Science Advances
AAAS

Supplementary Materials for

A heterogeneous mantle and crustal structure formed during the early differentiation of Mars

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Sci. Adv. **10**, eadn9830 (2024)
DOI: 10.1126/sciadv.adn9830

The PDF file includes:

Information on modeling in Figure 1
Figs. S1 to S3
Legends for tables S1 to S5
References

Other Supplementary Material for this manuscript includes the following:

Tables S1 to S5

Tables S4 and *S5* represent compilations of available literature data for HSE abundances and Os isotopes, and S isotopes, respectively.

Modelling in Figure 1

Shown are two crystallization models. For modelling, it was assumed fractionation was driven by crystallization of olivine. Two sets of bulk partition coefficients were applied to the models: solely olivine crystallization (pyroxene partition coefficients are similar to or lower than olivine) and mixtures of olivine, Cr-spinel and sulfide crystallization. Even at an extreme of 10% olivine fractionation, HSE compositions cannot be explained by crystallization of this phase alone. Better fits come from mineral assemblages where a maximum of 10% olivine (±clinopyroxene) is fractionally crystallized with proportions of 0.98 olivine, 0.019 Cr-spinel and 0.001 sulfide. The HSE support crystallization of an olivine (±clinopyroxene)-dominated assemblage, but with minor spinel and sulfide co-crystallization.

Model 1 assumes melting from a depleted martian mantle (lithosphere) source, followed by fractional crystallization, and shows the results for 0-10% olivine crystallization with co-crystallization of Cr-spinel and sulfide, in the proportions 0.98-0.94 olivine, 0.02-0.06 Cr-spinel, with <0.001 sulfide, using the partition coefficients compiled in Table 4 of *(26)*. Model 2 shows continued fractional crystallization after removal of a dunite cumulate component in the same mineral proportions. Model 1 reproduces chassignite compositions reasonably well. Model 2 does not reproduce the Pd in nakhlites as well, but model fits are strongly affected by the partition coefficients, which are empirical estimates from terrestrial, not martian magmas. Consequently, fO_2 and other intensive parameters for the magmas are likely to be important *(38)*. Martian mantle normalization is from *(32)*.

