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Distributions of extraterrestrial and terrestrial chromite grains in ordovician limestone of Sweden and China

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More then 80 fossil meteorites were recovered from mid-Ordovician marine limestone in the Thorsberg quarry in the southern Sweden. These meteorites have been identified as fragments of the L-chondrite parent body (asteroid) which was destroyed in a catastrophic collision in space ~470 Ma [*Schmitz et al.,* 1997; *Heck et al.,* 2004]. In this quarry together with meteorites, there were also found the relic sediment-disperse extraterrestrial (EC) and terrestrial (OC) chromite grains. Similar grains were also found in several correlated sediment beds of other quarries in Sweden and in China [*Cronholm, Schmitz*, 2010].

Sediment-dispersed EC grains are two orders-of-magnitude more abundant over a part, representing a few million years, of mid-Ordovician strata compared to background levels. Detection of the solar wind noble gases in EC grains (Fig. 1) has allowed to identify unequivocally and convincingly these grains as micrometeorites which have been generated as dust during the disruption of the L chondrite parent body and arrived on all Earth over a timescale of 1-2 Myr [*Heck et al*., 2008; *Meier et al.,* 2010].

We can see on Fig. 1, the difference of ^{20}Ne content in the extraterrestrial and terrestrial chromite grains exceeds two orders-of-magnitude.

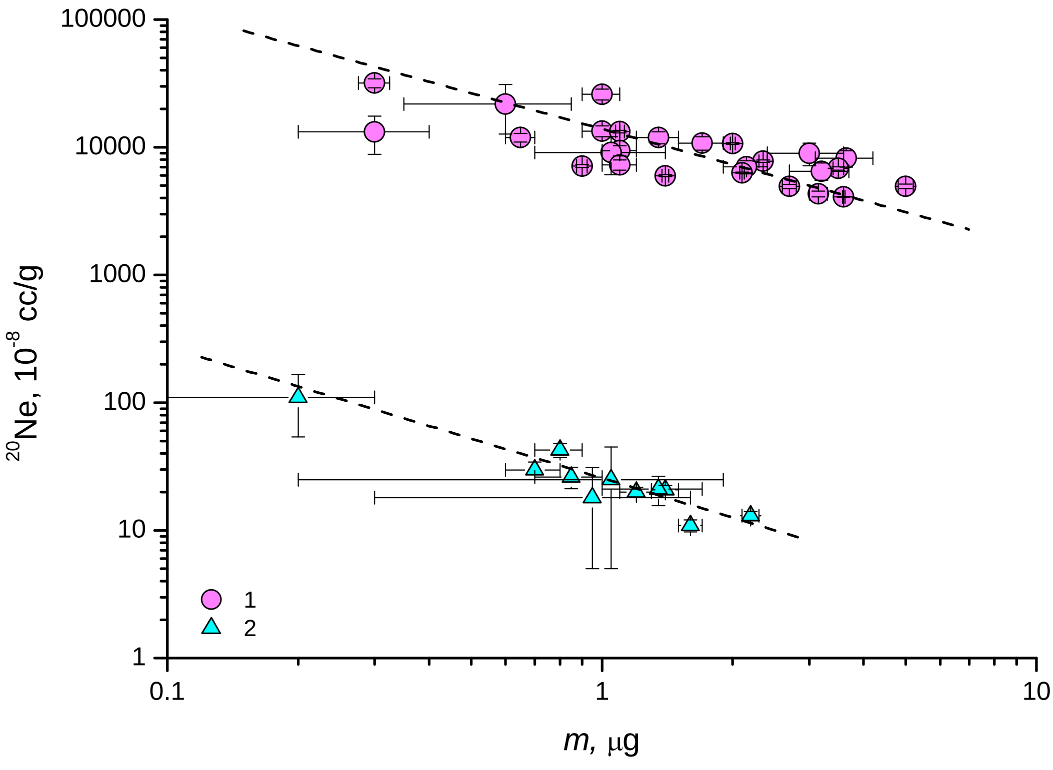

Fig. 1. Content of ^{20}Ne in individual extraterrestrial (1) and terrestrial (2) chromite grains vs. mass of grains (according to [*Meier et al.*, 2010]). Dotted lines are regression lines.

