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U-Th-Pb, Sm-Nd, Rb-Sr, and Lu-Hf Systematics of Returned Mars Samples.

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As Drake et al. [1] emphasized, the advantage of studying returned planetary samples instead of accepting in situ measurements cannot be overstated. A wider range of state-of-the-art analytical techniques with higher sensitivities and accuracies can be applied to returned samples. Measurements of U-Th-Pb, Sm-Nd, Rb-Sr, and Lu-Hf isotopic systematics for chronology and isotopic tracer studies of planetary specimens cannot be done in situ with desirable precision.

Returned Mars samples will be examined using all the physical, chemical, and geologic methods necessary to gain information on the origin and evolution of Mars. Drake et al. [1] evaluated oxygen isotopes, noble gases, and siderophile trace-element abundances for constraining theories regarding the origin of the solar system and the assembly of the planets. We argue that the radiometric systems listed above, especially U-Th-Pb, can also provide some vital data on the evolutionary history of the planetary body. Because the U-Th-Pb system includes three decay schemes, two of which involve U-Pb, it can provide insight into a rock's history prior to crystallization by using a concordia plotting method [2]. Our group has suggested that the Nakhla meteorite may have originated from a large planetary body, possibly from Mars, based on U-Th-Pb, Sm-Nd, and REE abundances (Nakamura et al., [3]). Some other studies of SCN meteorites (e.g., Bogard and Johnson, [4]; McSween, [5]) have also suggested the same idea. A Martian origin for the SNC meteorites is now generally conceded based on recent detailed studies of the Shergotty meteorite (Laul et al. [6] and references therein).

SNC meteorites have distinctly low $^{206}Pb/^{204}Pb$ values, between 12 and 15 (Nakamura et al., [3]; Chen and Wasserburg, [7]), whereas those for the Earth and the Moon are 18-20 and 150-500, respectively (Fig. 1). These values indicate that the SNC meteorites evolved in a unique environment with a low $^{238}U/^{204}Pb$ (μ) $\simeq$ 5 during the history of the solar system. This μ value is distinctly lower than that for the Earth (8±2), the Moon (20-~300), and eucrites (100-150), implying that the SNC parent planetary body was rich in volatile elements compared to the Earth. If SNC meteorites do come from Mars, then Mars must be enriched in volatile elements. The volatile-rich Mars interpretation, however, contradicts the contention of Anders and Owen [8] that Mars is intrinsically poorer in volatiles compared to the Earth [7]. Because lead is a chalcophile element, which could be removed to the Martian core as is often inferred from terrestrial basalts (the Earth's Pb "paradox"), either the smaller core of Mars may have been less effective in the removal of Martian Pb, as Chen and Wasserburg [7] have suggested, or core differentiation was delayed on Mars (2.7-3.6 b.y., [9] compared to ~4.3 b.y. for the Earth [10]; however, only Nakhla data suggest this). Detailed Pb isotopic analyses of Martian samples would provide a unique opportunity to investigate this problem, as well as to obtain chronological information.

Analytical techniques used in the study of U-Th-Pb, Sm-Nd, and Rb-Sr systematics have been improved tremendously during Apollo sample investigations. Expecting future improvements (such as an ion microprobe [11], analysis of three systematics using only a few hundredths of a gram or less of a returned Martian sample (the study of Lu-Hf systematics requires, at present, larger sample sizes compared to the other three systems) would provide ample information regarding the accretionary and evolutionary history of the Martian planetary body and possibly other planets of our solar system.

If the Mars samples are collected by deploying a rover vehicle for the lander's 401-day stay, a wide variety of rocks, soils, and other materials will be collected [1]. For chronological purposes, igneous rocks are of particular interest to us. We think that the volcanic Tharsis region has the greatest potential as a landing site. Not only would the numerous documented flows of the Tharsis Montes provide sampling of young and intermediate-age volcanics, but the adjacent Syria Planum may possibly provide a chance at much older rocks exposed in the prominent fractures of Noctis Labyrinthus [12].

