An in-depth look into martian magmatism and shergottite formation through olivine-hosted melt inclusions in a poikilitic shergottite suite

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Overview

What are poikilitic shergottites?
Poikilitic shergottites are martian cumulate rocks that can be used to understand melt evolution on Mars from the crust-mantle boundary all the way up to shallow depths. Shergottites are also further characterized as enriched (NWA 10618, NWA 7755) and intermediate (NWA 11065, NWA 11043, ALHA 77005) based on light rare earth elements and isotopic compositions.

Driving research question: Is there a petrological link between the poikilitic shergottites and other shergottite subgroups?

Why should we care? Determining petrological relationships between the different shergottite subgroups will help constrain the heterogeneity of the martian mantle and crust.

What did we do? We conducted melt inclusion analyses on a suite of poikilitic shergottites including Northwest Africa (NWA) 11043, NWA 10618, NWA 11065, NWA 7755, and Allan Hills (ALHA) 77005 to calculate their parental trapped liquid (PTL) compositions.

What did we find out? Although compositionally not as primitive, the poikilitic shergottite PTL compositions are similar to that of the olivine-phyric PTL compositions, suggesting a potential relationship.

What is next: We will conduct isotopic analyses to determine the crystallization ages and source compositions of the suite.

Introduction

Why study poikilitic shergottites?

- 3 types of shergottites based on texture and lithology: poikilitic, olivine-phyric, and basaltic. Poikilitic is most abundant
- Poikilitic shergottites have a bimodal texture (2 different textural zones): poikilitic (early-stage) and non-poikilitic (late-stage)
- Both textures contain melt inclusions (MI) that can be analyzed to determine parental melt compositions at time of MI entrapment
- Comparison of poikilitic and non-poikilitic parental melt compositions gives insight into martian interior

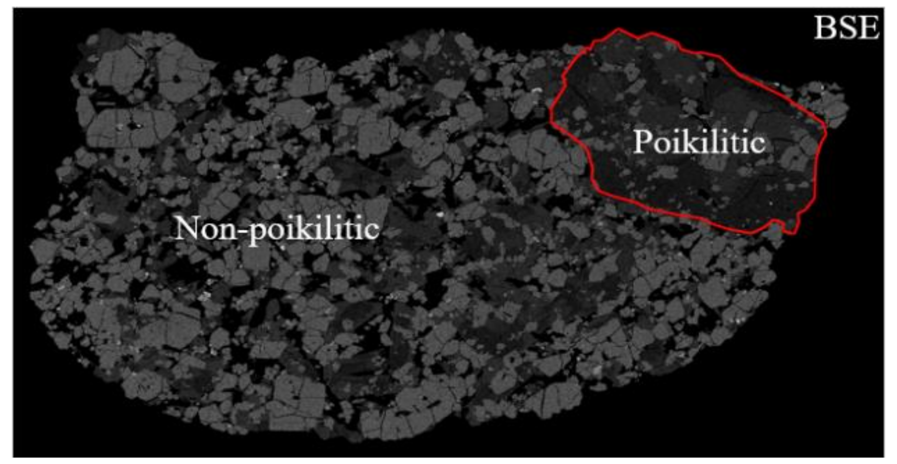


Figure 1: Backscattered electron (BSE) image of NWA 10618 depicting poikilitic vs. non-poikilitic textures. Poikilitic texture represents slow cooling at depth Non-poikilitic texture represents fast cooling through ascension of the magma

