

SPECTROCHEMICAL CHARACTERISTICS OF CHROMIUM SPINELS FROM THE SITTAMPUNDI ANORTHOSITE COMPLEX, SOUTHERN INDIA: IMPLICATIONS FOR REMOTE IDENTIFICATION OF LUNAR SPINELS. P. M. Thesniya¹, V. J. Rajesh¹, R. Saranya², ¹Department of Earth and Space Sciences, Indian Institute of Space Science and Technology, Thiruvananthapuram-695547, India (thesniyathesni91@gmail.com; rajeshvj@iist.ac.in), ²Department of Geology, University of Kerala, Thiruvananthapuram-695 581, India.

Introduction: The spectroscopic techniques such as Laser Raman, Fourier Transform Infrared (FTIR), and hyperspectral have been employed widely to understand the mineral chemistry and crystal structure, and identify the functional phases and organic molecules in geological materials on Earth and other planetary bodies [1]. The present study used these spectroscopic techniques combined with Electron Probe Micro Analysis (EPMA) to understand the spectral-compositional relationships of the Cr-spinel (Mg, Fe^{2+})(Cr, Al, Fe^{3+}) $_2\text{O}_4$ present in chromitite bodies associated with Sittampundi Anorthosite Complex (SAC), southern India (Fig. 1). The changes in the spectral pattern and absorption or peak centers as a function of the varying chemistry and crystal structure have been discussed. The approach of the comparative spectral-chemical studies will enable us to interpret the chemistry of lunar spinels from their remotely observed reflectance spectra. The study also explores the possibilities of SAC Cr-spinels as a probable chemical analogue for lunar spinels of similar compositions.

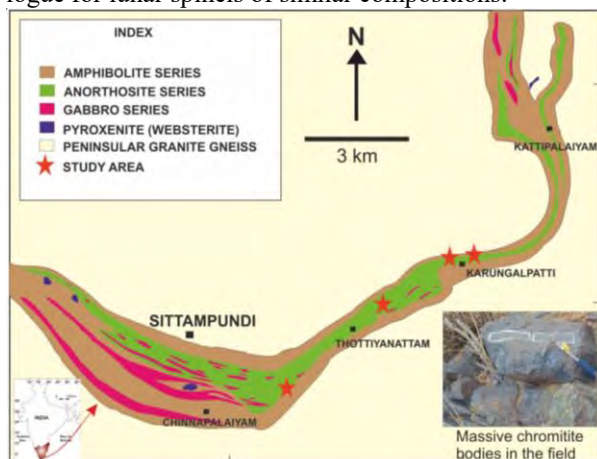


Figure 1 Detailed geological map of the Sittampundi Anorthosite Complex showing the distribution of various lithologies [2].

Methods: The polished thin-sections were used for EPMA analysis of the Cr-spinel samples using a JOEL JXA-8230 Electron Probe Micro Analyzer with WDS spectrometry positioned. The Raman measurements of the powdered Cr-spinel samples were obtained in the ReniShaw Laser Raman spectrometer (Renishaw plc, U.K.). Raman signals in a broader range of 100 cm^{-1} to

4000 cm^{-1} with a spectral resolution of 0.3 cm^{-1} were measured. The FieldSpec® Pro 3 Spectroradiometer by Analytical Spectral Device (ASD) Inc. (calibrated to NIST) operating in the spectral range of 0.35 to $2.5\text{ }\mu\text{m}$ in the visible- near-infrared (VNIR) region was used for obtaining the reflectance spectra of the Cr-spinel samples in the laboratory-based conditions. The FTIR spectra were recorded in the mid-IR range between 400 cm^{-1} to 4000 cm^{-1} with a spectral resolution of 0.5 cm^{-1} and wavelength accuracy of 0.1 cm^{-1} at 1600 cm^{-1} using a PerkinElmer Spectrum Fourier transform infrared (FTIR) spectrometer (PerkinElmer Inc.). The obtained spectral data using these spectroscopic techniques were then compared with the mineral chemistry to understand the spectrochemical characteristics.

Results and Discussions: Fe- and Al-rich composition of Cr-spinels are characteristic of the SAC-hosted chromitites, with Cr_2O_3 contents and the Cr# ranging from ~ 32 - 37 wt\% and 0.44 - 0.53 , respectively. The measured Raman peaks of Cr-spinels appear to be a continuous spread in the regions between ~ 430 - 500 cm^{-1} , ~ 500 - 625 cm^{-1} , and ~ 625 - 800 cm^{-1} (Fig. 2a). The prominent peak corresponding to the A_{1g} mode varies from 703 cm^{-1} to 714 cm^{-1} with a shoulder around 671 cm^{-1} . Other peaks are centered near $\sim 468\text{ cm}^{-1}$, 528 cm^{-1} , and $\sim 585\text{ cm}^{-1}$ corresponding to the E_g , $\text{F}_{2g}(2)$, and $\text{F}_{2g}(3)$ modes, respectively [3]. The longward shift in the A_{1g} peak (~ 705 - 714 cm^{-1}) is suggested to be caused by the substitution of Al^{3+} in the spinel structure. The A_{1g} peak position near 705 cm^{-1} in the Raman spectra is attributed to the coexistence of (Mg, Fe) in the tetrahedral site and (Al, Cr) in the octahedral site, respectively (Fig. 3a).

