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Phyllosilicates and nanophase aluminosilicates at Mawrth Vallis and their geochemical implications

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Abstract

Modelling of TES data has shown the presence of allophane in several sites on Mars with the highest abundances in the Mawrth Vallis region [1]. Analyses of CRISM data at Mawrth Vallis are also consistent with the nanophase aluminosilicates allophane and imogolite in the upper Al/Si-rich phyllosilicate-bearing unit [2,3]. We report here on recent lab analyses of several allophane and imogolite samples and new analyses of CRISM and TES data enabled with this larger spectral library. Clay-type components are modelled across the Mawrth Vallis region at ~50-75 vol% in bright units and ~35-55 vol % in dark units using TES data. Identification of nanophase aluminosilicates at Mawrth Vallis helps reconcile the NIR and TIR data of the region, and has important implications for understanding past pedogenic and igneous processes.

1. Introduction

Allophane and imogolite are amorphous hydrated aluminosilicates typical of volcanically-derived well-drained soils [e.g. 4]. The ideal formula for allophane is $1\text{-}2SiO_2 \bullet Al_2O_3 \bullet 2\text{-}3H_2O$ with a molar Si/Al ratio between 0.5-1, while imogolite has an Si/Al ratio closer to 0.5. Continued weathering of allophane-rich and imogolite-rich soils can produce halloysite or montmorillonite, also observed at Mawrth Vallis.

1.1 NIR spectra of Al/Si-OH species

OH stretching and bending vibrations produce distinctive bands near 1.4 and 2.2 µm for AlOH and SiOH bonds in aluminosilicates. Additional H_2O bands are observed near 1.9 and 3 µm for hydrated minerals. Spectra of allophane include a doublet at 1.38 and 1.40 µm due to the OH stretching overtone, a broad H_2O band near 1.92 µm, and an OH combination (stretch+bend) band near 2.19 µm (Fig. 1, [5]). Imogolite spectra have similar features at 1.92 and 2.19 µm, but the OH overtone occurs at 1.37 and 1.39 µm (Fig. 1, [5]). In contrast, spectra of Al-smectites and opal have an H_2O combination band at 1.91 µm and an OH combination band at 2.21 µm. The latter is extended towards longer wavelengths for opal spectra.

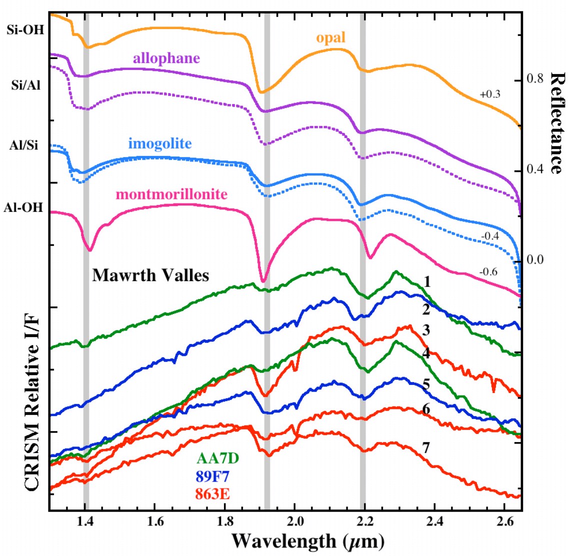

Figure 1: NIR lab spectra of aluminosilicates compared with CRISM data of Mawrth Vallis.

1.2 Mid-IR spectra of Al/Si-OH species

Allophane and imogolite spectra exhibit an H_2O bending doublet near 6.0-6.2 µm and several Si-O-Al vibrations in the mid-infrared (Fig. 2, [5]). Features occur in allophane spectra at ~1030 and 940 cm^{-1} (9.7 and 10.6 µm), 610 cm^{-1} (16.4 µm) and 545, 420 and 335 cm^{-1} (~18, 24, and 30 µm), and in imogolite spectra at ~1030 and 930 cm^{-1} (9.7 and 10.8 µm), 595 cm^{-1} (16.8 µm) and 495, 415, and 335 cm^{-1} (~20, 24, and 30 µm). These features are readily distinguishable from those of montmorillonite (near 1060, 520 and 470 cm^{-1}) and opal (near 1250, 1115, and 480 cm^{-1}).

