COSMIC RAY EXPOSURE AGE DETERMINATIONS OF COSMIC SPHERULES FROM MARINE SEDIMENTS

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Abstract. The cosmic ray exposure ages of deep sea metallic spherules were determined by various methods; low level countings (Ni-59), neutron activation analysis (Mn-53), high energy accelerator mass spectrometry (Be-10,Al-26) and mass spectrometry (K isotopes). The exposure ages of 0.3 - 50 Ma were obtained. According to Poynting-Robertson effect, the starting points (supplying sources) are located at inner region of the orbit of Saturn.

1. INTRODUCTION

This is a summary paper of the cosmic ray exposure age determinations of cosmic, metallic spherules from marine sediments. This work is based upon the data obtained preliminary by various methods [1] - [4].

Until now, the identification of the deep sea spherules as extraterrestrial has been studied on the basis of chemical and petrological data. An independent and more definitive characterization would be the presence of cosmic ray induced (cosmogenic) nuclides in the spherules. In addition to the identification, these cosmogenic nuclides carry also some potential information on the irradiation history of the cosmic spherules.

2. THE CALCULATION FORMULA OF THE COSMIC RAY EXPOSURE AGES

The cosmic ray exposure age (T) is calculated as follows;
(a) The amounts of the accumulated, cosmogenic stable nuclides (including extremely long-lived radionuclides; ex.K-40) (S) is devided by the production rate (R), so we have

$$T = S/R.$$

(b) The activity ratio (A) of the two long-lived radionuclides induced from the same target material (ex; iron) by

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cosmic rays is obtained in the following formula;

$$A = \frac{\lambda_1 N_1}{\lambda_2 N_2} = \frac{g_1[1 - \exp(-\lambda_1 T)]}{g_2[1 - \exp(-\lambda_2 T)]},$$

where g = the production rate of the nuclide at 1 A.U. from the sun, λ = the mean life of the nuclide. So the common age (T) can be calculated. Here, we have g = nσf, where n = the target atom numbers, σ = the production cross section and f = the cosmic ray intensity. In the case of the solar cosmic rays, the flux is dependent on the radial distance from the sun. However, we can cancell out the radial factors from the ratio of (g_1/g_2). Therefore, the cosmic ray exposure age (T) is free from the origin, motion, source position and trajectories of the dust (micro-meteorites) in the solar system. In the case of the high energy Galactic cosmic rays, the cosmic ray intensity is approximately constant except the closest region of the sun. Therefore, the ratio of (g_1/g_2) is also independent of the dust motion and orbits in the interplanetary space.

3.THE OBTAINED RESULTS

From [1] to [3], the data are obtained from the determinations of two cosmogenic radionuclides and the last one is obtained by isotopic anomalies determined with mass spectrometry.

TABLE I

reference	spherules size (μm)	nuclides	method	exposure age (Ma)	starting position
[1]	total sediments	Ni-59 Mn-53	LLD & (n,γ)	0.30	2.6 AU (s=24 um)
[2]	metallic 180 - 330	Be-10 Al-26	AMS	3.9	2.0 AU (s=260 um)
[3]	metallic 180 - 260	Ni-59 Mn-53	LLD & (n,γ)	0.01	~1.0 AU
[4]	metallic	K-39 K-40 K-41	MASS SPECTRO-METRY		
	360			21 + 15	3.4 AU
	340			3.4 +2.9	1.7 AU
	300			19 + 8	3.5 AU
	300			52 + 23	5.7 AU

[LLD] = low level radiation countings, [AMS] = accelerator mass spectrometry.

In the first experiment [1] we have measured Ni-59 and Mn-53 in the nickel and manganese fractions extracted chem-

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ically from large volume of deep sea sediments. Therefore, we have not seen any meteoritic materials in that sediments. We obtained a "mean" value of the cosmic ray exposure age as 0.3 Ma. In this experiment we have not discussed the size, chemical compositions,colour,density and other properties of the spherules, so to said, we have skipped the recognition of cosmic materials in the sediments.

In the second work, the nuclides were determined by the tandem Van de Graaf, University of Pennsylvania[2].

In the third experiment [3], the cosmic ray exposure age of the metallic spherules in several size groups have been studied in order to obtain the information of the dust motion in the interplanetary space due to Poynting-Robertson effect. However, manganese nuclides induced in iron parent bodies by nuclear reaction is liable to evaporate away from the parent bodies by atmospheric heatings [5]. Therefore, we could obtains apparently such a short age.

In the fourth work, the cosmic ray exposure ages were determined through the excess amounts of K-40 induced by spallogenic reaction with Galactic cosmic rays using a high sensitive mass spectrometer [4].

4. CONCLUSION

According to Poynting-Robertson effect, the cosmic ray exposure age (T) is written with the formula;

$$T = 700\cdot ad(r^2 - 1),$$

where a = the size of the dust, d = the density of the dust and r = the starting point of the dust (AU),from which the dust is removed and irradiated by the cosmic rays.
Of coarse, the size of the spherules is not the same of the pre-atmospheric, original size of the dust. Therefore, we take the spherule-size as the lower limit, so that the cosmic ray exposure time is obtained as the upper limit.

The data used in this work suggest, that almost all spherules have come from the inner region of the orbit of Saturn.

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