The possible reason of the overestimation of cosmic-ray exposure ages of the Sweden fossil meteorites

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Overestimate of the cosmic-ray exposure ages of fossil meteorites of Sweden can be caused by foreign neon with high content of ^{21}Ne.

Key words: fossil meteorites, cosmic-ray exposure age

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The parent asteroid of L-chondrites has catastrophically broken up in the asteroid belt at about 500 Ma. The fact that this event caused the delivery of the asteroid's fragments to the Earth soon after its destruction was confirmed by the unusually large occurrence of fossil meteorites in marine limestone of mid-Ordovician in southern Sweden [*Schmitz et al*., *1997; Heck et al., 2004*].

Heck et al. [*2004, 2008*] measured the contents of noble gases in the chromite grains recovered from these meteorites and calculated their exposure ages (T_{21}). From the analysis of these data, *Alexeev* [*2010*] found that the values of the exposure ages calculated from ^{21}Ne by *Heck et al*. [*2004, 2008*] linearly depend on a mass of grain samples in *logarithmic coordinates.* At the same time, the values of T_{21} linearly depend on the ^{20}Ne contents (Fig. 1). Hereafter, the equation parameters of the regression lines were calculated by Williamson's method [*Williamson*, *1968; Alexeev, 2000*] taking into account the errors of both coordinates. It is essential to note, that this dependence is shown not only for set of samples of different meteorites, but also for samples of s meteorite (Brunflo).

Alexeev [*2010*] suggested that the increase in the concentration of ^{21}Ne and the corresponding values of T_{21} observed for the decreasing mass (*M*) of samples (sizes of grains) could be caused by the contribution of nucleogenic ^{21}Ne ignored in the calculations of T_{21}. However, the results of measurements of the content of noble gases in the individual chromite grains of terrestrial origin performed by *Meier et al*. [*2010*] put into question the validity of the explanation of the obtained dependence of T_{21} on *M* suggested by *Alexeev* [*2010*], but did not explain the nature of this dependence. Below, the possible explanation of the found dependence is discussed.

We have compared dependences of the content of ^{21}Ne vs. ^{20}Ne in the chromite grains of a terrestrial origin and in the grains separated from fossil meteorites (Fig. 2). The equation parameters of the regression lines are given in the Table. The parameter $b = 0.00283 \pm 0.00088$ for chromite grains of a terrestrial origin, within the limits of a statistical error, coincides with value of the $^{21}Ne/^{20}Ne_{atm}$ ratio for an atmosphere (0.00298). However, parameter $b = 0.0084 \pm 0.0005$ for meteorite grains is significantly above the $^{21}Ne/^{20}Ne_{atm}$ value.

The found anomalous dependence of the ^{21}Ne content on ^{20}Ne content can be explained by the presence of gases of terrestrial origin in the admixtures that were not completely removed from the cracks and cavities in the chromite grains of meteorites. The enriching of neon by isotope of ^{21}Ne in the gas of these admixtures (when the ratio $^{21}Ne/^{20}Ne_{adm} >> {}^{21}Ne/^{20}Ne_{atm}$) will cause the contribution of ^{21}Ne ignored in calculations of the cosmogenic $^{21}Ne_{cos}$ content. The value of this contribution and the corresponding values of T_{21} will increase with decreasing sizes and preservation degree of the recovered grains. Such enrichment can be real, since the data obtained by *Verkhovskii et al.* [*1976*] for terrestrial rocks showed that the excess of the ratio $^{21}Ne/^{20}Ne$ relative to that for the terrestrial atmosphere reached 900%.

We have calculated, what mass portion (α) of impurity neon with the given value of the $^{21}Ne/^{20}Ne_{adm}$ ratio should be in a neon separated from meteorite samples for receiving the found inclination of a regression line (b=0.0084). Results are given on Fig. 3. So, for example, at excess of $^{21}Ne/^{20}Ne_{adm}$ value in 9 times in comparison with value of this ratio for an atmosphere (i.e., K =

$^{21}Ne/^{20}Ne_{adm}$ / $^{21}Ne/^{20}Ne_{atm}$ = 9), the 23 % of impurity neon in a neon separated from meteorite samples will cause the found value of the coefficient b = 0.0084 (see Table). If the value of K = 5 and, accordingly, $^{21}Ne/^{20}Ne_{adm}$ = 0.0149 then for the found value of b coefficient, a mass portion of impurity neon should be already 45 % (α=0.45; Fig. 3), etc.

There is the essential moment here. We speak on (1) mass portion of impurity neon in a neon separated from the meteorite sample, but not concerning (2) mass portion of contaminant in substance of the meteorite sample. The (2) can be essential less then the (1) at high neon concentration in the contaminant.

