GEOPHYSICAL RESEARCH LETTERS, VOL. 23, NO. 22, PAGES 3275-3276, NOVEMBER 1, 1996

NASA-CR-204690

Comment on "Mars as the parent body of the CI carbonaceous chondrites" by J.E. Brandenburg

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Geological and chemical data refute a martian origin for the CI carbonaceous chondrites.

I. Introduction

Brandenburg [1996] hypothesizes that the CI carbonaceous chondrites originated as water-deposited sediments on Mars, and seeks to show that CIs and recognized martian materials are so similar that a common origin is likely. However, that paper does not reconcile its hypothesis with available chemical and geological data on the CIs, on Mars, and on martian materials. Most available data are inconsistent with a martian origin for the CIs.

In the scientific method, knowledge progresses by the proposal and testing of new hypotheses. A hypothesis must be rejected if it and its predictions are inconsistent with the available data. Modified hypotheses can be proposed to explain inconsistent data, but such modifications can grow upon themselves, yielding Gordian tangles of exceptions and special cases. Occam's Razor cuts through such tangles - one should choose the simplest hypothesis that fits the data. The simplest hypothesis consistent with all available data is that the CI carbonaceous chondrites did not originate on Mars.

Here, I will first consider *Brandenburg's* [1996] proposal that the CIs formed as water-deposited sediments on Mars, and that these sediments had limited chemical interactions with their martian environment. Finally, I will address oxygen isotope ratios, the strongest link between the CIs and the martian meteorites.

II. 'Martian Geology' of CIs

Brandenburg [1996] proposes that the CI chondrites formed as water-deposited sediments early in Mars' history, with the sediment derived from asteroidal material accreting onto Mars. This hypothesis is inconsistent with the petrography of the CIs themselves, and inconsistent with the geology and geochemistry of early Mars.

Above all, the CI meteorites are not sedimentary rocks deposited from water. The CIs contain no petrographic features that would be expected in a water-laid sediment, e.g., layering in composition or grainsize, cross-bedding, or evidence of soft-sediment deformation [*Dodd*, 1981]. The CIs consist of chemically distinct domains rich in clay and serpentine with small proportions of magnetite and anhydrous silicate minerals such as olivine and pyroxene [*Dodd*, 1981]. This structure suggests that the CIs are breccias, and the ranges in O isotopic compositions of their constituents [*Rowe et al.*, 1994] suggest that the CIs are polymict. In this light, it seems probable that the CIs are impact breccias of chondritic asteroidal materials, extensively altered in place.

Further, it seems highly unlikely that a sediment formed on Mars during its early history could contain only extra-martian material. The CI meteorites formed at ~ 4.5 Ga [*MacDougall et al.*, 1984; *Endress et al.*, 1996], a time when Mars' surface was being struck repeatedly by large meteorites and asteroids. Impact crater scars from this time are abundant on the martian southern highlands, and impacts would have distributed ejecta widely across Mars. It seems unlikely that a water-filled basin on Mars, putative site of CI sedimentation, could have avoided collecting some of this impact ejecta. All known martian materials are derived from basaltic magmas, and the southern highlands crust (of which we have one meteoritic sample) also appears to be basaltic [*Singer and McSween*, 1993; *McSween*, 1994; *Treiman*, 1995]. These martian basaltic materials are quite distinct from CIs [*Dreibus and Wänke*, 1985] and ought to be readily recognized within CIs. Yet CIs contain no known physical or chemical traces of this martian material (anhydrous silicates in CIs are not martian, as their solar flare tracks suggest extended interplanetary exposure [*Dodd*, 1981]).

III. Chemical Closure

Brandenburg [1996] hypothesizes further that some element abundances and isotopic ratios in the 'CI sediments' are like those of Mars, while others retain primordial compositions: "CI material would be 'leftovers' of Mars accretion with solar composition and Martian isotopics." It is not clear from *Brandenburg* [1996] whether the CI material had 'Martian isotopics' (presumably meaning of C, H, N, and O) after or before it landed on Mars, but neither option is reasonable.

'Martian isotopics' after Mars

In the first option, with the CIs' "Martian isotopics" arising through chemical interactions on Mars, the CIs must somehow be prevented from exchanging elements other than C, H, O, and N with their martian environment. Alteration of hypothetical CI precursors on Mars could have had little effect on most elemental abundances - such 'isochemical' alteration is, in fact, the standard model for formation of CIs [*Dodd*, 1981]. However, noble gases are readily exchanged during aqueous alteration [e.g., *Drake et al.*, 1994], and one should expect that noble gas abundances and isotopic composition in 'martian CIs' would resemble those of Mars.