The increase in the ^{20}Ne content with decrease of mass of grains is caused by increase in a specific surface of grains at decrease of their sizes. The identical inclination of the regression lines (parameter of *b* in the equation of lines, Tab. 1) is evidence of the surface-correlated mechanism of capture of gases as solar (for EC grains) and terrestrial (for OC) origins. High abundance of fossil meteorites (in the Thorsberg quarry) and relic chromite grains (in all quarries) have given the basis for the assumption, that the stream of extraterrestrial material to the Earth during several millions years ~470 Ma was, at least, on two orders of magnitude above, than now [*Schmitz et al*., 2003; *Alwmark, Schmitz*, 2009].

Table 1. The parameters of the equation for the regression line $\lg(^{20}Ne) = a + b \times \lg m$ for the dependence of the content of ^{20}Ne (10^{-8} cm^3g^{-1}) on the mass (m, μg) for the extraterrestrial (EC) and terrestrial (OC) individual chromite grains from the Thorsberg quarry, southern Sweden. [1)]

Chromites	a	b	R
EC	4.14 ± 0.1	-0.93 ± 0.02	-0.77 ± 0.08
OC	1.41 ± 0.3	-1.03 ± 0.13	-0.88 ± 0.07

[1)] According to [*Meier et al*., 2010].

However, the beds with high abundance of extraterrestrial chromite grains have high abundance and terrestrial grains also (Fig. 2). For comparison of concentration of both grain populations (EC and OC), we shall enter the factor of enrichment (K) for extraterrestrial (K_{EC}) and terrestrial (K_{OC}) grains:

$$K_{EC} = (N_{EC}/M)_{FM} / (N_{EC}/M)_{NFM} \text{ и } K_{OC} = (N_{OC}/M)_{FM} / (N_{OC}/M)_{NFM}.$$

Here N is the number of extraterrestrial (N_{EC}) or terrestrial (N_{OC}) grains found in the limestone mass of M. The FM index is related to the limestone beds equivalent with those, containing fossil meteorites. The NFM index is related to the beds that have formed during other time. N_{EC}/M and N_{OC}/M are concentration of extraterrestrial and terrestrial grains in limestone correspondingly.