Let's return to parameters of the equation of regression lines on Fig. 2 (see Table). For the chromite grains separated from meteorite samples, the value of the a parameter $(0.0081\pm0.0013)\times10^{-8}$ cm^3 g^{-1} at production rate of cosmogenic $^{21}Ne_{cosm}$ of $P_{21} = 7.04\times10^{-10}$ cm^3 g^{-1} Myr^{-1} [*Heck et al., 2004; 2008*] corresponds to cosmic-ray exposure age of T_{21} = 0.12 ± 0.02 Myr. This value is apparently the most probable value of exposure age of all found meteorites. The higher values of age calculated by *Heck et al.* [*2004; 2008*] are caused, most possibly, not considered contribution of impurity ^{21}Ne. The value of this contribution increases with reduction of preservation and the sizes of chromite grains. This fact leads to overestimate of exposure ages.

Similar calculation for chromite grains of a terrestrial origin according to the found value of parameter $a = (0.0066 \pm 0.0166)\times10^{-8}$ sm^3 g^{-1} gives value of "exposure age" T_{21} = 0.09 ± 0.24 Myr. This age does not differ from zero within the limits of an error of definition. Let's note, however, rather high error of definition of age in this case, more than on order of magnitude exceeding this for meteorite samples.

Results of the fulfilled analysis allow understanding the reason of overestimate of exposure ages of the fossil meteorites. These results are an additional argument in favour of a hypothesis, that all fossil meteorites found in the south of Sweden can be fragments of one big meteorite which fell out as large shower near the Thorsberg quarry about 470 million years ago approximately in 120 thousand years after catastrophic destruction of the L chondrite parent body.

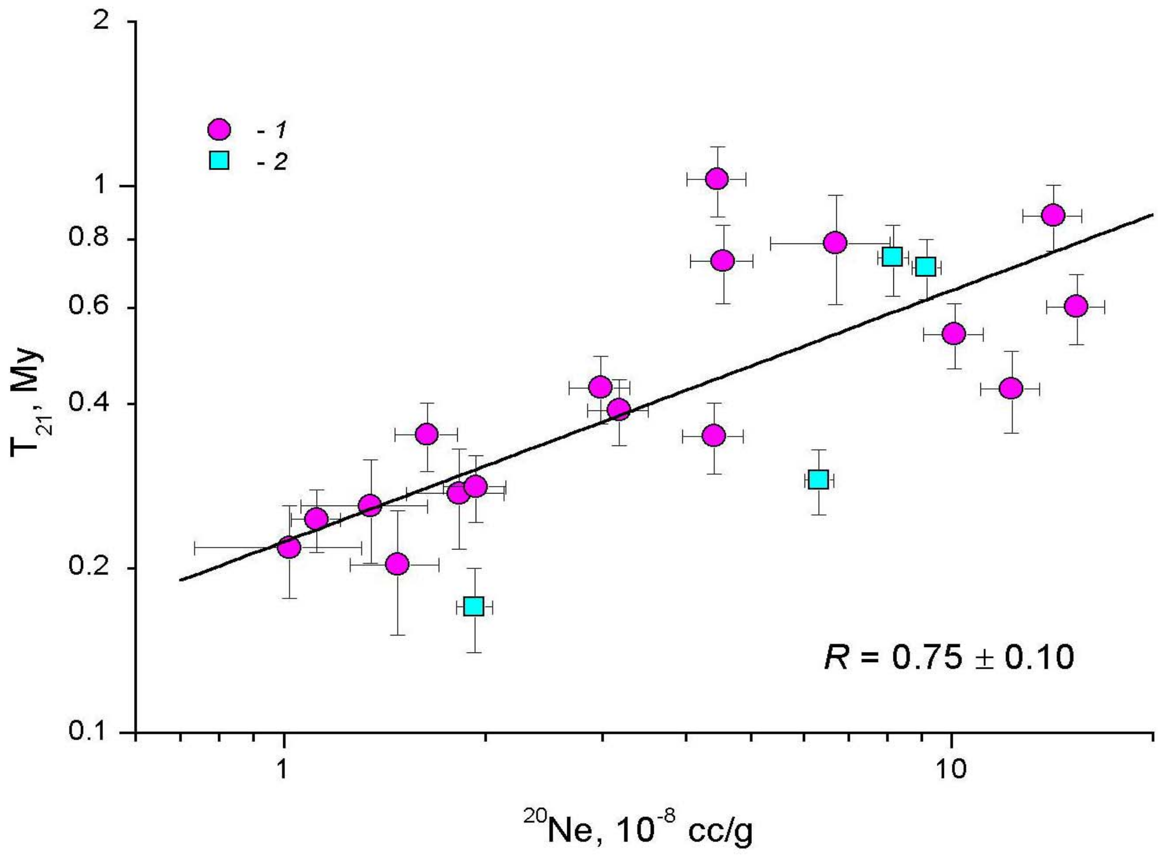

Fig. 1. Values of the exposure age (T_{21}) of fossil meteorites depending on the content of ^{20}Ne in the samples of chromite grains. 1 – meteorites of the non-Ark group [*Alexeev*, *2010*]; 2 – samples of the Brunflo meteorite. A straight line is regression line. (According to *Heck et al.* [*2004, 2008*]; *Heck* [*2005*].)