Methods

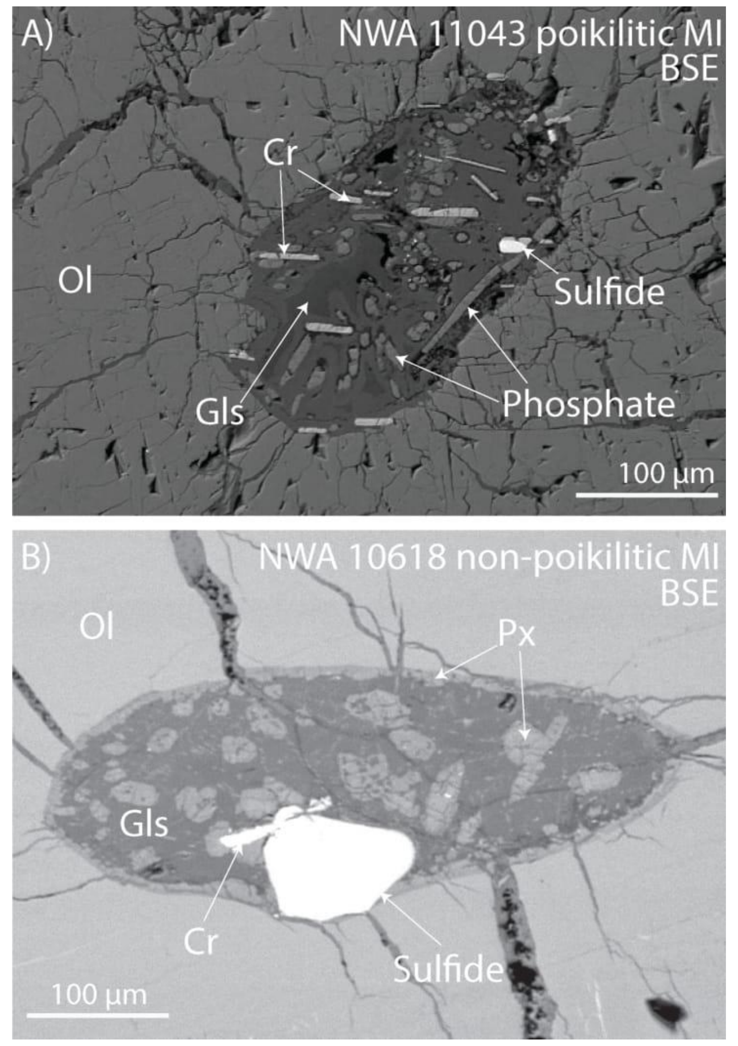
Electron microprobe analysis of inclusions:

- 15 kV accelerating voltage, 10 nA beam current
- Beam Size dependent on phase size [1]
- For small/microlitic phases, defocused beam size (10 um) was used to take a bulk analysis. Then each phase composition was determined through averaging of the results [2]
- Bulk compositions of MI were calculated from microprobe results and modal abundance values

Parental trapped liquid composition modeling:

- PETROLOG3 software used to correct Fe-Mg loss in the bulk compositions to generate an accurate PTL composition. Requires estimated FeOt value to run [2]
- Estimated FeOt value used to calculate PTL of MI in poikilitic textures from Combs et al., 2019 [4]
- After determining the PTL composition of the MI in the poikilitic texture for a meteorite, we then ran that composition through MELTS thermodynamic phase equilibria modeling software to determine the FeOt to use to calculate the non-poikilitic PTL composition for that meteorite [4]

Results: Melt Inclusions



Olivine-Hosted Melt Inclusions
•Inclusions present in poikilitic and non-poikilitic textures
•Melt inclusions are characterized as pockets of melt trapped inside a host crystal [5]
•Inclusions vary in size (10um–400um), shape, and mineral phase content
•Total inclusions analyzed: NWA 11043 (n=1), NWA 10618 (n=3), NWA 11065 (n=3), NWA 7755 (n=3), ALHA 77005 (n=4)

Fig 2. (A) Back-scatter electron image of a poikilitic inclusion in NWA 11043 (B) Back-scatter electron image of a poikilitic inclusion in NWA 10618 Ol: Olivine, Gls: Glass, Px: Pyroxene, Cr: Chromite

Results: Parental Trapped Liquid Compositions

What are parental trapped liquid (PTL) compositions?

- Composition representative of the parental magma at time of entrapment
- Calculated from the results of MELTS & PETROLOG3 software
- As expected, the poikilitic texture MI are more primitive than the non-poikilitic texture MI in the same meteorite