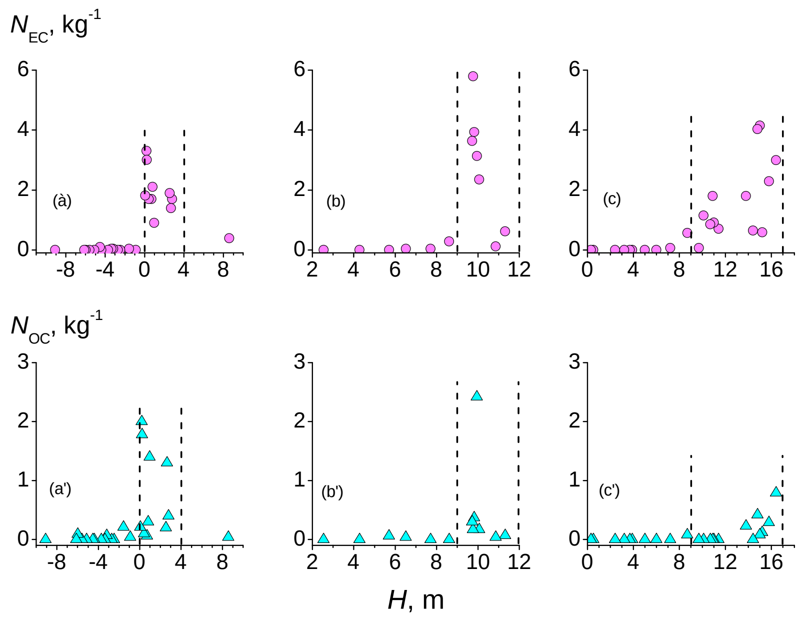

Fig. 2. Distribution of the extraterrestrial (a, b, c) and terrestrial (a', b', c') chromite grains in Ordovician limestone in the quarries of Sweden – Thorsberg + Hällekis (a, a'), Killeröd (b, b'), and China – Puxi River (c, c'). The H is a column depth. Dotted lines are marked the time intervals of the accumulation of sediments with fossil meteorites in the Thorsberg quarry. (According to [*Schmitz, Häggström,* 2006; *Häggström, Schmitz,* 2007; *Cronholm, Schmitz,* 2010].)

From the data shown in the Table 2, we can see, for example, the concentration of extraterrestrial grains in the Thorsberg and Hällekis quarries in the beds equivalent with those containing fossil meteorites, exceeds concentration of EC grains in the layers that have formed during other time, in 49 ± 13 times (i.e. K_{EC}=49). At the same time, the factor of enrichment for terrestrial grains is equal to K_{OC} = 28 ± 9, that within the limits of an error is in accord with K_{EC} value. (The errors were calculated as $\sigma(N) = \sqrt{N}$.) For all data set (Tab. 2) the value of enrichment by the extraterrestrial chromite grains is on average equal to 40 ± 8. However, high concentration of the OC grains (K_{OC} = 23 ± 7) in the beds with high concentration of the EC grains can testify about processes of enrichment at the bottom of the sea because of hydrodynamical sorting that especially effectively could be occurred at formation of limestone beds in Sweden [*Cronholm, Schmitz,* 2010].

Table 2. Abundance of the extraterrestrial (EC) and terrestrial (OC) chromite grains in the quarries of Sweden (Thorsberg, Hällekis, Killeröd) and China (Puxi River). 1)

Quarry	Bed 2)	M, kg	N_{EC}	N_{OC}	N_{EC}/M, kg^{-1}	N_{OC}/M, kg^{-1}	K_{EC} 3)	K_{OC} 3)
Thorsberg &Hällekis	FM	173.9	332	142	1.91 ± 0.11	0.82 ± 0.07	49 ± 13	28 ± 9
	NFM	407.1	16	12	0.039 ± 0.010	0.029 ± 0.009		
Killeröd	FM	133.5	318	73	2.38 ± 0.14	0.55 ± 0.07	37 ± 12	42 ± 30
	NFM	153.4	10	2	0.065 ± 0.021	0.013 ± 0.010		
Puxi River	FM	165.3	283	25	1.71 ± 0.10	0.15 ± 0.03	26 ± 10	>5
	NFM	122.5	8	1	0.065 ± 0.023	<0.03		
All	FM	472.7	933	240	1.97 ± 0.07	0.51 ± 0.03	**40 ± 8**	**23 ± 7**
	NFM	682.9	34	15	0.050 ± 0.009	0.022 ± 0.006		

Notes:
1) According to [*Schmitz, Häggström,* 2006; *Häggström, Schmitz,* 2007; *Cronholm, Schmitz,* 2010];
2) FM и NFM – beds with and without fossil meteorites accordingly;
3) $K_{EC} = (N_{EC}/M)_{FM}/(N_{EC}/M)_{NFM}$; $K_{OC} = (N_{OC}/M)_{FM}/(N_{OC}/M)_{NFM}$. The values of K_{EC} and K_{OC} are factors of enrichment of limestone by extraterrestrial and terrestrial chromite grains respectively.

Taking into consideration these data, it is apparently possible to say about increase in a stream of *micrometeorites* on all Earth after destruction of parental body L-хондритов no more than several times but not on two orders of magnitude above than now. But for all that, the high concentration of fossil *meteorites* in the south of Sweden is most probably caused by fall of single meteorite shower nearby the Thorsberg quarry about 470 Ma [*Alexeev,* 2010].

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