References: [1] Drake, M. J., Boynton, W. V., and Blanchard, D. P. (1987) Eos 105. [2] Wetherill,G. W. (1956) Trans. Amer. Geophys. Union 37, 320. [3] Nakamura,N., Unruh, D. M., Tatsumoto, M., and Hutchison, R. (1982) Geochim. Cosmochim. Acta 46, 1555. [4] Bogard, D. D. and Johnson, P. (1983) Science 221, 651. [5] McSween, H. Y. (1985) Rev. Geophy. 23, 391. [6] Laul J. C. (1986) Geochim. Cosmochim. Acta 50, 875. [7] Chen J. H., and Wasserburg, G. J. (1986) Geochim. Cosmochim. Acta 50, 955. [8] Anders E. and Owen T. (1977) Science 198, 453. [9] Solomon, S. C. and Chaiken, J. (1976) Proc. Lunar Sci. Conf. 7th, 3229. [10] Allegre, C. J., Brevart, O., Dupre, B. H., and Minster, J.- F. (1980) Phil. Trans. Royal Soc. London, A297,447. [11] Compston, W., Willams, I. S. and Meyer, C., (1984) J. Geophys. Res., 89, Supplement, B525. [12] Solomon, S. C. and Head, J. W. (1982) J. Geophys. Res. 87, 9755.

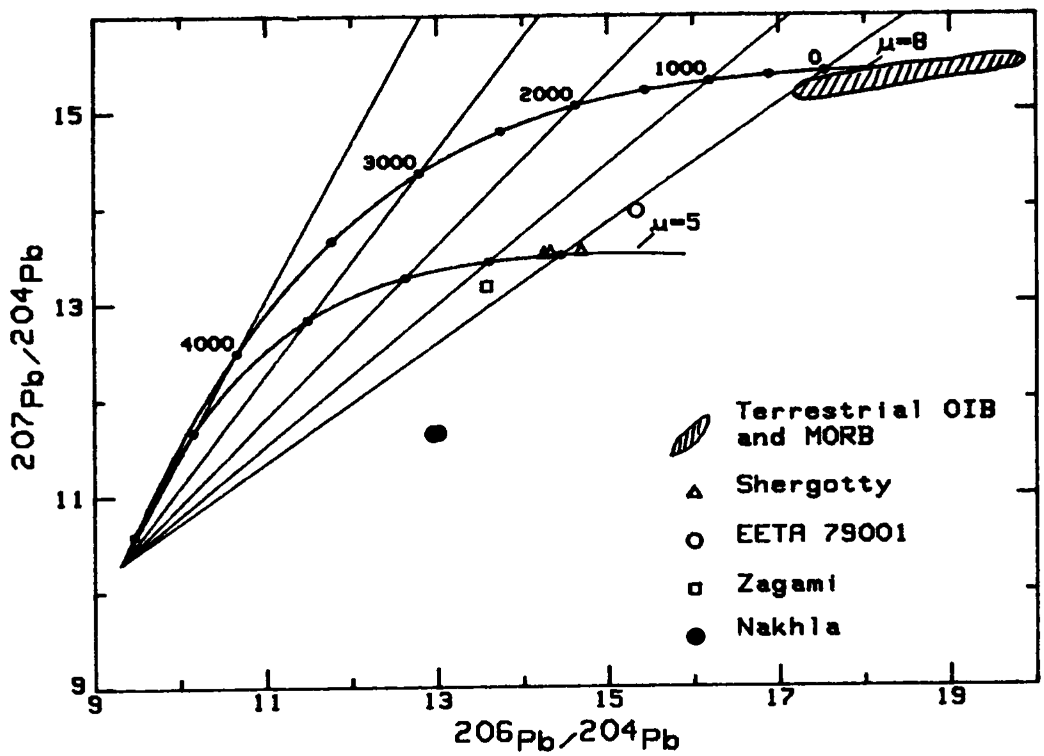

Fig. 1 $^{206}Pb/^{204}Pb$ vs. $^{207}Pb/^{204}Pb$ diagram for SNC meteorites and terrestrial oceanic basalts. The Pb growth curves having a primordial Pb (Cañon Diablo troilite Pb) at 4.56 Ga ago and present-day μ values of 5 and 8 are shown. SNC meteorite data plotted by open symbols are from [7], and Nakhla data plotted by solid circles are from [3].