

Chemically altered basalt at high-latitudes on Mars: TES, OMEGA, and GRS integrated data sets

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TES, OMEGA, and GRS provide unique and complementary insights into martian compositions. TES and OMEGA measure the compositions of the upper hundred to tens of microns while GRS measures the upper few tens of centimeters. TES oxide abundances (wt. %) for the Surface Type 1 (ST1) and 2 (ST2) global spectral endmembers are calculated by combining compositions of mineral-phase endmembers in proportion to their relative modeled abundances (vol. %). TES chemical trends reveal higher abundances of FeO for ST1 (ST1 15.2 % vs. ST2 12.4 %) and higher abundances of SiO₂ for ST2 (ST2 57.9 % vs. ST1 53.9 %). Results from OMEGA are in agreement with TES oxides. OMEGA pyroxene maps are closely correlated with the equatorial-distribution of ST1 (High FeO) while high-latitude ST2 materials lack evidence of mafic absorption bands and are consistent with an enrichment of high-silica phases.

Recent GRS studies report chemical trends (wt. %) for 'regions' dominated by TES ST1 (RT1) and ST2 (RT2) materials. GRS RT2 chemistries have higher abundances of FeO (RT2 20.1 % vs. RT1 17.6 %), K, and Th compared to RT1. Abundances of SiO₂ (RT1 44.7 % and RT2 45.8 %) and K/Th ratio do not show significant spatial variations.

The constant K/Th ratio across RT1 and RT2 is not consistent with subaqueous or deep subaerial aqueous weathering of basalt as K would fractionate from Th. Fractional crystallization and subduction zone magmatism could enrich K and Th, however GRS does not detect an enrichment of Si as would be expected. The lack of any enrichment in SiO₂ between GRS RT1 and RT2 indicates that evolved volcanics (andesites) are not present in high-abundances at regional-global scales. The favored model from the GRS team is thus initial bulk differentiation processes on Mars producing compositionally distinct magma source regions in the mantle. RT1 and RT2 basaltic provinces with distinct trace element compositions could then be produced. Differences in SiO₂ between TES ST1 and ST2, however, must also be taken into consideration. Thin coatings or rinds of secondary high-silica phases (tens of microns) affect the shape and position of absorptions in emission spectra of basalt. Such coatings on Mars may form from near-surface ice and/or surface-atmosphere interactions with little to no water penetrating or cycling into the surface. Limited degrees of alteration in only the upper few tens of microns of the surface would affect TES derived chemistries and may be undetectable to GRS due to a deep sampling depth. TES, OMEGA, and GRS data sets support: 1) Distinct magma source regions and basaltic compositions for ST1-RT1 and ST2-RT2 and 2) Secondary coatings or rinds of amorphous high-silica phases at high-latitudes on ST2-RT2 basalt.

New experimental constraints on the Na-in-cordierite thermometer and its application to high-grade rocks

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The mineral cordierite is a common and important rock-forming mineral in medium- and high-grade aluminous rocks of the amphibolite- and granulite- facies. Large cations such as Na and K in cordierite can also be considered for thermobarometry. Experimental investigations with synthetic starting materials have shown that the Na content decreases not only with increasing T (Mirwald, 1986; Thompson *et al.*, 2002) but also strongly depends on $a\text{H}_2\text{O}$ (Thompson *et al.*, 2002).

To investigate the systematic variation of Na-in cordierite with T in metapelites we performed experiments using a natural quartzphyllite sample (Grt + Bt + Mus + Chl + Ab + Qtz). The experiments were done in a hydrothermal apparatus at 0.3 GPa and at six different temperatures ($T = 580^\circ\text{C}$, 630°C , 650°C , 680°C , 730°C , 780°C) with varying amounts of H₂O present (dry, H₂O-undersaturated, H₂O-saturated). In addition, experiments which contain significant amounts of H₂O were also buffered with respect to $f\text{O}_2$ (HM-buffer). The experimental investigations yielded the assemblage cordierite + biotite + muscovite + quartz at 580°C . Above 650°C and 680°C , K-feldspar + plagioclase + melt were also observed. T conditions, calculated by using the coexisting feldspars, yielded T of 640°C and 682°C in excellent agreement with the experimental conditions, indicating a high degree of equilibration within the experiments. In all experiments cordierite is present and the Na content in cordierite shows a systematic variation which strongly decreases with increasing T ranging from 0.154 Na apfu at 580°C to 0.059 Na apfu at 780°C . Preliminary results indicates the variation of Na-in-cordierite can be described with a linear function such as: $T(^{\circ}\text{C}) = (\text{Na [apfu]} - 0.43002)/(-0.000474)$.

Application of this thermometer to contact metamorphic rocks from the island Kos (Kalt, 1998) and to migmatites from the Bayerische Wald (Variscan Belt, Germany, Kalt *et al.*, 1999; Tropper *et al.*, 2006) yields contrasting results. Whereas the agreement above 700°C is very good, below this T , our calibration yields T which is too high, compared to conventional thermometry. One of the reasons of the discrepancy could be the presence of Na-bearing muscovite in our experiments, which might perturb Na partitioning into cordierite at these T .

References

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