In fact, the noble gases in CIs are quite distinct from those in any known martian source, and cannot have exchanged

Paper number 96GL03075.
0094-8534/96/96GL-03075$05.00

significantly with any of them. Noble gases abundances and isotope ratios in CI chondrites have a characteristic pattern [*Pepin*, 1992], which is not found in any known martian material. The martian mantle (represented by the Chassigny meteorite) has Xe isotope ratios that are 'solar,' not like CIs [*Ott*, 1988]. The martian atmosphere (represented from the EETA79001 meteorite) has Xe isotope ratios that could possibly have been derived from CI-like Xe by extensive fractionation, but its Kr isotope ratios are 'solar' and not like CIs [*Pepin*, 1992]. The martian hydrosphere is poorly known, but the best available sample of its noble gases is even more enriched in Xe than the martian atmosphere [*Drake et al.*, 1994], and not like noble gases in the CIs.

Thus, if the 'CI sediments' acquired "Martian isotopics" on Mars, the chemical interactions involved must have been excruciatingly selective. The 'CI sediments' must have been separated from their martian environment by a semi-permeable membrane, a Maxwellian demon, that passed O, C, H, and N freely, but rebuffed all other elements including the noble gases. I believe this hypothesis fails Occam's Razor.

'Martian isotopics' before Mars

The other option, that the CIs already had 'Martian isotopics' before they landed on Mars and formed into sediments, requires that the CIs had no detectable chemical interactions with their martian environment. So, no elements in the CIs record any trace of a martian origin. In effect, this option requires that asteroids with exactly the composition of CIs were present in the early solar system; these asteroids, and not Mars, are then the parent bodies of the CIs.

IV. Oxygen is not Persuasive

Brandenburg's [1996] most persuasive link between the CI chondrites and the martian meteorites is oxygen isotopes; both meteorite groups have similar deficiencies in ^{16}O relative to the Earth and Moon, i.e., a similar $\Delta^{17}O \approx +0.3‰$ [*Clayton and Mayeda*, 1983; *Rowe et al.*, 1994]. This similarity admits the possibility that the CIs and martian meteorites come from the same planet. However, similarity in O isotopes is not proof that the CIs and martian meteorites came from the same planet.

Sample heterogeneity in the CIs weakens the argument that similar $\Delta^{17}O$ values for CI chondrites and martian meteorites suggest a common planet of origin. Current determinations of $\Delta^{17}O$ appear to be uncertain to $\sim \pm 0.05‰$ (vis. *Rowe et al.* [1994]), and $\Delta^{17}O$ of bulk martian meteorites ranges from +0.2 to +0.4‰ [*Clayton and Mayeda*, 1983]. Given that analytical uncertainty, the CI chondrites are heterogeneous in oxygen isotopes, with $\Delta^{17}O$ of the bulk meteorites ranging from +0.11 to +0.53‰, and $\Delta^{17}O$ of their clay-rich matrix materials ranging from -0.31 to +0.78‰ [*Rowe et al.*, 1994]. Given this level sample heterogeneity, it is not clear that the martian meteorites and the CIs truly have the same $\Delta^{17}O$.

If the martian meteorites and the CIs do, in fact, have the identical $\Delta^{17}O = \sim +0.3‰$, this identity would still not be proof that they came from the same planet. Other solar system materials also have $\Delta^{17}O = \sim +0.3‰$, including: some chondrules in ordinary chondrites, some chondrules in enstatite chondrites, and silicate inclusions in the Netschaëvo iron meteorite [*Clayton et al.*, 1983; *Clayton*, 1993]. The latter silicates contain chondrules and may be related to the ordinary chondrites. None of these materials appears to be closely related to either the CIs or the martian meteorites.

V. Conclusion

In sum, *Brandenburg's* [1996] hypothesis requires that the ancient precursors to the CIs land on Mars, collect in masses free from indigenous martian material, undergo extremely limited or selective chemical exchange with the martian environment, and be completely shielded from Mars' geological and geochemical history. This hypothesis is inconsistent with the overwhelming bulk of geochemical and geochemical data. No doubt, the hypothesis of a martian origin for the CIs could be elaborated with exceptions and special cases to account for each objection raised here. Yet the simplest hypothesis, consistent with all available data, is that the CI carbonaceous chondrites did not originate on Mars.

Acknowledgments: Reviews by Steven Clifford, John H. Jones, and an anonymous reviewer are appreciated. Lunar and Planetary Institute contribution #894.

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(Received May 24, 1996; Accepted July 18, 1996)