Martian rocks that reached to Earth were ejected in 10 possible ejection events. R. R. Mahajan[1], [1]Physical Research Laboratory, Ahmedabad-380009, India, email : ramakant@prl.res.in

Introduction: Till date about 136 SNC meteorites have been recovered on the Earth [1]. These meteorites were launched from various locations of Martian surface. These rocks were ejected from Martian surface in different ejection events, it is therefore obligatory to estimate the number of events responsible for their ejection. Understanding the ejection events can help us to constrain the possible source regions of these meteorites from Mars. In this work, the cosmic ray exposure age based on noble gases are used for determine the possible ejection events. Here I propose that, 10 discrete ejection events are required to eject the rocks from Mars.

Ejection events :

The ejection ages of SNC meteorites were earlier discussed by Nyquist et al. 2001, Eugster et al. 1997 & 2002 and Garrison and Bogard (2000). Around 5-8 ejection events were suggest [3, 4] as responsible for launching the Martian meteorites. This was based on noble gas data of ~23 SNC meteorites. However, the cosmic ray exposure ages based on noble gases of about 53 meteorites are now known. It has been interpreted that a rock is ejected from a parent body as an object and delivered to Earth without further breakup in the interplanetary space (simple cosmic ray exposure history). The ejected material is continuously exposed to the cosmic rays during the interplanetary passage till it falls on the Earth. The duration of travel in the interplanetary space therefore can be calculated using cosmogenic nuclide. The production rate of cosmogenic noble gas nuclide is a function of the primary cosmic-ray intensity, the target elemental abundances and shielding. There are different factors, such as compositional heterogeneity of the meteorites, loss of helium etc, can cause uncertainty in the exposure age determination [5]. In the present work, grand average cosmic ray exposure ages were determined using all the available ages (based on ^{3}He, ^{21}Ne, ^{38}Ar or average) in literature, and grand average age is treated as the exposure age of the meteorite in space. There are only five falls (out of 53), while the rest are all finds among SNC meteorites. For falls, the ejection is (grand average) the cosmic ray exposure age. However, for finds, the terrestrial age, that is duration after the fall till recovery, of finds is added to the grand average exposure age to get the ejection age (T_e) for the meteorite. As there is error in the calculated ages given by different authors, that has been compensated by taking 5% error in the grand average age.

Methodology:

The distribution of ejection ages for Martian meteorite is plotted in Fig 1. It ranges from 0.59 Ma to 16.73 Ma. The Fig. 1 shows that there are discrete ejection events. The meteorites with nearest ages are clubbed; they are within the error bars of the mean indicative age.

The mean age is interpreted as one ejection event. The histogram of the exposure ages was drawn that is shown in Fig.2. It can be concluded on the basis of Figures 1 and 2 that 10 possible ejection events on Mars were responsible for the 53 meteorites that fell on Earth.

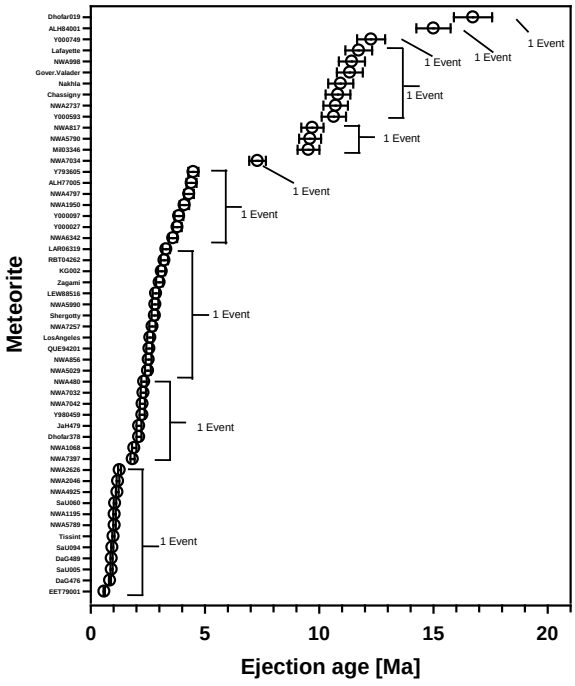

Fig.1 Ejection ages of Martian meteorites

These ten events respectively occurred at 0.92 Ma (12 meteorites); 2.12 Ma (8 meteorites); 2.77 Ma (12 meteorites); 4.05 Ma (7 meteorites); 7.3 Ma (1 meteorite); 9.6 Ma (3 meteorites); 11.07 Ma (7 meteorites); 12.27 Ma (1 meteorite); 15 Ma (1 meteorite); 16.73 Ma (1 meteorite). The meteorites with their corresponding age distribution is given in Table 1. It is proposed that the ejection age clusters represent common ejection processes or impact events irrespective of crystallization age, subtype etc. If there is any pairing in finds

(from cold or hot desert), they may decrease the number of meteorite candidate at one cluster, but not the number of events.