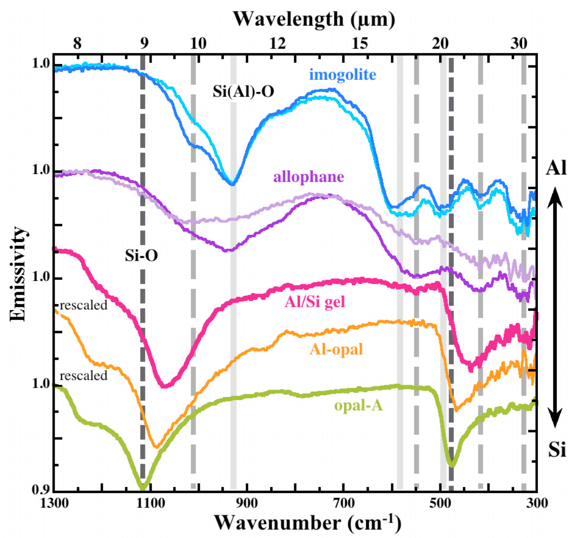

Figure 2: Emissivity spectra of amorphous aluminosilicates.

2. CRISM analyses of Al/Si-rich clay components at Mawrth Vallis

The Mawrth Vallis region consists of a lower Fe/Mg-rich clay unit and an upper Al/Si-rich clay unit [3]. CRISM data of the upper clay unit at Mawrth Valles exhibit variations in the spectral features near 1.4, 1.9 and 2.2 µm indicating the presence of multiple minerals/phases including hydrated silica, Al-smectite, kaolinite/halloysite, allophane/imogolite and related Al/Si phases (Fig. 1, [3]). Some regions exhibit spectra more consistent with allophane than other species indicating that allophane may be spectrally dominant in those regions.

3. TES analyses at Mawrth Vallis

Models of TES data in clay-rich regions at Mawrth Vallis identify ~10-25 vol.% allophane and imogolite and the incorporation of these species in the spectral library improves the fit. TES models also identify montmorillonite, silica, and zeolite in significant abundances (>20 vol.%) in these areas, further suggesting that there are a variety of secondary aluminosilicates in the upper units of Mawrth Vallis.

6. Summary and Conclusions

The presence of allophane and imogolite in the clay-rich units at Mawrth Vallis are consistent with young soils derived from volcanic material. Alteration progresses from imogolite to allophane to halloysite in mildly acidic, well-drained environments having a moderate water/rock ratio [6]. Wet/dry cycling favors formation of smectites. The presence of imogolite, allophane, opal, montmorillonite, halloysite, zeolite and other species in the upper Al/Si-rich clay unit at Mawrth Vallis indicates variable hydration and geochemical conditions during their formation in the Noachian. Modeling of these bright units indicates 50-75% hydrated aluminosilicates, depending on the spectra included in the model. Modeling of darker units includes lower phyllosilicate abundance and higher zeolite, imogolite and silica abundance indicating a different alteration environment.

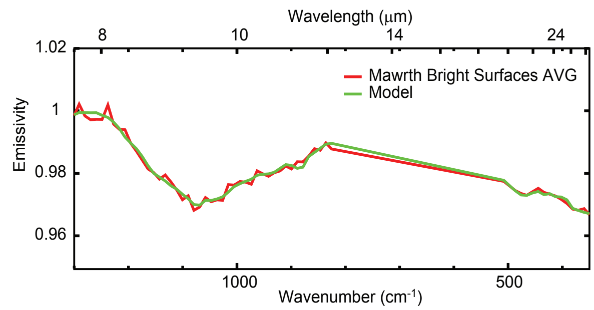

Figure 3: Mawrth Vallis average bright region TES and modeled spectra.

Acknowledgements

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