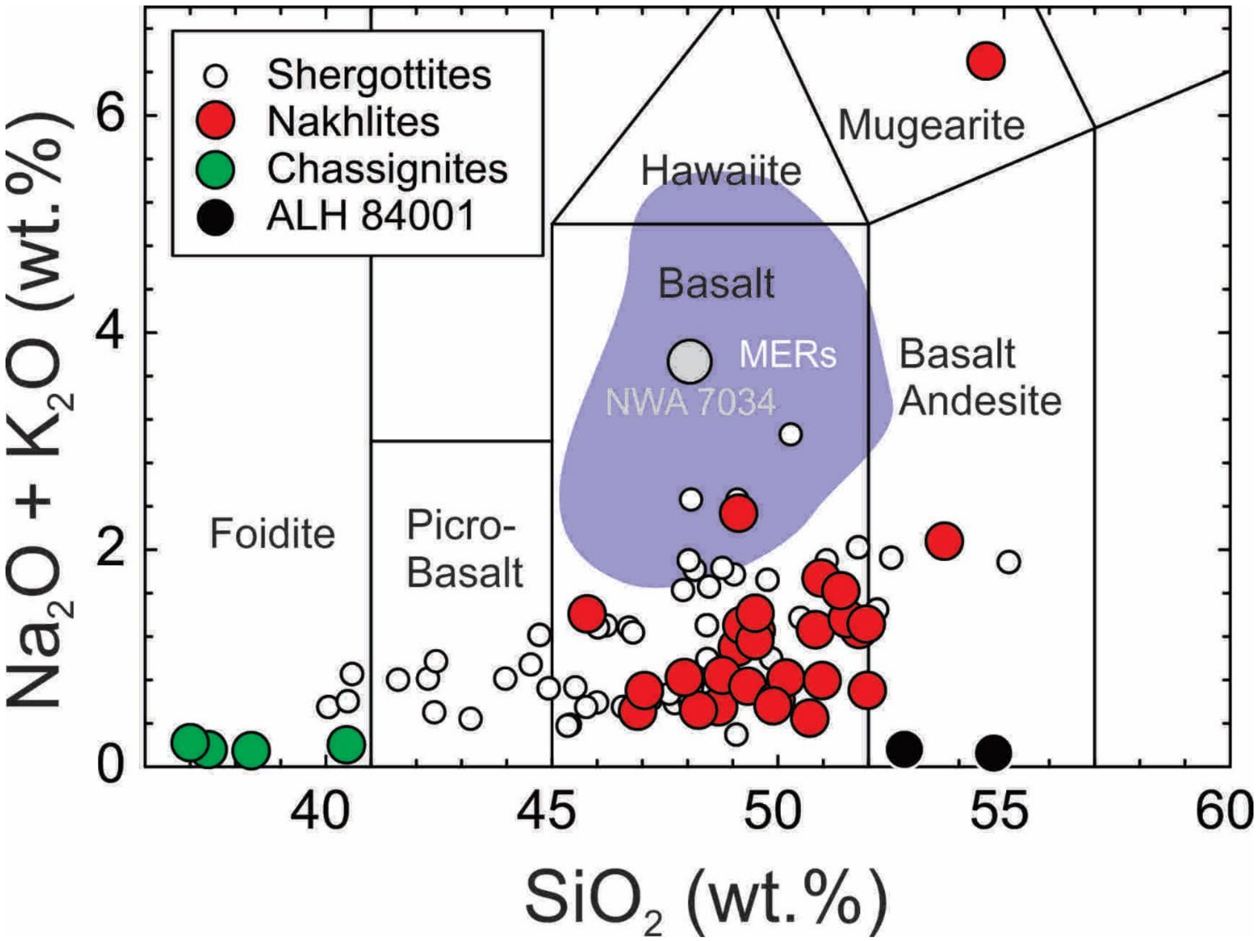

Fig. S1

Total alkali versus silica diagram for martian meteorites. Data for nakhlites, chassignites and ALH 84001 are presented in *Table S2*, or can be found in *(16)*. NWA 7034 data from *(19)* and Mars Exploration Rover (MER) field from *(4)*.

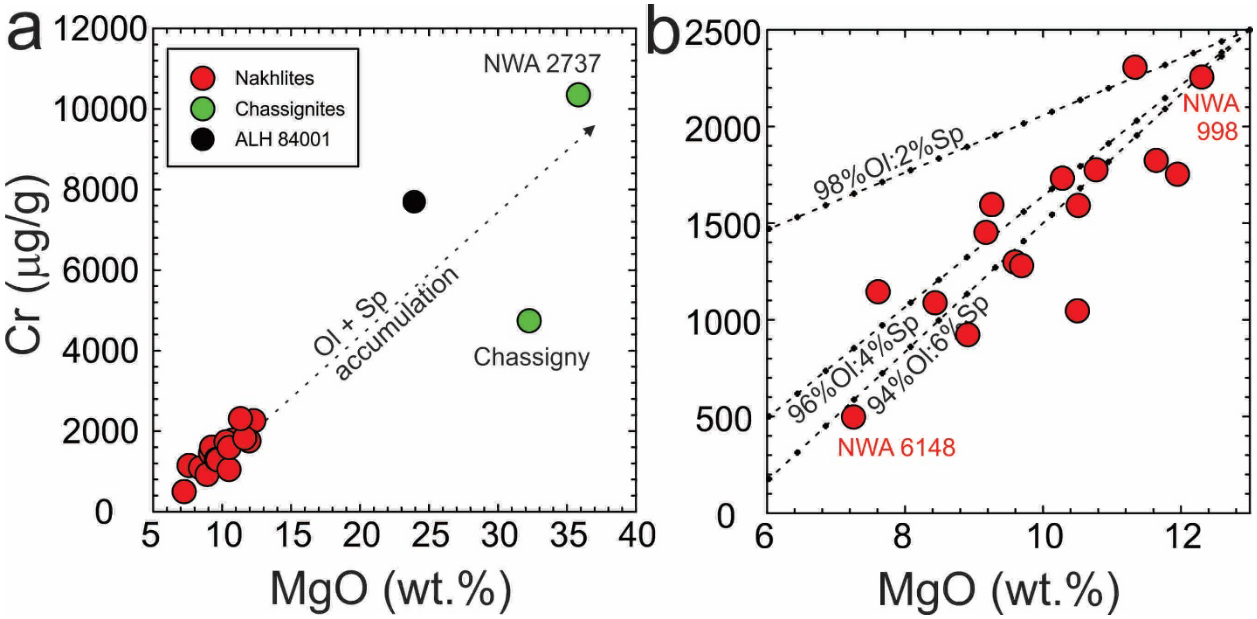

Fig. S2

Plots of MgO versus Cr for (a) chassignites, nakhlites and ALH 84001 and (b) only for nakhlites. Chassignites have MgO and Cr compositions consistent with accumulation of olivine and spinel. ALH 84001 is less MgO-rich, consistent with being an orthopyroxenite. Nakhlites are cumulative rocks containing augite and are broadly basaltic (*Fig. S1*), but their Mg-Cr systematics can be modelled by removal of olivine/clinopyroxene and spinel. Partition coefficients for modelling are from *(49)*.

