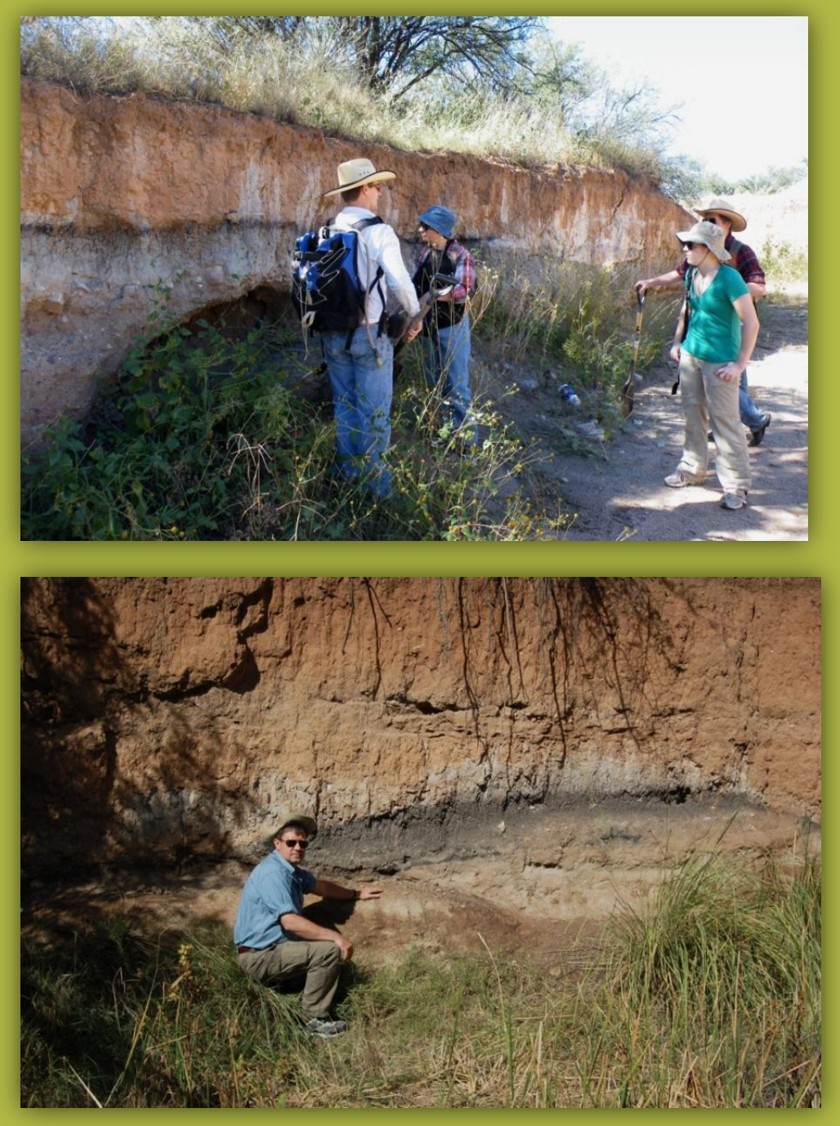


Fig. 1. Late Pleistocene outcrops in Murray Springs, AZ displaying occurrences of the black mat.

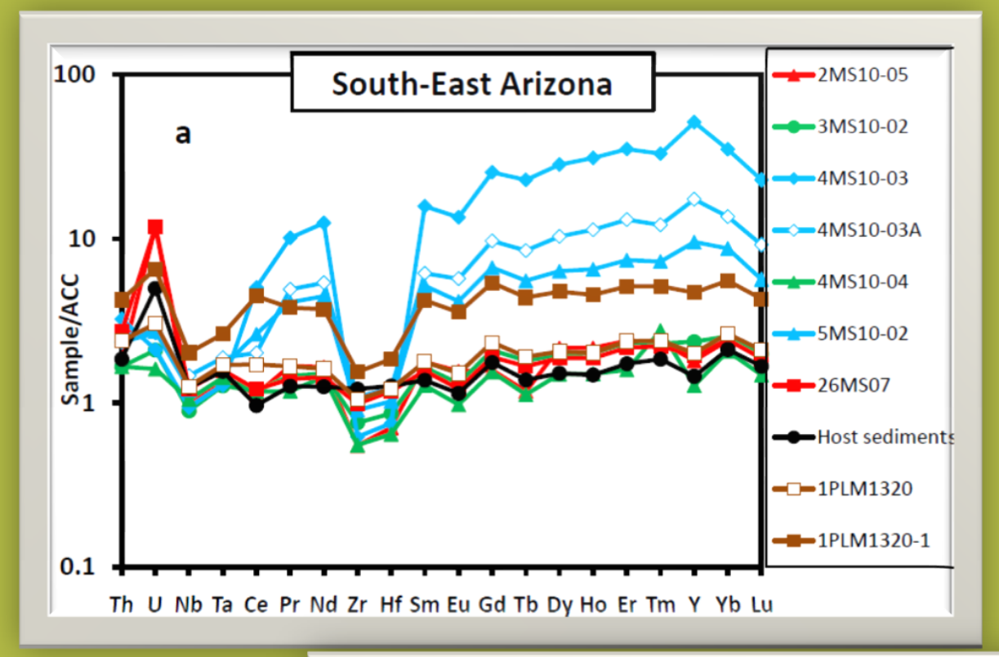
Fig. 2. Occurrences of the Usselo Horizon in Lommel-Maatheide, Belgium (left) and Lutterzand, the Netherlands (right).

