Technology, Pasadena, California 91109, USA
[7]Space Science Institute, Boulder, Colorado 80301, USA
[8]Center for Earth and Planetary Studies, Smithsonian Institution, Washington DC 20560, USA
[9]US Geological Survey, Flagstaff, Arizona 86001, USA
[10]Botanical Museum, Harvard University, Cambridge, Massachusetts 02138, USA
[11]Department of Geosciences, State University of New York, Stony Brook, New York 11794, USA
[12]Department of Earth and Planetary Sciences, University of Tennessee, Knoxville, Tennessee 37996, USA
[13]NASA Ames Research Center, Moffett Field, California 94035, USA

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McCollom & Hynek reply

Replying to: S. W. Squyres *et al. Nature* 443, doi:10.1038/nature05212 (2006)

Squyres *et al.*[1] contend that our proposed volcanic origin for Meridiani Planum[2] is inconsistent with more recently obtained data[3]. But although the new data reveal some variation in chemical composition, this variation is small (Fig. 1a) and mainly due to modest variations in magnesium and sulphur, with concentrations of the other elements remaining essentially constant[3]. In a volcanic model, this variation can be readily explained by mobilization of highly soluble magnesium sulphate salts during the later stages of alteration and diagenesis (Fig. 1a), as in the sedimentary/evaporite model in which sediments that were initially deposited with uniform composition are subsequently modified[3–5]. Although morphological features in the bedrock may be consistent with aeolian and fluvial origins[6], this interpretation is not unique, particularly as features with similar grain size, sorting and morphology are seen in base surge deposits[2,7–9]. Neither chemical nor morphological data therefore preclude a volcanic origin.

Squyres *et al.* claim[1] that their model is misrepresented in our Fig. 1 (ref. 2). However, the apices of the shaded triangle represent not the present composition of the mineral components, but the bulk composition of the potential primary chemical inputs in the sedimentary/evaporite model: a siliciclastic component, sulphate salts precipitated from evaporating groundwater, and iron that may have been mobilized to form haematite. In our Fig. 1 (ref. 2), the composition of the siliciclastic component was represented as basalt, consistent with their descriptions[3–5,10]. Although weathering of silicate minerals is discussed[4,5,10], the current mineralogical composition of silicates in the bedrock places no definitive constraints on the chemical composition of the original siliciclastic component; this is because it is inherently unclear whether the current minerals represent primary inputs or secondary alteration products. Consequently, the inferred presence of phyllosilicates and silica[4,5,10] cannot be used reliably to constrain the bulk chemical composition of the original siliciclastic input.

Squyres *et al.*[1] suggest that we should have placed one apex of the shaded triangle at the Si + Al end-member (their Fig. 1b), but this is valid only if one of the primary chemical inputs had a bulk composition consisting of just Si + Al. However, the Si:Al ratio is constant throughout Meridiani bedrock[3], and both the abundance of SiO_2 (48–53% by weight on a sulphur-free basis) and the Si:Al ratio (4.7–5.3) of the bedrocks are nearly identical to martian basalts[11] (48–51% by weight SiO_2; Si:Al, 3.5–7.2). There is thus no evidence for significant mobilization of Si or Al into the rocks, and Fig. 1b of Squyres *et al.*[1] does not accurately portray primary chemical inputs.

We agree that the current chemical composition of Meridiani bedrock can be accounted for by combining evaporitic and siliciclastic components[12]. However, this siliciclastic component would have to have been substantially depleted in divalent cations and enriched in Si+Al relative to basalt before it ever interacted with evaporating fluids, not just before it was incorporated into the current outcrop (Fig. 1b). This critical requirement is not discussed in descriptions of the sedimentary/evaporite scenario[3–5,10], nor has a plausible source for such a large amount of material with this composition been proposed. Furthermore, it would be necessary for evaporating groundwater to add divalent cations to the cation-depleted siliciclastic material in the right proportions to result in their basalt-like chemical compositions[12], which seems improbable. The sedimentary/evaporite scenario has significant shortcomings and alternative models[2,7] need to be considered.

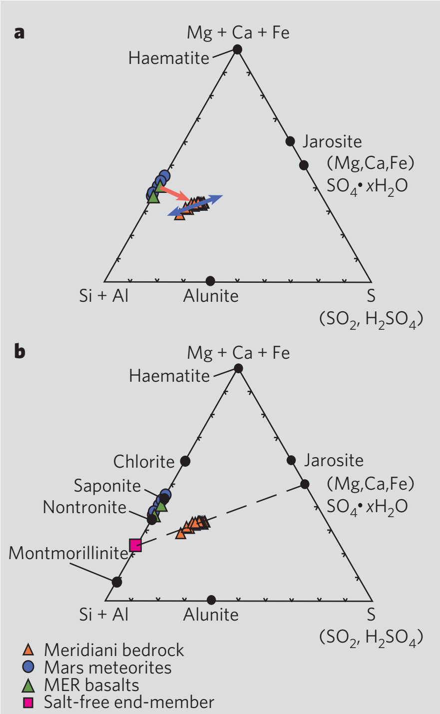

Figure 1 | Ternary diagrams showing relative molar abundances of major elements for Meridiani bedrock. Diagrams include data discussed by Squyres *et al.*[1] and typical martian basalts[2]. **a,** In a volcanic scenario[2], bedrock compositions are attributable to reaction of basaltic ash with sulphuric acid from volcanic vapours. Minor scattering among compositions can be accounted for by mobilization of magnesium sulphate salts in the later stages of alteration (arrows). **b,** In a sedimentary/evaporite scenario, extrapolation from bedrock compositions to remove sulphate salts would require the original siliciclastic component to be substantially depleted in divalent cations and enriched in Si + Al relative to martian basalt[12].

Thomas M. McCollom*†, Brian M. Hynek†
*Center for Astrobiology and †Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, Colorado 80309, USA
e-mail: mccollom@lasp.colorado.edu

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