

## **Natrojarosite formed in the Matanomadh Formation, Kutch, India: A Na analog of jarosite on Mars**

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### **ABSTRACT**

We report mineralogy, chemical composition, visible near-infrared (VNIR) spectroscopy, and X-ray near-edge spectroscopy of phyllosilicate-sulfate mineral assemblages, including natrojarosite, from the Matanomadh Formation (Palaeocene) of the Kutch region in Gujarat, India. The unit-cell parameters of sulfate minerals and VNIR spectral properties are consistent with natrojarosite and other minerals. The mineralogy and unit-cell parameters indicate supergene or hydrothermal alteration conditions within the Kutch region. The Fe oxidation record ( $\text{Fe}^{3+}/\text{total Fe} \sim 0.83$ ) is quantified using Fe K-edge XANES. Additionally, the Fe-S bond length for natrojarosite is determined to be 3.158 Å, and the experimental result fits well with the modeled iron sulfate data curve. The occurrences of natrojarosite and associated natroalunite and kaolinite in the post-Deccan volcanic province are consistent with an oxidizing environment and periodic shift of humid to arid environments that appear to be similar to the early geologic history of Mars. The oxidative alteration of pyrite further enhances the formation of natrojarosite. Our results, in concert with earlier studies, highlight the formation process of natrojarosite and provide insights into detailed mineralogy at the Kutch region and the magnitude of the redox state. The natrojarosite and the associated minerals (including anhydrite and other sulfates) argue for acidic and water-limited conditions analogous to the Noachian-Hesperian epoch of Mars, with implications for past weathering processes.

**Keywords:** Natrojarosite, sulfate, matanomadh, terrestrial analog, Mars, VNIR, XANES-EXAFS, Earth Analogs for Martian Geological Materials and Processes