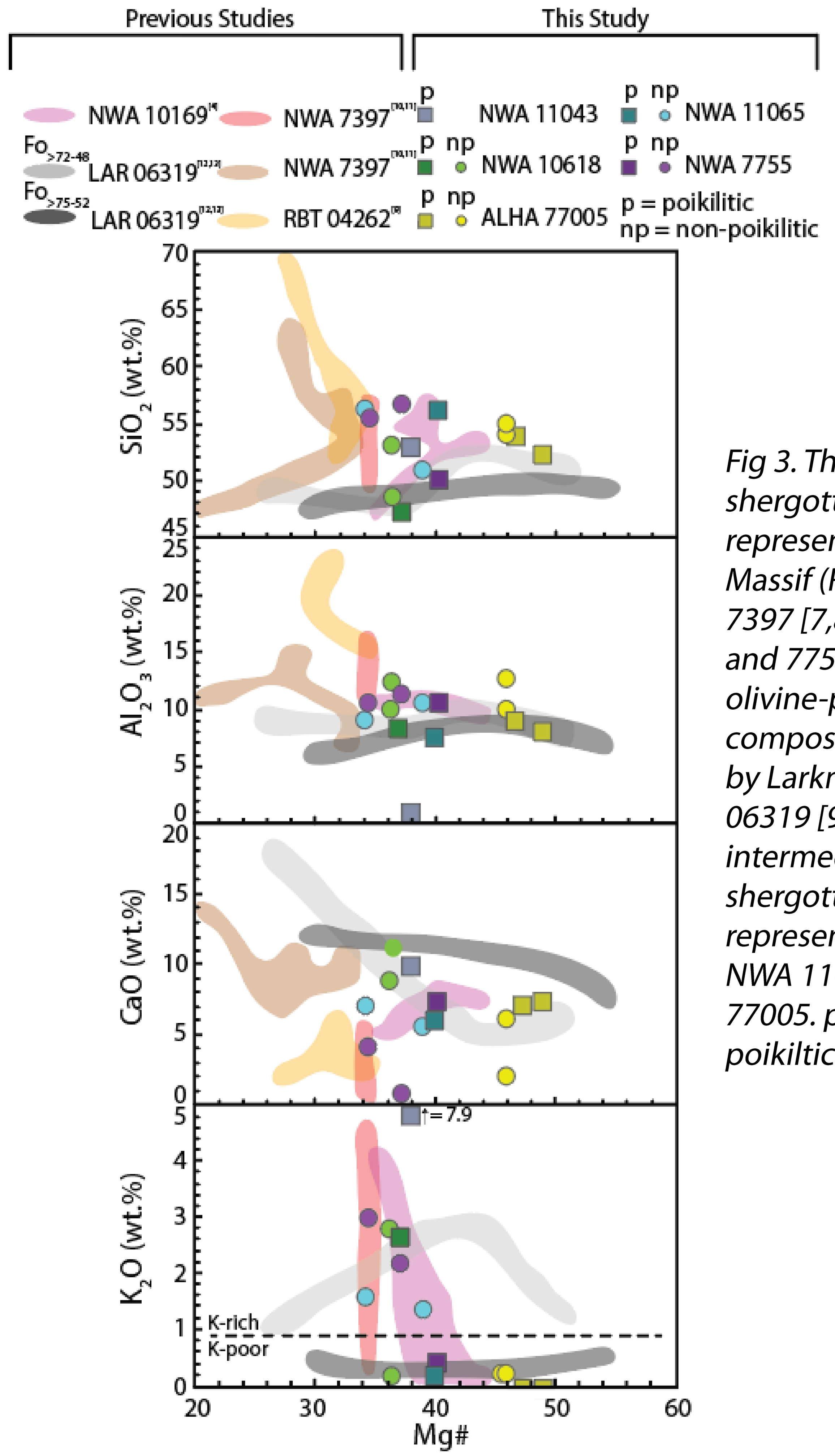


Fig 3. The enriched poikilitic shergottite compositions are represented by Roberts Massif (RBT) 04262 [6], NWA 7397 [7,8], 10169 [4], 10618 and 7755. The enriched olivine-phyric shergottite composition is represented by Larkman Nunatak (LAR) 06319 [9,10]. The intermediate poikilitic shergottite compositions are represented by NWA 11065, NWA 11043, and ALHA 77005. p: poikiltic np: non-poikiltic

Discussion & Conclusions

Poikilitic shergottites and olivine-phyric shergottites may share a petrological link such as a common magmatic system, and likely share similar petrogenesis and magmatic histories

- NWA 7755, NWA 11065, NWA 11065, NWA 11043, and NWA 10618 have similar PTL compositions to NWA 10619 [4] and LAR 06319 [9,10] based on K_2O, CaO, and Al_2O_3 and SiO_2 oxide wt.%
- Poikilitic shergottite PTL compositions are not as primitive, and cover a smaller range Mg# (37–48) than olivine-phyric shergottite PTL compositions Mg# (~28–54), but fall within the olivine-phyric shergottite PTL composition range

Poikilitic shergottites may go through a common magmatic process resulting in addition of K-rich metasomatized material during melt evolution

- Large range of variability of K_2O/Na_2O ratio (0.02–2) between samples
- K-enrichment is evident in Mi in the non-poikilitic texture in this study (NWA 10618, NWA 11065, and NWA 7755) and previous studies (NWA 7397 [7,8] and NWA 10169 [4]) suggesting that K-enrichment is a common occurrence in the evolution of the non-poikilitic texture zone

Implications for martian petrology and the scientific community

- This study has implications that will improve our understanding of the martian interior, including magmatism and evolution, allowing us to not only better understand the formation and evolution of Mars but also other rocky planetary bodies
- The data compiled from this work is a necessary precursor to the Mars sample return mission for future comparisons

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