ORDOVICIAN FOSSIL METEORITES IN SWEDEN: NUMEROUS METEORITE FALLS OR SINGLE METEORITE SHOWER? V.A. Alexeev, Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, Moscow 119991 Russia; e-mail: AVAL37@chgnet.ru

Introduction: Heck et al. [1] found, the exposure ages of Ordovician fossil meteorites are all close to or less than a million years. These ages generally increased according to their position in the sediment column and the difference between the highest and lowest ages is consistent with presumed total deposition time of the sediments of 1-2 Ma. According to [1], these data provide evidence of a *long-lasting* rain of meteorites following the destruction of the L-chondrite parent asteroid ~480 Ma ago. In our report we present the results of the analysis of the data from [1]. This analysis has allowed us to draw other conclusions.

Noble Gases: Principal feature which has been found is a distinct correlation between the mass of the samples (batches) and the contents of the noble gases ^{4}He, ^{20}Ne, ^{21}Ne, and ^{22}Ne for two groups of samples: one group is from the bed of Arkeologen (Ark) and another group is from other beds (non-Ark) (Fig. 1 and Table 1).

Exposure Ages: The negative correlation is also observed between the estimated in [1] exposure ages and the mass of the samples (Fig. 2). Though it is obvious, the exposure age (duration of an irradiation by cosmic rays) cannot depend on the mass of the analyzed sample. Such correlation is caused by the insufficient taking into account of the contribution of nucleogenic $^{21}Ne_{nucl}$. The contribution of the $^{21}Ne_{nucl}$ was calculated in [1] on the assumption that ratio of $^{21}Ne_{nucl}$/ $^{4}He_{rad}$ =3.7 10^{-8} for crystal rocks (according to [2, 3]). However, this ratio has been found in [3] not for crystal rocks but for terrestrial gases. The $^{21}Ne_{nuc}$/ $^{4}He_{rad}$ ratio in crystal rocks can be essentially higher than in terrestrial gases due to better retention of $^{21}Ne_{nuc}$ in the rocks in comparison with of ^{4}He [4].

Discussion: In chromites, the nuclei of $^{21}Ne_{nuc}$ (E ~0.15 MeV) have very short range of ~0.2 μm in comparison to the range of α-particles (^{4}He nuclei) from decay of Th and U (E_{α} = 4.01-8.75 MeV) which is ~10-30 μm. This difference can be responsible for higher $^{21}Ne_{nuc}/^{4}He_{rad}$ ratios in small chromite grains in comparison with the larger grains. This grain size (i.e. mass) dependence was taken into account by normalization of the $lg^{21}Ne$ values in the Fig 1 to the $lg^{21}Ne$ value on regression line for lgM = -4.4 (the maximal mass M = 40 μg,). It allowed us to calculate the high limiting values of the exposure ages $T_{21\ norm}$. For all samples of non-Ark group, these $T_{21\ norm}$ values are the same within the limits of errors. The average age value is 0.31 ± 0.02 Ma. The obtained $T_{21\ norm}$ ages *does not depend* on the position of the meteorite in the stratigraphic column (Fig. 3a).The average limiting value of the exposure age for meteorites of the Ark group is defined as 0.06±0.02 Ma. The difference of the average ages of two groups can be caused by different contribution of U/Th α-particles in formation of $^{21}Ne_{nuc}$ in the Arkeologen bed and in overlying strata grains. Distribution of normalized ^{4}He contents (Fig 3b) confirms this assumption.

Chemical composition of the extraterrestrial chromite (EC) grains from close located Thorsberg and Hallekis quarries (4 km) is identical, but there are significant differences at comparison with EC grains from distant (~500 km) Lockne crater (Loftarstone) (Fig 4, Table 2).

Conclusion: The found features in distributions of noble gas contents and of exposure ages imply the falling single meteorite shower. Time of this event corresponds to the stratigraphically oldest occurrence of meteorites in the column. Meteorites in the younger strata most likely are a result of redeposition. In this case there is no necessity to set up a hypothesis of intensive flux of meteorites to Earth during ~1-2 Ma about 480 Ma ago.

References: [1] Heck Ph.R. et al. (2004) *Nature, 430,* 323. [2] Leya I., Wieler R. (1999) *JGR, 104,* 15439. [3] Tolstikhin I.N. (1978) In: *Terrestrial Rare Gases, ed. by E.C. Alexander, Jr. and M. Ozima, Center Academic Publications Japan,* 33. [4] Verkhovskii A.B., Shukolyukov Yu. A. (1976) *Geokhimiya, 5,* 778 (in Russian). [5] Schmitz B., Haggstrom Th. (2006) *MAPS*, 41, 455. [6] Alwmark C., Schmitz B. (2007) *EPSL 253,* 291.

Table 1 The correlation coefficients between mass of the samples and the noble gas contents or the T_{21} values

Group*	^{4}He	^{20}Ne	^{21}Ne (Fig. 1)	^{22}Ne	T_{21}
non-Ark	-0.85±0.08	-0.89±0.05	-0.88±0.06	-0.91±0.05	-0.83±0.08
Ark	-0.96±0.03	-0.98±0.02	-0.95±0.04	-0.96±0.03	-0.80±0.14

* non-Ark – Gla 001, Goda 001, Tre 002, Sex 002, 003 and Gol 001; Ark – Ark 002, 007 and 030 [1].