ANALYTICAL METHODS

Trace element concentrations in the BM (SE 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.

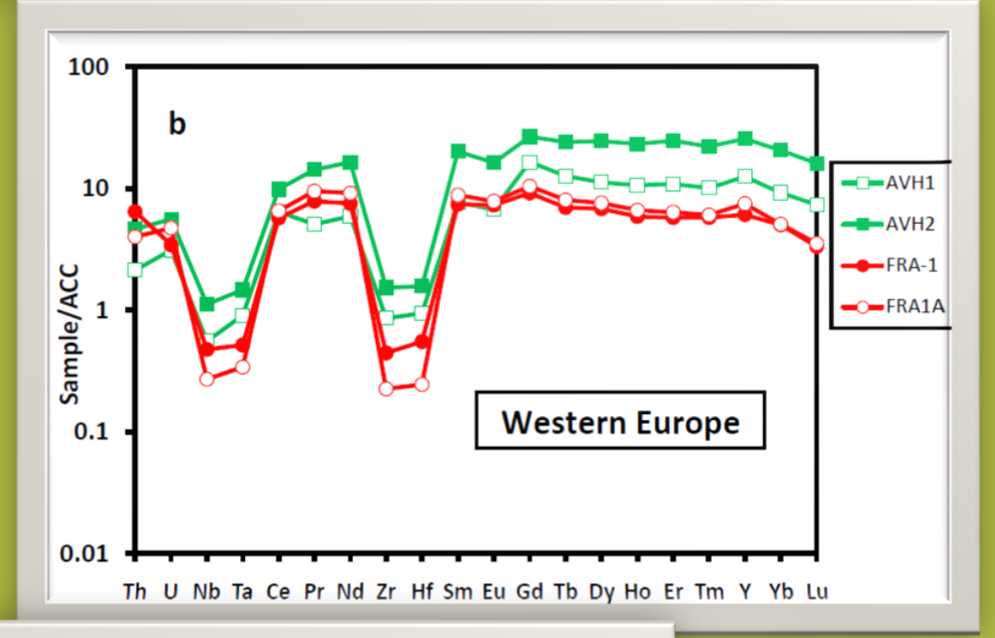
Fig. 3. The Nine Circles Analytical Cosmochemistry laboratory equipped with the Thermo Finnigan Elelemen2 ICP-MS (on the left) coupled with the CETAC LSX-213 Nd: YAG laser ablation unit (on the right).

