SEDIMENT-DISPERSED EXTRATERRESTRIAL CHROMITE IN ORDOVICIAN LIMESTONE FROM RUSSIA.

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Introduction: More than 40 fossil L-chondrites have been found in the mid-Ordovician Kinnekulle limestone in southern Sweden [1, 2]. These finds have been interpreted as the result of a sharp increase of the flux of meteorites onto the Earth, caused by catastrophic destruction of asteroids. Indeed, the improved ^{40}Ar-^{39}Ar dating techniques applied to several L-chondrites indicate a single L-chondrite asteroid breakup event at 470±6 Ma [3], in perfect agreement with a refined age estimate of the middle Ordovician meteorite shower at 467.3±1.6 Ma [4]. This allows to identify the fossil meteorites as rapidly transferred collisional fragments. On the other hand, the fossil meteorites from the Kinnekulle quarry could be fragments of a single meteorite shower. However, further searches by Swedish scientists showed that across an area of more than 250,000 km^2, rocks coeval with the limestones containing the fossil meteorites are enriched in extraterrestrial chromite grains similar by composition to L-chondritic chromites [5]. This is a weighty argument for hypothesis about sharp increase of meteorite influx. In this case Ordovician deposits in different parts of the Earth should show higher content of extraterrestrial material in intervals of similar age. To shed light on this question, we investigated one of the sections of Ordovician rocks in northwest Russia.

Results. In Sweden, fossil meteorites and cosmogenic chromite have been found in outcrops of the conodont zone *Lenodus variabilis* (the trilobites zone *Asaphus expansus)*. Four sections in the center and eastern parts of the Baltic-Ladoga Klint in Russia, with rocks ages similar to the Swedish sections, have been examined. We collected limestone samples of several kilograms each. Then these samples have been dissolved in a cold HCl. After this treatment, the remaining material contained significant amounts of clay and iron hydroxides. To remove these, the remaining material was carefully sifted and grinded. A final residue was achieved only for two samples collected from the same outcrop near the mouth of the Lynna river.

The first sample (6.5 kg) represented interval locally named Lynna bed. This interval contains *Lenodus variabilis* conodonts and *A. expansus* trilobites. The sample was collected 0.4 m below the top of this bed. The second sample (4.02 kg) was obtained right in the boundary zone of the trilobites *A. expansus/A. "raniceps" – A. striatus*. This zone corresponds to the boundary of the Lynna and Sillaoruska beds. The weak-magnetic fractions were separated from the remains of these rocks by electro-magnetic separation unit, and then chromite-like grains were separated from these fractions, mounted in epoxy and polished. Using electron probe microanalysis, chromite grains were identified in the samples. In the lower sample, four grains of chromite were identified; and nineteen in the upper. Grain size of chromites ranged from 20 to 100 µm. We also have analyzed chromites from two ordinary L chondrites Tsarev (L5) and Sayh al Uhaymir 001 (SaU 001) (L5) in order to compare their chemical compositions with Ordovician chromites.

In the first stratigraphically lower sample chromites had an average composition (wt%: Al_2O_3 - 5.0, TiO_2 - 2.7, FeO - 26.1, MgO - 3.4 with Cr/(Cr+Al)=88.5) corresponding to that of the Swedish fossil meteorites and ordinary chondrites. Chemical composition of chromite from the Tsarev chondrite is very similar to chromites from this sample. Two chromite grains were enriched in Ni (up to 0.5 wt%). The composition of chromites from the upper sample on average (wt%: Al_2O_3 – 5.3, TiO_2 - 2.9, FeO - 26.5, MgO – 1.9; Cr/(Cr+Al)=88) corresponded to the composition of chromites from the fossil meteorites and ordinary chondrites. It is also very similar to composition of chromites of SaU 001. Only two grains differ from others (wt%: Al_2O_3 – 22.9, TiO_2 - 0.6, MgO – 8.4; Cr/(Cr+Al)= 51).

In addition, an XRF analysis was performed for ours limestone sample to assess lateral transport of terrigenous material in the paleobasin. Al_2O_3 and SiO_2 values, indicating the clay content, decrease upward in the section by more than 1.5 times.

Discussion and conclusions. The major-element composition of terrestrial chromites (Mg, Fe, Cr) varies in a wide range [6], within which fall the compositions of chondrite chromites (H, L and LL groups). Thus, based on a comparison of the major-element compositions of chromites found in Ordovician sedimentary rocks, one cannot draw conclusions about their genesis. However, if we even propose that the sedimentary-dispersive chromites had terrestrial origin, diversity of rocks making up the Baltic Shield should lead to a wide diversity of chromite compositions in the sediments, that is not the case. The compositions of our chromites vary in a very narrow range. Only two grains in our upper sample differed sharply from the compositions of the others (high Al_2O_3) and may be terrestrial chromites, because terrestrial chromite has wide range contents of Al_2O_3 unlike chromite from ordinary chondrites [7, 8]. Moreover, the content of terrigenous material (clay) showed an inverse correlation to the number of chromite grains in the rock. Upward in the section, the content of chromite grains increases by nearly five times (0.6 to 2.9 grains/kg), while the clay content decreases by 1.5 times.

Besides that, the thin size and low number of terrigenous material, represented mainly by the clay, suggests there was an insignificant influence of aeolian and hydrodynamic factors on the distribution of chromites within the basin. It means that observed chromite grains most probably were not a component of terrigeneous material. It should be noticed that chromite grain enrichment in Lynna area has an opposite signature to the Swedish sections, in which the number of chromite grains decreases upward in the section. Indeed, this may be explained by the insufficient sampling statistics.

The microelement composition of chromites from both samples obviously differs in TiO_2, MnO and V_2O_3 from that of terrestrial chromites (Fig. 1 a, b), and are very similar to that of fossil Ordovician meteorites and ordinary chondrite group [7,8]. Therefore we can propose that chromite grains, extracted from the Lynna Ordovician limestones, are extraterrestrial. It is necessary to notice, that the composition of two NiO-rich chromite grains from the lower sample is unusual. Chromites with similar high NiO content were described as newly formed in large impact events on Earth [9]. The addition of small amounts of such material into Ordovician sediments cannot be excluded, since the meteorite flux may contain large bodies, which could have formed explosive meteorite craters.

The main result of our investigation is the discovery of a high content of extraterrestrial chromite grains in Ordovician limestones of Russia those are coeval to Swedish limestones, bearing the fossil meteorites and extraterrestrial chromite grains. The cosmogenic chromites from the Ordovician sediments of Sweden and Russia are close in composition and are localized in a narrow stratigraphic interval in the sections separated by several hundreds kilometers (~700 km), assuming their similar sources. This is a weighty argument in favor of that the Ordovician L-chondrite stream was not a local phenomenon. In addition one should keep in mind that significantly increased cratering rate in Ordovician may be also related to the L-chondrite asteroid breakup [2, 3]. We plan to continue more detailed study of possible variations of the meteorite flux in the mid-Ordovician. Further searches for the traces of cosmic material in the mid-Ordovician sediments should be continued in other regions in order to specify the scale of the extraterrestrial influx onto the Earth in Ordovician.

This work was supported by the Natural History Museum of Dedovsk city, Moscow region, Russia.

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Fig. 1. Chemical composition of chromite from upper and lower samples of Ordovician rocks in Russia in comparison with chromite compositions of Tsarev and SaU 011 L5 chondrites, average chromite composition of Swedish Ordovician paleometeorites, H and L chondrites [7], and H, L, LL chondrites [8].