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Nucleocosmochronology of Dergaon meteorite

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Abstract By considering relative abundance ratio of ^{40}K / ^{40}Ar in Dergaon meteorite we have estimated age of the Dergaon meteorite as 2 12 Ga The result obtained by P N Shukla *et al* by cosmogenic element is 4 7 Ga and they are found to be same order of magnitude

Keywords Meteorite, Dergaon

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1. Introduction

The Dergaon meteorite was collected from a sugarcane field near Ahajati bil, around 20 km south-west of Dergaon of Golaghat District, Assam [$92^0$52E- $26^0$41'50"N]. The fall was initially sighted on 02.03.2001 at around16.40 local time. Preliminary minerologic and petrographic studies suggested that the meteorite belongs to the H5 Group chondrite with a unique K composition (Figure 1).

In this paper we present the probable age of the meteorite by means of radioisotopes present in the meteorite and brief outline of nucleocosmochronology [1-3] of Dergaon meteorite.

2. Calculation

In chronological models for nucleosynthesis [4], the number of N_A of nuclei of atomic mass A in the interstellar medium vary as a continuous function of time over the nucleosynthesis prior to the formation of the solar system from $t = 0$ to $t = \Delta$

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Thus

$$\frac{dN_A}{dt} = \lambda_A(t) \quad N_A \qquad 0 \le t \le \Delta \tag{1}$$

where

$\lambda_A(t) \rightarrow$ Production function

ζ_A Mean radioactive life time for the nucleus.

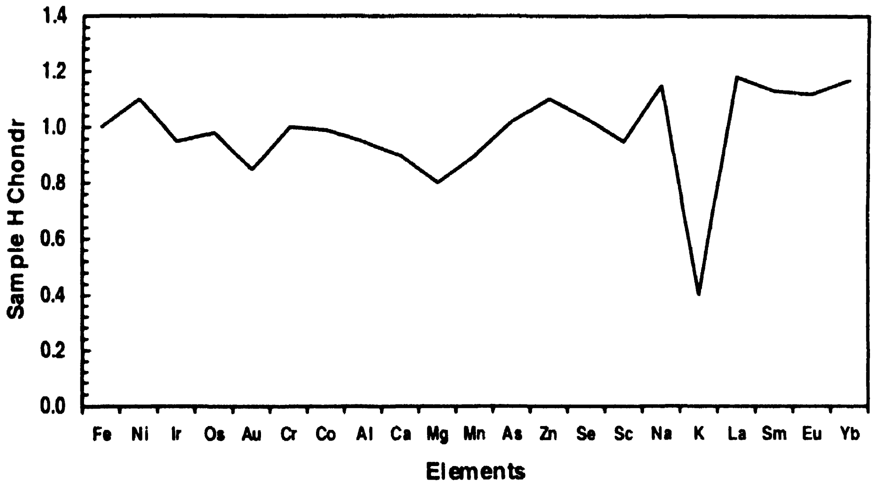

Figure 1. Chemical composition of Dergaon meteorite.

Here the production function is applicable to a given process of nucleosynthesis. The number N_A is the number which is produced in this process and which survives decay from $t = 0$, when process started in galaxy, to $t = \Delta$, when process contributed to the solar system material. The formation of the solar system marked the end of nucleosynthesis contribution to the solar system. Again, between the nucleosynthesis event contributing to the solar system and the meteorite formation time there is a time interval, which is represented by a standard Gambit. Now by the time of formation of the parent body of meteorite is meant the time when meteorite material becomes a closed system with no further changes in the nuclear abundances except for those due to radioactive decay and no separation of radioactive nuclei from their decay product. Therefore, if we represent the age of the solar system by A_s and age of the meteorite by A_M, we have

$$A_s = A_M + \delta\ . \tag{2}$$

The schematic diagram for this is represented in Figure 2.

So to predict the age of the solar system, the meteorite age has to be evaluated.

Now the value of standard gambit is δ =0 17 x 10^9 yrs*, Therefore, in finding out the age of the solar system, the age of the meteorite plays a vital role

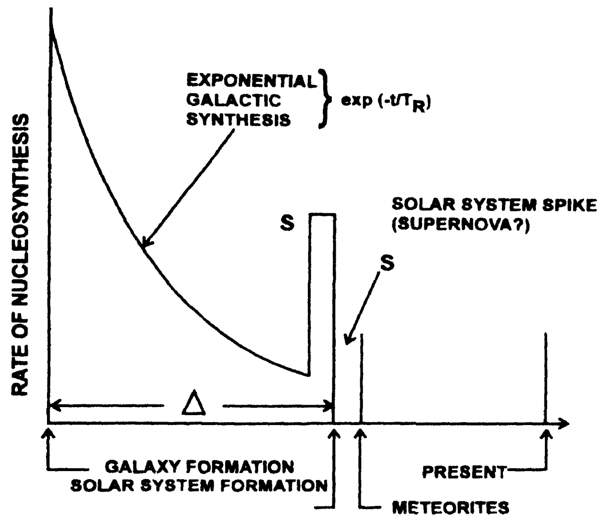

Figure 2 Chronological model of nucleosynthesis showing exponential synthesis [4]

To find the age of the meteorite we use radiometric or radioisotope dating method For a radiogenic isotope the equation which represents radioactive decay is

$$D_{now} = D_{original} + D_{now}\ (e^{\lambda t} - 1)$$

$D \rightarrow$ Daughter Nuclei

$P \rightarrow$ Parent Nuclei

$$\Rightarrow t = 1/\lambda\ \ln\ [(D_{now} - D_{original})/\ P \qquad + 1]$$

For above naturally occurring isotopes could be used In Dergaon meteorite radioisotopes present in it during time of fall are recorded in Table 1

