TWO SOURCE AREAS FOR THE SNC METEORITES: PETROLOGIC, CHEMICAL AND CHRONOLOGIC EVIDENCE. Allan H. Treiman, Lunar and Planetary Institute, 3600 Bay Area Blvd. Houston TX 77058-1113. [713-486-2117; treiman@lpi.jsc.nasa.gov]

The **SNC** meteorites (Shergottites, Nakhlites, Chassigny) are samples of the Martian crust, and so are of surpassing planetologic importance. The **SNC**s have been inferred to come from a single impact crater on Mars. However, no known crater fits all known constraints. The sum of petrologic, chemical, and chronologic data suggests two distinct sites of origin: **S** from one, **NC** from another.

INTRODUCTION: The **SNC** meteorites are rocks of basaltic parentage, propelled from Mars by meteoritic impact. The **SNC**s have been important in providing "ground truth" to studies of mantle and magmatic processes, the hydrosphere, and atmosphere composition. But their utility is limited because their source(s) on Mars are not known. Most studies have suggested that the **SNC**s were ejected from Mars by a single meteorite impact in or near Tharsis [1-4, but see 5,6]. Nine potential source craters in Tharsis were located by [1], but none are consistent with constraints imposed by all of the **SNC**s. Multiple source craters on Mars have been considered but rejected [4,5], partly on cratering and orbital dynamic bases and partly because all **SNC**s were inferred to have the same crystallization age.

TWO SOURCE CRATERS: S ≠ NC. However, the sum of petrologic, chemical, and recent chronologic evidence suggests that the **SNC**s originated at two distinct sites on Mars. The most important data set is that the crystallization ages for **S** are significantly younger than for **NC** (Table 1). **S** and **NC** are different in most other respects. From Table 1, it appears that **S** and **NC** have been distinct through their whole histories, from source mantle through magma composition through low-temperature aqueous alteration through impact ejection.

TABLE 1. Selected Properties of **SNC** Meteorites, Chronological Order.

	S	**NC**
Effective Mantle Source $^{238}U/^{204}Pb$: 4,500 m.y. [7]	~5	~2
Magma Composition: Rb/Sr, Nd/Sm etc.	≤CI (Depleted) [8]	>>CI (Enriched) [9,10]
Crystallization Age	~180 m.y. [11,12]	~1,250 m.y. [8,9]
Pre-terrestrial Aqueous Alteration of Silicates (where present; all include salts)	Aluminosilicate [13]	Smectite-Iron Oxide [14,15]
Shock Pressure (maskelynite vs. plagioclase)	>> 29 GPa	< 29 Gpa
Cosmic Ray Exposure Age	2.8±0.3, 0.5 m.y. [5]	11±1 m.y. [5]

Constraints on the mantle sources [7,16] are least secure, but it appears that **S** and **NC** sources must have experienced some significantly different geochemical events since 4,500 m.y. The most parsimonious conclusions from these data are that **S** and **NC** had essentially nothing to do with each other, and formed at different sites on Mars.

SINGLE CRATER ORIGIN? The current paradigm for **SNC** origins involves ejection from Mars by a single impact [1-5]. Ejection at ~180 m.y. [1-3, favored by 4] is no longer tenable in that the 180 m.y. event recorded in S is igneous crystallization (Table 1). Ejection of the **SNCs** from a single crater at 11 m.y. (cosmic ray exposure age for **NC**) might be possible if the crater ejection zone overlapped distinct **S** and **NC** terranes, or hit a veneer of **S** over **NC**. But, ejection and subsequent orbit evolution must somehow ensure that 1) of materials exposed to cosmic rays for 11 m.y., only **NC** lithologies arrive at Earth, and 2) of materials exposed to cosmic rays for 2.5 m.y. or less, only **S** lithologies arrive at Earth. Neither scenario seems likely to me. EETA79001 has a younger cosmic ray exposure age, 0.5 m.y. [5], than the other **S**. This age could represent a collision in space [17], but could also represent a third impact event on Mars.

IMPLICATIONS: If the **SNC** meteorites left Mars in two separate impact events, at least some current understandings of Mars and its surface processes must be revised.

1). Some objections to the nine potential source craters of [1] are removed. A single impact need not have had access to all **SNC** lithologies, so meteorite source craters in monolithologic, simple units are permitted. Among the choices of [1], **S** might have come from craters 1, 3, 7, or 9 and **NC** might have come from craters 2 or 4-9.

2). One (or more) of the following must be incompletely understood: mechanics of ejection of meteorites from Mars; absolute ages of Martian surfaces inferred from crater-count statistics; or distribution of craters-forming events in time. The underlying problem here is that **two** meteorite-ejecting impacts are required in the last 11 m.y. This would suggest an embarrassingly high cratering rate on Mars unless: 1) craters smaller than 35 km can eject SNC parent meteoroids [1,4]; 2) Mars surfaces are much younger than in current estimates [18]; or 3) crater-forming events on Mars are not randomly distributed in time (idea from J. Jones).

3). The lack of meteorites from old Martian surfaces becomes a problem. In single-crater models (accepting current estimates of surface ages [18]) the lack of meteorites from surfaces older than 1,300 m.y., >95% of the Mars surface [1], can be ascribed to chance. But the probability of the only two meteorite-forming impacts on Mars avoiding these old surfaces is $\leq$ 0.0025. So, it becomes likely that older surfaces have experienced impacts that could have propelled meteorites to Earth. Perhaps the physical properties of older surface materials preclude ejection of meteorite-sized fragments, or perhaps materials from the older surfaces terranes do fall to Earth (e.g., altered basaltic rocks, sandstone, conglomerate, granite, rhyolite, or anorthosite [19]) and are not recognized as meteoritic.

ACKNOWLEDGMENTS. Discussions with J. Jones and M. Lindstrom have helped clarify my thoughts and (with luck) this presentation.

[1] Mouginis-Mark P.J. et al. (1992) J.G.R. 97, 10213-10336. [2] Wood C.A and Ashwal L.D. (1981) Proc. Lunar Planet. Sci. Conf. 12th, 1359-1375. [3] Nyquist L.E. (1983) Proc. Lunar Planet. Sci. Conf. 13th, A785-A798. [4] Vickery A.M. and Melosh H.J. (1987) Science 237, 738-743. [5] Bogard D.D. et al. (1984) G.C.A. 48, 1723-1740. [6] Ott U. and Begemann F. (1985) Nature 317, 509-512. [7] Chen J.H. and Wasserburg G.J. (1986) L.P.S. XVII, 113-114. [8] Smith M.R. et al. (1984) Proc. 14th Lunar Planet. Sci. Conf. B612-B630. [9] Nakamura N. et al. (1982) G.C.A. 46, 1555-1573. [10] Nakamura N. et al. (1982) Meteoritics 17, 257-258. [11] Jones J.H. (1986) G.C.A. 50, 969-977. [12] Jagoutz E. (1989) Geochim. Cosmochim. Acta 53, 2429-2442. [13] Gooding J.L. and Muenow D.W. (1986) G.C.A. 50, 1049-1059. [14] Treiman A.H. and Gooding J.L. (1991) Meteoritics 26, 402. [15] Treiman A.H. et al. (1993) Meteoritics 28, 86-97. [16] Jones J.H. (1989) Proc. 19th L.P.S.C., 565. [17] Treiman A.H. (1993) Meteoritics 28, 451. [18] Strom R. et al. (1992) in Mars, 383. [19] Lindstrom M. et al. (1994) This Volume.