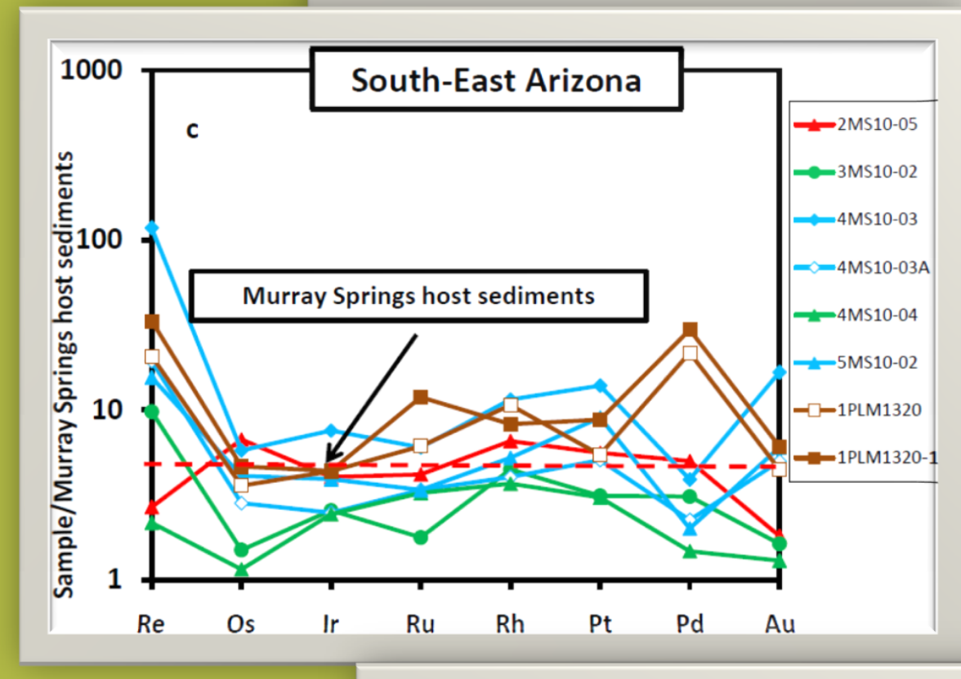
RESULTS



Trace element compositions of the LYDB material and the BM itself are different: the BM displays trace element concentrations similar to those of the average continental crust (ACC), while the LYDB is strongly enriched in REE (up to 800xCI chondrite) and relatively depleted in Ta, Nb, Zr, and Hf (down to 30xCI chondrite) (Fig. 4a). UH samples display patterns similar 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 chondritic values, accompanied by an Os – to - 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 for BM samples (Fig. 5e).

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).





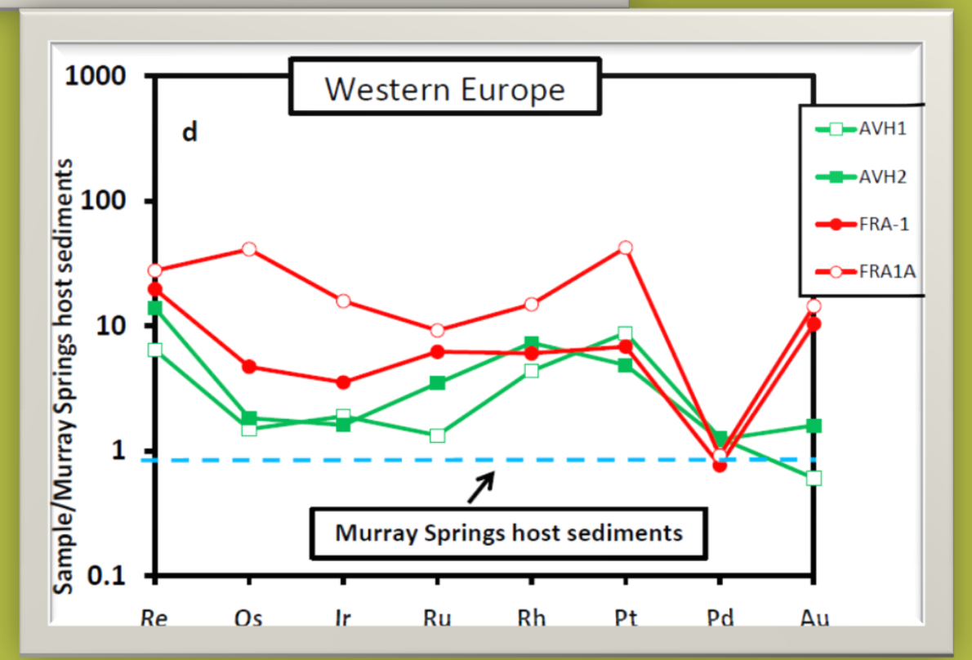


Fig. 4. Spider-diagrams for samples from SE Arizona and W. Europe: a, b ACC-normalized trace element diagrams; c, d host sediment-normalized PGE diagrams.