Table. The parameters of the equation of the regression line $^{21}Ne = a + b \times {}^{20}Ne$ for the terrestrial chromite grains (OC) and for grains of fossil meteorites

Samples	a, 10^{-8} cm^3 g^{-1}	b	R
OC (11)	0.0066 ± 0.0166	0.00283 ± 0.00088	0.70 ± 0.16
Meteorites (21)	0.0081 ± 0.0013	0.0084 ± 0.0005	0.78 ± 0.09

Notes: In parentheses, the number of samples is given. R is the correlation coefficient. (According to *Heck et al.* [*2004, 2008*]; *Heck* [2005]; *Meier et al.*[*2010*].)

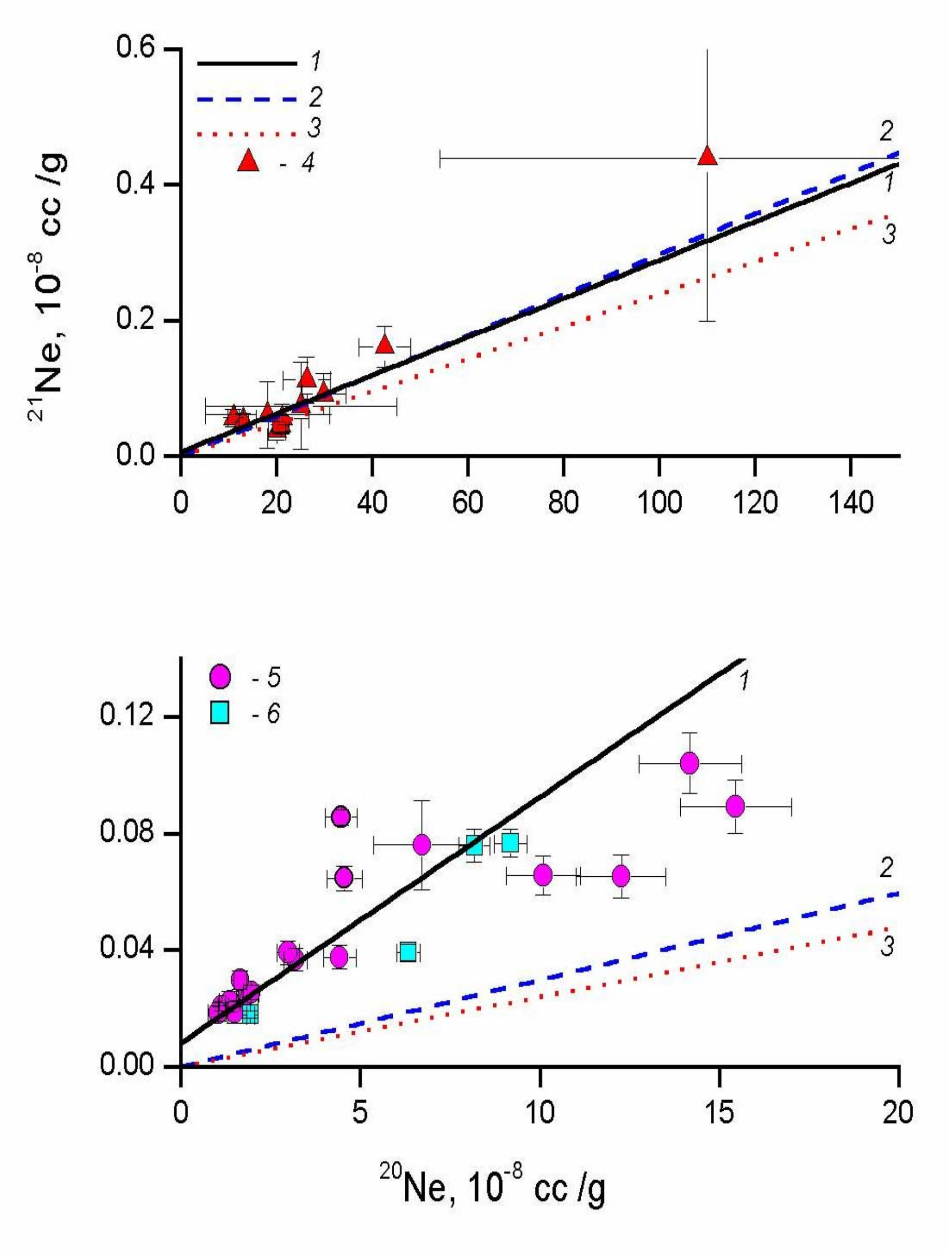

Fig. 2. The ^{21}Ne content vs. ^{20}Ne in the terrestrial chromite grains (*4*; above) and in grains recovered from fossil meteorites (below). *1* – Regression lines; *2* and *3* – interrelations of isotopes of neon of