Table 2 The average element concentration (wt %) in the extraterrestrial chromite grains recovered from mid-Ordovician limestone in the Thorsberg and Hallekis quarries [5] and from Loftarstone (Lockne crater) [6]. The errors are standard deviations (1σ) of the *average* values and of the *individual* measurements (in parentheses)

Location	TiO_2	MgO	MnO	Cr_2O_3
Thorsberg	3.21 ± 0.02 (0.19)	2.51 ± 0.09 (0.64)	0.77 ± 0.01 (0.17)	57.41 ± 0.09 (1.40)
Hallekis	3.17 ± 0.03 (0.19)	2.62 ± 0.08 (0.56)	0.82 ± 0.02 (0.14)	57.74 ± 0.13 (0.91)
Loftarstone	2.60 ± 0.05 (0.43)	1.84 ± 0.19 (1.51)	1.47 ± 0.07 (0.57)	57.75 ± 0.13 (1.11)

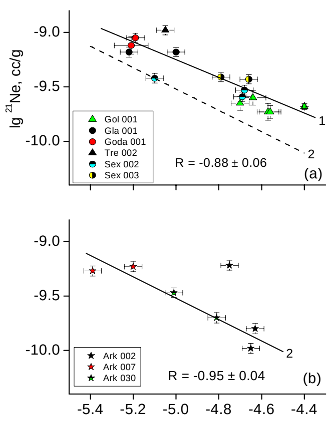

Fig. 1

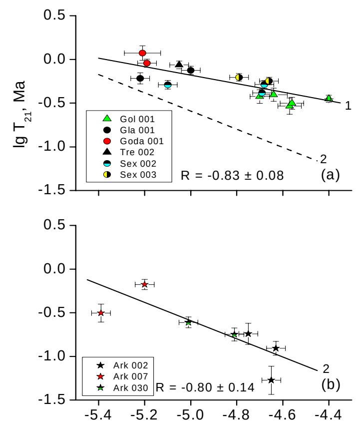

Fig. 2

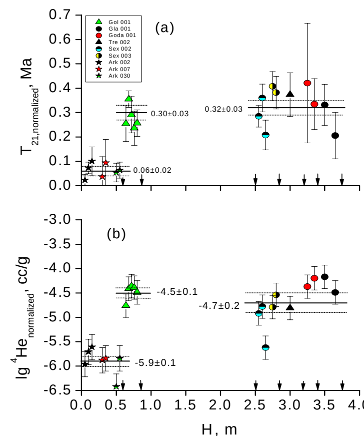

Fig. 3

Fig. 1 The negative correlation between the ^{21}Ne contents and mass of samples of non-Ark (a) and Ark (b) groups of fossil meteorites (according to data [1]).

Fig. 2 The negative correlation between cosmic-ray exposure ages and mass of the samples of non-Ark (a) and Ark (b) groups of fossil meteorites (according to data [1]).

Fig. 3 The normalized exposure ages of the fossil meteorites (a) and of the ^{4}He contents (b) in chromite grains depending on a location of meteorites in the 3.7 m column in the Thosberg quarry, southern Sweden. H is the depth relative to base of Arkeologen bed. Arrows designate boundaries of the beds. Horizontal lines are average values (±1σ).

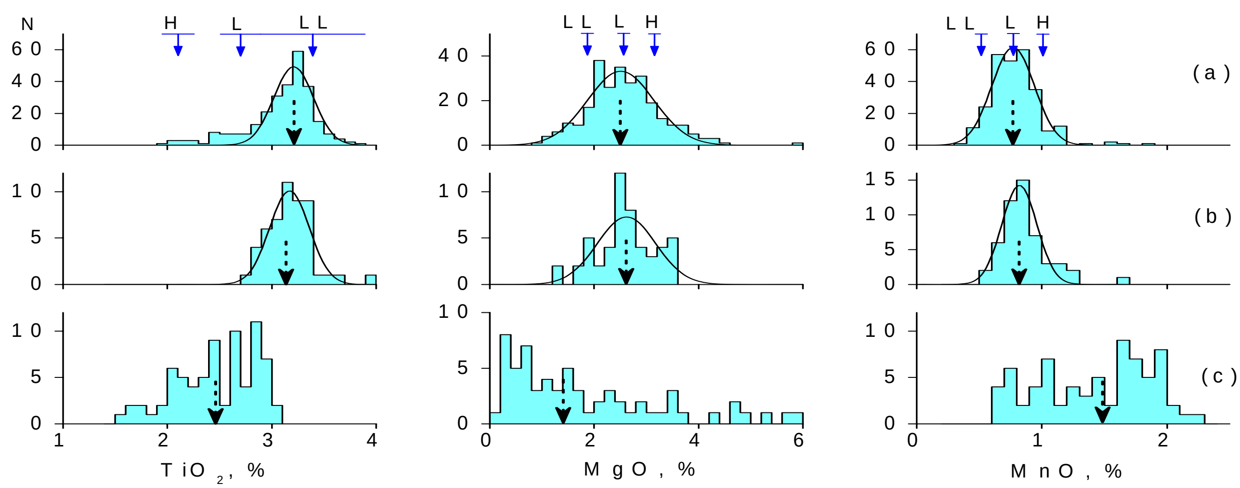

Fig. 4 Distributions of the TiO_2, MgO, and MnO contents in chromite grains from (a) Thorsberg and (b) Hallekis quarries, southern Sweden (according to data [5]) and from (c) Lockne shock crater, central Sweden (according to [6]). The arrows denote the average values for distributions and for H-, L-, and LL-chondrites.