The hyperspectral data of the Cr-spinels showed diagnostic absorption bands at $0.49\text{ }\mu\text{m}$, $0.59\text{ }\mu\text{m}$, $0.69\text{ }\mu\text{m}$, $0.93\text{ }\mu\text{m}$, $1.3\text{ }\mu\text{m}$, and $2\text{ }\mu\text{m}$ (Fig. 2c). The $2\text{ }\mu\text{m}$ and $0.93\text{ }\mu\text{m}$ bands appear to be relatively stronger and broader in all the samples, apparently due to a relatively higher abundance of Fe^{2+} in the samples. The $2\text{ }\mu\text{m}$ band position is at relatively shorter wavelengths than that of the typical Cr-spinels due to enhanced Al content ($\sim 25\text{ wt\%}$) in the SAC Cr-spinels. The $2\text{ }\mu\text{m}$ band position shows a positive correlation with the Cr# and Cr_2O_3 contents, whereas a negative correlation with Al_2O_3 content. This linear relationship is explained by the substitution of Al and Cr for one another. The ob-

served linear relationship between 2 μm band position and Cr/Al abundances can be used to differentiate Al-spinels and Cr-spinels based on their spectrochemical characteristics (Fig. 3b). The FTIR analysis revealed peaks corresponding to the Cr-spinel vibrational modes between 913-1098 cm^{-1} , attributed to the combined effect of ν_2 and ν_3 vibrations arising from the octahedrally coordinated ions in the Cr-spinel structure.

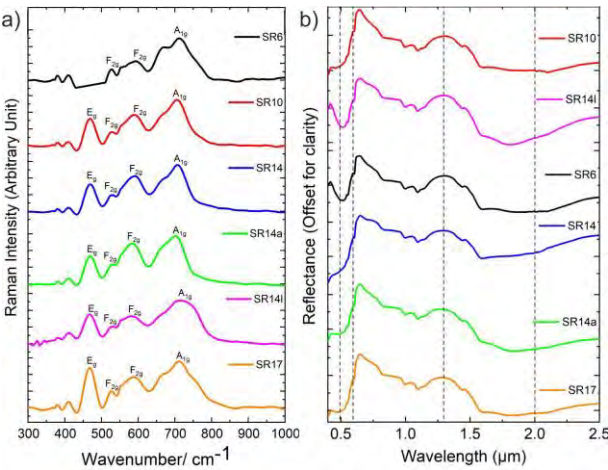


Figure 2 (a) Laser Raman spectra of Cr-spinels from the SAC showing the diagnostic Raman intensity lines corresponding to E_g , F_{2g} , and A_{1g} symmetries. The Al_2O_3 content increases from bottom to top in the figure. (b) Normal reflectance spectra of Cr-spinels from the SAC.

The comparison of the spectral features of SAC Cr-spinels with those of the previously identified spinels from Sinus Aestuum has enabled the interpretation of probable occurrences of Fe- and Cr-bearing spinels in the Sinus Aestuum on the Moon (Fig. 3c) [4].

Conclusions: The inferences based on the spectrochemical relationships will add as a reference for distinguishing lunar Al spinels from the Cr-spinels. Further, the SAC-hosted Cr-spinels could act as a potential analogue for lunar Fe- and Al-rich spinels provided the constraints on their formation processes involving melt-wall rock interaction on both the planetary bodies.

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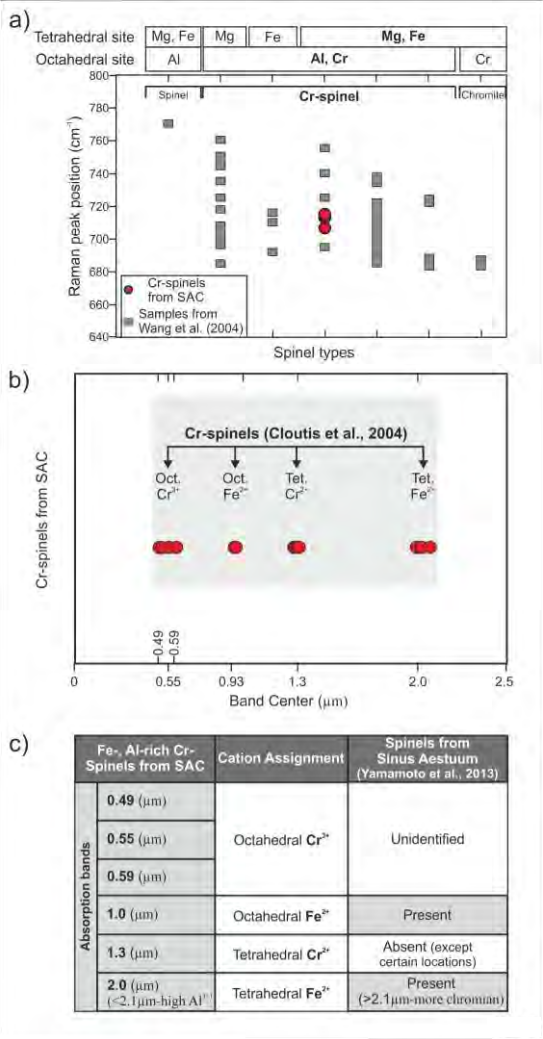


Figure 3 (a) The A_{1g} peak position of the SAC Cr-spinels and their corresponding cation distribution in the tetrahedral and octahedral sites of the spinel structure. The data are plotted in comparison with the A_{1g} peak distribution and their cation assignment from Wang et al. (2004) [5]. (b) The absorption band centres of Cr-spinels from SAC and their corresponding cations of tetrahedral and octahedral sites [1]. (c) The absorption band centres in SAC Cr-spinels compared with those from the Sinus Aestuum region on the Moon [4] and their corresponding cation assignment.

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