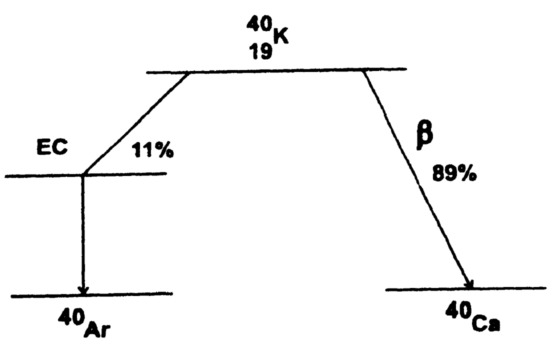

Figure 3. Principal decay mode of ^{40}K [1]

Table 1. Radioisotopes at the time of fall (March 2, 2001) of Dergaon meteorite [3]

		γ -energy	Koilaghat fragment 1 4 kg		Balidua fragment 1 8 kg		Balidua box 55 5 g	
Isotope	Half-life	(keV)	cpm	dpm/kg	cpm	dpm/kg	cpm	dmp/kg
^{48}V	16 d	983 5			0 37±0 03	14 4±1 2		
		1311 6			0 29±0 02	15 4±1 1		
^{51}Cr	27 7 d	320 07			0 18±0 03	46±7 7		
^{7}Be	53 3 d	477 56	0 15±0 02	56 1±7 5	0 17±0 01	47±2 8		
^{58}Co	70 78 d	810 75	0 11±0 01	5 3±0 5	0 15±0 01	5 3±0 4		
^{56}Co	78 8 d	846 75	0 11±0 01	5 5±0 5	0 14±0 01	5 1±0 4		
^{46}Sc	83 9 d	889 26	0 11±0 01	5 5±0 5	0 15±0 01	5 5±0 4		
^{57}Co	271 35 d	122 07	0 26±0 01	9 1±0 4	0 28±0 02	7 2±0 5		
^{54}Mn	312 2 d	834 8	1 59±0 01	76 5±0 9	1 92±0 02	68 2±0 9	0 24±0 01	84 7±3 5
^{22}Na	2 6 Y	1274 54	1 02±0 01	71 6±1 0	1 39±0 01	72 0±0 8	0 11±0 01	56 6±5 1
^{60}Co	5 27 Y	1173 23	0 02	<1 4				
		1332 51	0 003	<0 2	0 02±0 01	<1 0		
^{26}Al	7 3 × 10^5Y	1808 65	0 52±0 004	52 2±0 7	0 74±0 01	54 9±0 9	0 06±0 003	44 2±2 2
^{40}K	1 28 × 10^9Y	1460 75	0 96±0 01		1 30±0 01		0 15±0 006	
(K=340 ppm)[a]								

The occurrence of ^{40}K can be used for dating purpose

In the case of potassium the principal kind of decay is to ^{40}Ca and ^{40}Ar However, decay to ^{40}Ca is not useful because ^{40}Ca is the most common isotope and the amount produced radiogenically is not detectable Decay scheme for ^{40}K is shown in Figure 3

Since two separate decay types are possible, the decay equation is somewhat complicated.

Let λ be the total decay constant. λ_{Ar} be the decay constant for K Ar and λ_{Ca} be the decay constant for $K \rightarrow Ca$. Then total decay

$$\frac{d^{40}K}{dt} = \left(\lambda_{Ar} + \lambda_{Ca}\right) {}^{40}K = \lambda {}^{40}K$$

Now the decay equation for $K \rightarrow Ar$ leads to

$$Ar^{40}_{now} = Ar^{40}_{original} + \left(\lambda_{Ar}/\lambda\right) K^{40}_{now}\left(e^{\lambda t} - 1\right)$$

As original $Ar^{40}_{original}$ would not survive formation except under very unusual circumstances, we put

$$Ar^{40}_{original} = 0$$

$$t = 1/\lambda \ \ln\left[Ar^{40}_{now}/K^{40}_{now}\,(\lambda/\lambda_{Ar}) + 1\right]$$

where decay constants $\lambda, \lambda_{Ar}, \lambda_{Ca}$ are given in Table 2.

Table 2. Decay constants λ, λ_{Ar}, λ_{Ca} [2]

λ_{Ca}	λ	λ_{Ar}
4.962 X 10^{-10} yrs^{-1}	5 543 X 10^{-10} yrs ^{1}	0 581 X 10 ^{10} yrs ^{1}

The relative abundances of K^{40} and Ar^{40} are reported in Table 3

Table 3. Relative abundances of ^{40}K and ^{40}Ar

Target Isotope	% Abundance
^{36}Ar	0 337%
^{38}Ar	0 063%
^{40}Ar	99 6%
^{39}K	99 10%
^{40}K	0 0119%
^{41}K	6 88%

Therefore, from Tables 2 and 3 we can find out the age of the Dergaon meteorite

3. Result

Thus the result obtained for the age of the meteorite by using radiometric dating and the result obtained by P.N. Shukla *et al* [3] by cosmogenic element are

Calculated Value	2.12 Ga
P.N. Shukla	4.7 Ga

4. Conclusion

Age of the Dergaon meteorite gives only the first step for galactic evaluation Future measurement and more elaborate studies will be required for the study of *s*-process, *r*-process and *p*-process in the element formation of the Dergaon meteorite and thereby a better understanding of the nuclear cosmochronology of Dergaon meteorite.

Acknowledgment

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