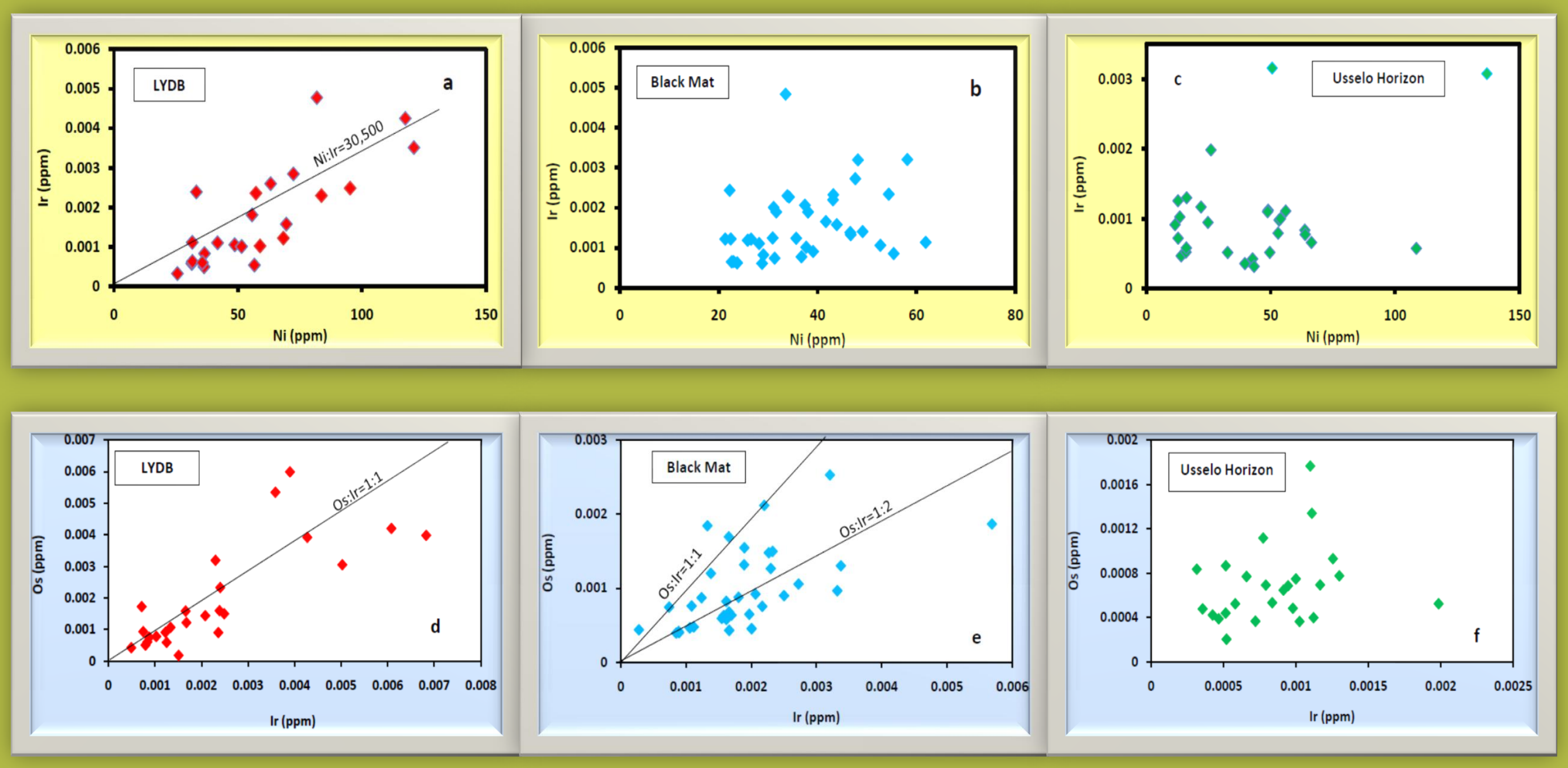


Fig. 5. Binary diagrams for LYDB, BM and UH samples: a, b, and c are Ni vs. Ir diagrams, LYDB samples display distinct positive correlation between the elements with the slope of ~30,500; BM and UH samples do not display any correlation; d, e, and f are Os vs. Ir diagrams displaying various Os-to-Ir ratios for LYDB, BM and UH samples.

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 conflagrations may have been triggered that resulted in a generation (at least partially) 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 Ni. If we invoke an ET object (Fig. 6), a positive correlation between Ni and Ir for the LYDB (Fig. 5a) is explainable since a lot of meteorites displays just exactly such composition. However, in order to explain additional REE enrichment, we still need to involve terrestrial processes such as conflagration which could enrich resulted material in REE [6]).

Fig. 6. An artist's view to the fall of the Younger Dryas (12.9 ka) comet/meteorite (from [7])

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 sheer 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

[1] Firestone R.B. et al., 2007. *Proceedings of the National Academy of Science* **104**, 16016-16024.
[2] Haynes C.V. et al., 2010. *Proceedings of the National Academy of Science* **107**, 4010-4015.
[3] Kaiser K. et al., 2009. *Boreas* **38**, 591-609.
[4] Higgins M.D. et al., 2011. *42nd Lunar and Planetary Science Conference*, 1504.
[5] Agiorgitis G., Wolf R., 1984. *Chemical Geology* **42**, 277-286.
[6] Walsh P.N. et al., 1960. *Journal of the American Ceramic Society* **43**, 229-233.
[7] Toner M., 2010. *American archaeology* **Fall,** 12-18.