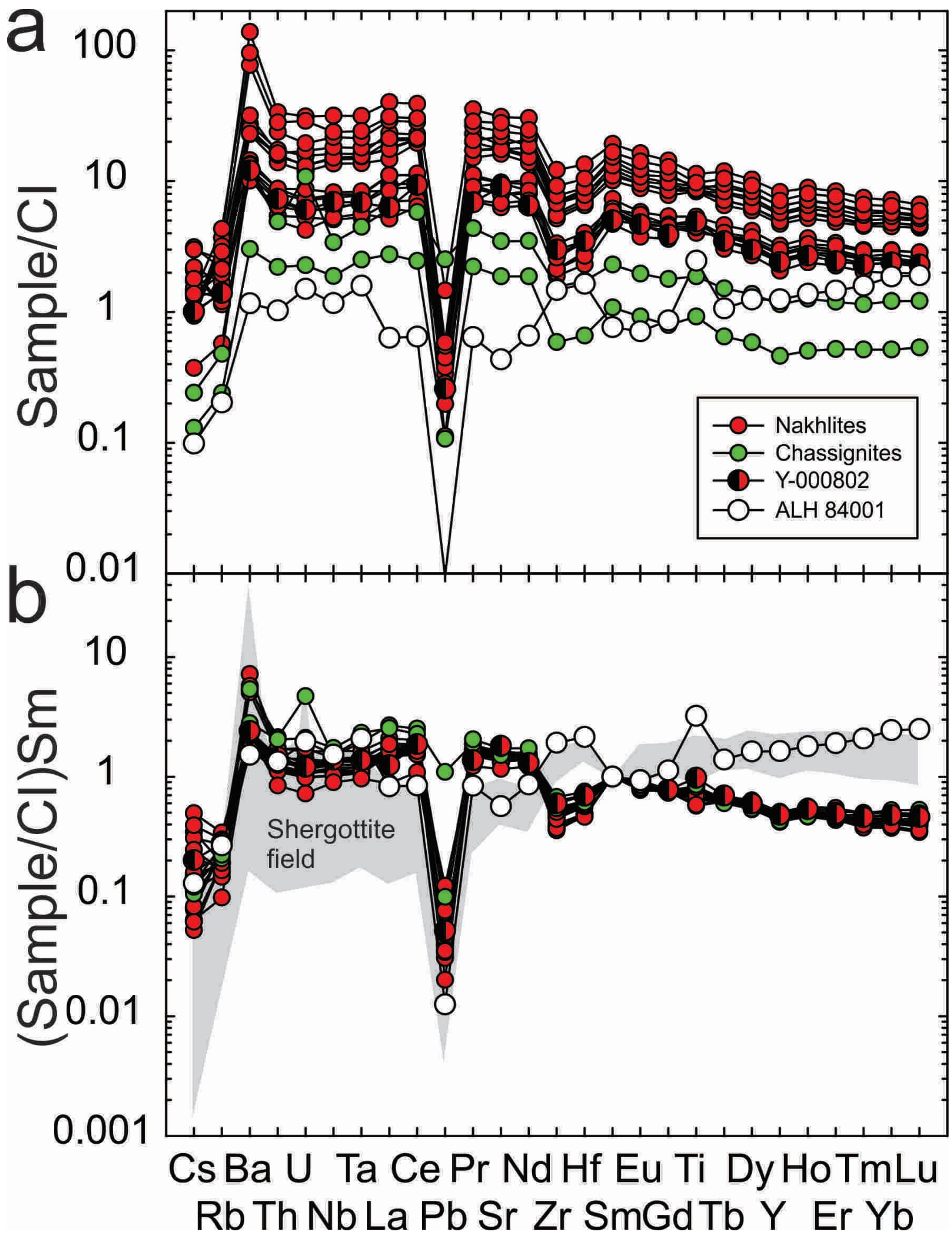

Fig. S3

Incompatible trace element (ITE) diagrams normalized to (a) CI chondrite and (b) double normalized to CI chondrite and then Sm. The similarity of ITE patterns for nakhlites and chassignites are clear in (b), whereas ALH 84001 is more similar in composition to shergottites. Data for nakhlites, chassignites and ALH 84001 are presented in *Table S2*, or can be found in *(16)*.

Table S1: Highly siderophile element abundances (in ng/g) and ^{187}Re-^{187}Os for nakhlites, chassignites and ALHA 84001.

Table S2: Bulk rock major- and trace-element abundance data for nakhlites, chassignites and ALH 84001.

Table S3: Blank contributions to samples analyzed in this study.

Table S4: Highly siderophile element abundances (in ng/g) and ^{187}Re-^{187}Os for nakhlites, chassignites and ALHA 84001, including published data, shown in *italics*.

Table S5: Osmium isotopes and S isotopes for nakhlites, chassignites and ALHA 84001.

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