terrestrial atmosphere ($^{21}Ne/^{20}Ne = 0.00298$) and a solar wind ($^{21}Ne/^{20}Ne = 0.00239$), accordingly; *5* – meteorites of non-Ark group; *6* – samples of the Brunflo meteorite. (According to *Heck et al.* [*2004, 2008*]; *Heck* [*2005*]; *Meier et al.* [*2010*].)

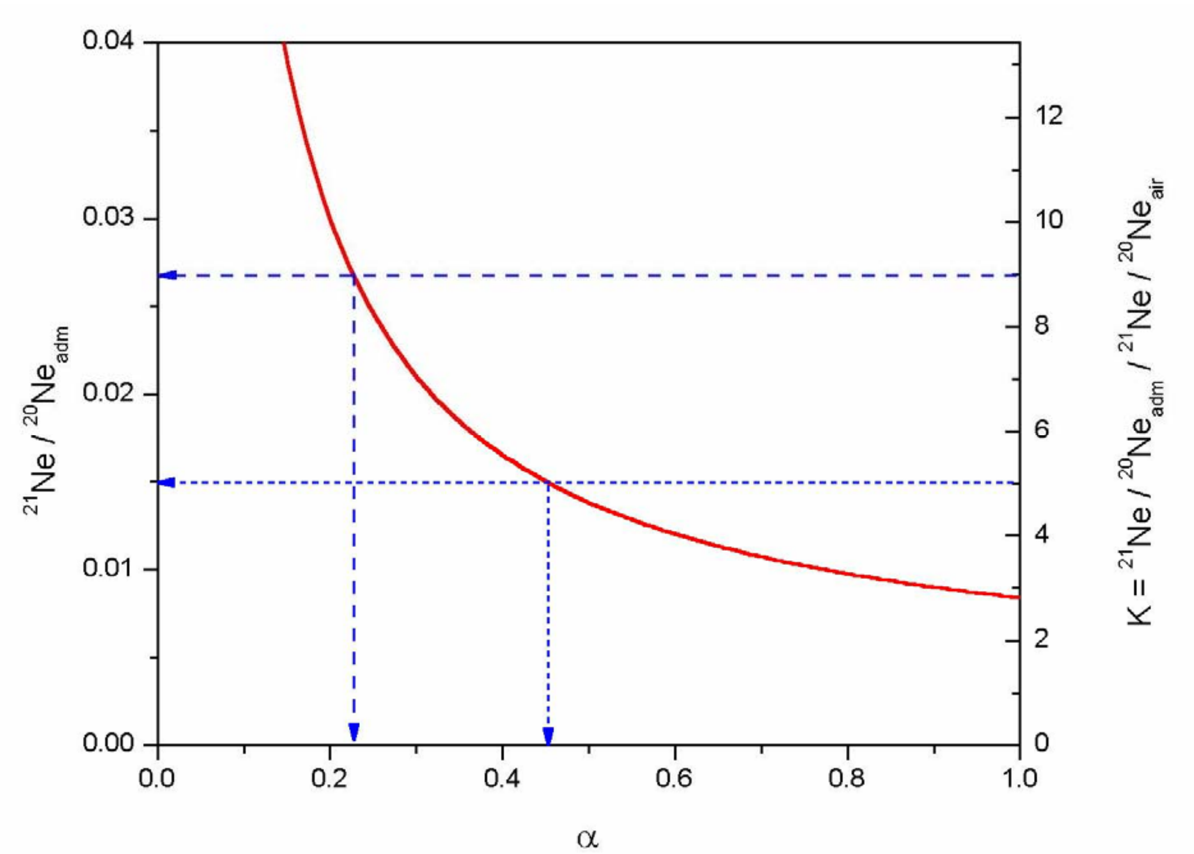

Fig. 3. The interrelation of the $^{21}Ne/^{20}Ne_{adm}$ value of impurity neon and the mass fraction (α) of this neon in a neon separated from the meteorite samples for receiving the found value of $^{21}Ne/^{20}Ne_{meas}$ =0.0084 (according to Fig. 2 and the Table). The curve equation is $^{21}Ne/^{20}Ne_{adm} = (^{21}Ne/^{20}Ne_{meas} - {}^{21}Ne/^{20}Ne_{atm} \times (1-\alpha))/\alpha$.

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