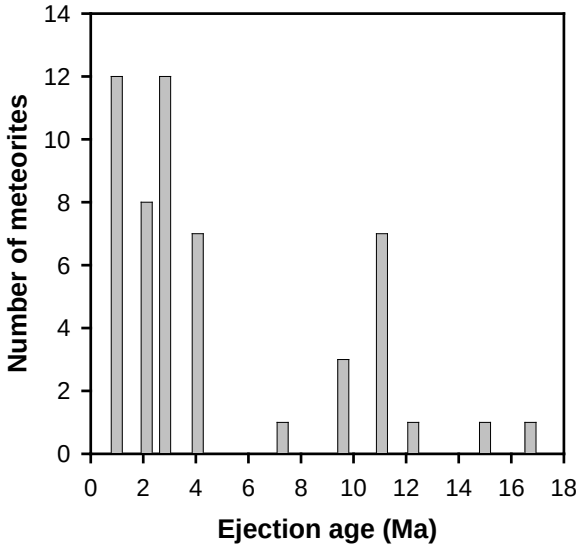

Fig. 2 Histogram of the ejection ages for the Martian meteorites.

Table 1 The ages of the possible ejection events of different Martian meteorites

Te (Ma)	Range ages (Ma)	Number	Meteorites
0.92	0.59-1.26	12	EET79001, DaG476, SaU005, DaG489, SaU094, Tissint, NWA5789, NWA1195, SaU060, NWA4925, NWA2046, NWA2626
2.13	1.83-2.33	8	NWA7397, NWA1068, Dhofar378, JaH479, Y980459, NWA7042, NWA7032, NWA480
2.83	2.5-3.3	12	NWA5029, NWA856, QUE94201, LoaAngeles, NWA7257, Shergotty, NWA5990, LEW88516, Zagami, KG002, RBT04262, LAR06319,
4.07	3.6-4.49	7	NWA6342, Y000027, Y000097, NWA1950, NWA4797, ALH77005, Y793605
7.3	7.3	1	NWA7034
9.61	9.53-9.7	3	Mil03346, NWA5790, NWA817
11.08	10.64-11.73	7	Y000593, NWA2737, Chassigny, Nakhla, Governador Valdares, NWA998, Lafayette
12.27	12.27	1	Y000749
15	15	1	ALH84001
16.73	16.73	1	Dhofar019

The ejection events that occurred at 0.92 Ma (12 meteorites), 2.12 Ma (8 meteorites), 2.77 Ma (12 meteorites), 4.05 Ma (7 meteorites) and 11.07 Ma (7 meteorites) were the major ejection events on Mars. Ejection event with less number of meteorites indicates that either the event was less energetic compared to other events or they could not survive in space due to different interplanetary processes such as those which show old cosmic ray exposure ages.

It is implied from the younger ejection ages that range from 0.59 Ma to 16.73 Ma, that Martian surface is continuously getting impacted in recent years.

Conclusion:

The rocks from Mars were ejected in 10 discrete events which landed on Earth as meteorites from Mars. The ages of the 10 possible ejection events are 0.92 Ma, 2.12 Ma, 2.77 Ma, 4.05 Ma, 7.3 Ma, 9.6 Ma, 11.07 Ma, 12.27 Ma, 15 Ma, 16.73 Ma.

References:

[1] Meteoritical society database (http://www.lpi.usra.edu/meteor/metbull.php, accessed 11 Dec 2014), [2] Nyquist L. E., et al. (2001) Space Sci. Rev. 96, 105-164, [3] Eugster O., et al. (1997) *Geochim. Cosmochim. Acta, 57,* 1115-1142, [4] Eugster O., et al. (2002) *Meteoritics & Planet. Sci., 37,* 1345-1360, [5] Garrison D. H. and Bogard D. D. (2000) *Meteoritics & Planet. Sci., 33,* 721-736.