GEOCHEMICAL TRENDS IN MARTIAN SPINELS AND COEXISTING OLIVINE: A COMPARATIVE STUDY WITH TERRESTRIAL SPINELS. E Allan¹, N. Hooper², Y. Liang². ¹The Florida Planets Lab, Department of Geological Sciences, University of Florida, Gainesville, FL 32611, ²Department of Earth and Planetary Sciences, Brown University, Providence, RI 02912. (allan.emilio@ufl.edu).

**Introduction:** Martian meteorites are currently the only samples available from Mars’ surface and interior. According to the Meteoritical Bulletin Database, there are 368 documented Martian meteorites to date. However, considering paired samples, the number of unique meteorites is reduced to 198 [1]. These meteorites are generally classified as Shergottite, Nakhliite, or Chassignite (SNC). However, our study specifically examines the Shergottite subgroup, drawing on data from the existing literature and our own analysis. Shergottites make up about 75% of all documented Martian meteorites and are a diverse group. They are classified based on texture and their enrichment or depletion in light rare earth elements (LREEs) [2]. Common major phases in SNC meteorites include olivine, augite, pigeonite, and maskelynite, with varying abundances. The minor oxides are composed of spinel group minerals such as chromite, ulvöspinel, ilmenite, titanomagnetite, and magnetite. These phases, often found as inclusions in major minerals such as olivine, can indicate the composition of the surrounding phenocryst. Spinel group minerals are therefore vital in identifying petrogenetic conditions in SNC meteorites, especially for estimating crystallization temperatures, and oxygen fugacity (fO₂). Currently, there is no complete compilation of spinel group mineral compositions in Martian meteorites. To fill this gap, we compiled 70 EPMA analyses of spinel from 61 Martian meteorites. We analyzed the trends in both major and minor element abundances and compared these to the trends in terrestrial spinels from Mid-Ocean Ridge Basalts (MORB), Ocean Island Basalts (OIB), and ophiolites.

**Results:** Several distinct trends emerged when comparing Martian and terrestrial spinels. Martian spinels display significantly lower Mg# (100Mg/Mg+Fe) than their terrestrial analogs (Fig. 1). The Martian spinels generally exhibit Mg# below 20 and show a continuous decrease in Mg# as crystallization progresses towards the ulvöspinel endmember. In contrast, terrestrial spinels have Mg# above ~20 and exhibit a strong negative correlation between these two indices. The terrestrial spinels progressively crystallize towards the chromite endmember as Mg# decrease. Notable exceptions among terrestrial samples include ophiolite chromitites and spinels from high Mg# and Cr# (100Cr/Cr+Al) MORB sample suites. The geochemical differences observed between Martian and terrestrial spinels may be attributed to

**Fig. 1:** Covariations of Cr# and Mg# of spinel in Martian meteorites and spinels from terrestrial settings (MORB, OIB, ophiolites). Data from the literature.

**Fig. 2:** Variations of ferric (YFe³⁺) and ferrous (Fe²⁺#) Fe in Martian and terrestrial spinels.

**Fig. 3:** Covariations of trivalent cation plot of Fe³⁺, Cr, and Al in Martian and terrestrial spinel.
differences in mantle source composition, parental melt composition, pressure of fractionation [3], and oxygen fugacity. Both Martian and terrestrial spinels follow the Fe-Ti trend of [3], where \( Y_{Fe^{3+}} (100Fe^{3+}/(Fe^{3+}+Cr+Al)) \) increases with increasing \( Fe^{2+}/ (100Fe^{2+}/Mg+Fe^{2+}) \) content, moving towards magnetite (Fig. 2). However, Martian spinels have higher \( Fe^{2+} \) contents, likely due to their lower Mg content. A portion of Shergottite ulvöspinel and ilmenite are characterized by low \( Fe^{2+} \) (# (~10) values. The Martian \( Fe^{2+} \) values show the closest resemblance to terrestrial spinels found in chromitites and flood basalts provinces [3]. Martian spinel compositions also significantly differ from that of terrestrial compositions when compared on the Cr-Al-Fe3+ ternary diagram (Fig. 3), trending towards the magnetite Fe3+ endmember beyond Al30. In contrast, spinels from MORB, ophiolites, and to a lesser extent, OIBs, extend along the Cr-Al join. The Martian trend is most analogous to terrestrial flood basalts and kimberlites [3].

The compiled data also included analysis of coequilibrium olivine and spinels in selected Shergottites (Fig. 4). Martian olivine (Fo = 50-85) [5] has a lower magnesium content compared to terrestrial olivine (Fo = 70-95) [6]. A slight decrease in Fo content is observed when comparing early-formed, poikilitic olivine chadacrysts with non-poikilitic olivine. Comparable patterns were observed in the Cr# of spinel inclusions within both poikilitic and non-poikilitic olivines, with an average decrease in Cr# between 5 to 10. An exception was found in spinels from the enriched shergottite Northwest Africa 1883 (not shown), where the spinel Cr# remained consistently at ~85 in both poikilitic (Fo = 70-75) and non-poikilitic (Fo = 55-60) olivine. The most significant variation was observed in the Ti# (100*2Ti/(2Ti+Cr+Al)) trend, which corresponds to the chromite-ulvöspinel-ilmenite series. Here, Ti# varied from approximately 10 in poikilitic chromite grains to between 40 and 80 in non-poikilitic spinels over the observed spinel Cr# and olivine Fo ranges.

**Martian Crystallization Temperatures:** From the findings of our study, we propose the application of using Martian chromites to enhance the calibration range of the Al-in-olivine thermometer [7,8]. As demonstrated, spinels relevant to Martian samples are distinguished by their higher \( Cr_{total} \) (Cr# ~80) and lower MgO (Mg# ~10) content compared to terrestrial analogs. However, the original calibration is restricted to samples with Cr# values ranging from 7 to 69 (see Fig. 5). This limitation could lead to imprecise estimates of crystallization temperatures when the original thermometer is applied to Martian samples. We suggest that additional experiments using Martian-specific compositions are needed to develop a robust set of Al-in-olivine thermometers for unraveling thermal history of Martian meteorites and future returned samples [9].

![Fig. 4: 3D plot of Cr#, 2Ti/(2Ti+Cr+Al), and Olivine Fo(100Mg/Fe+Mg) values for three intermediate shergottites: Allan Hills 77005 in circles, Northwest Africa 11043 in squares, and Northwest Africa 11065 in diamonds [4].](image)

![Fig. 5: Comparison of spinel compositions in this analysis and Coogan's [7].](image)