SPECTRAL, CHEMICAL AND ISOTOPIC INVESTIGATION OF ULTRAMAFIC-HOSTED MAGNESITES FROM SOUTHERN INDIA: IMPLICATIONS FOR NATURAL CO_2 SEQUESTRATION PROCESSES

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by

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ABSTRACT

Magnesite ($MgCO_3$) is among the most significant magnesium-bearing minerals globally, with diverse applications across industries such as refractories, metallurgy, aerospace, construction, and electronics. India ranks ninth in global magnesite production. Magnesite occurs in four primary types: (1) as a sedimentary rock, (2) as an alteration product of serpentine, (3) as a vein filling, and (4) as a replacement of limestone or dolomite. However, critical aspects, including the sources of carbon and magnesium, carbon transport mechanisms, and precipitation conditions for magnesite formation, remain subjects of debate. Notably, the oldest magnesite-hosting rock, dated to 3.5 Ga, is reported from the western Dharwar Craton.

This doctoral research undertakes an exhaustive investigation into the genesis and variability of magnesite deposits across southern India, with a detailed geochemical and petrological evaluation of magnesite-bearing lithologies from Attappadi (Kerala), Salem (Tamil Nadu), and Mysore (Karnataka). The study aims to elucidate genesis, mineralogical associations, and processes governing the formation of magnesite, while providing a comparative analysis of its modes of origin. The research methodology integrates rigorous field-based geological mapping and systematic sampling to ensure representative coverage of lithological variations. Petrographic analysis, involving the preparation of thin sections and high-resolution microscopic examinations, will facilitate the identification of mineral assemblages and the characterization of microtextural features.

Advanced spectroscopic techniques were employed to assess the mineralogical properties, spectral response to electromagnetic radiation, and potential applications in predictive mineral exploration and qualitative grade estimation. Trace element geochemistry, determined via inductively coupled plasma mass spectrometry (ICP-MS), provided insights into petrotectonic affiliations and magnesite formation environments. Stable

isotope analysis (C-O isotopes) using isotope ratio mass spectrometry (IRMS), coupled with radiogenic isotope studies via thermal ionization mass spectrometry (TIMS), refined the understanding of the depositional mechanisms, fluid sources, and relative chronological framework of magnesite formation.

This study explores the genesis and environmental significance of ultramafic-hosted magnesite deposits in southern India through detailed spectral, geochemical, and isotopic analyses. Advanced spectroscopic techniques, including hyperspectral, FTIR, and Raman spectroscopy, reveal magnesite's unique vibrational properties, confirming its mineral identity and crystal structure. Distinct absorptions at 2.3 and 2.5 μm (VNIR) and characteristic bands at 1434, 880, and 747 cm^{-1} (FTIR) correspond to carbonate group vibrations, while Raman peaks at 212, 332, 735, 1096, and 1460 cm^{-1} provide additional structural insights.

Stable carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotopic signatures provide a robust framework for understanding magnesite formation. Across regions such as Karnataka, Salem, Attappadi, and Thennilai, $\delta^{13}C$ values range from -5‰ to 0.94‰, and $\delta^{18}O$ values range from 25.5‰ to 30.6‰. These values suggest magnesite precipitation from meteoric water interacting with atmospheric CO_2 and contributions from organic carbon. Variations in isotopic values reflect site-specific differences in formation environments, including carbon sources, temperature, and fluid interaction dynamics. For example, the $\delta^{13}C$ signature transitions from -8.6‰ in primary sources to -4‰ to -2‰ in thinner veins, illustrating isotopic fractionation influenced by fluid composition, temperature, and residence time.

Geochemical analyses reveal elemental variability, with notable enrichments in Fe, Mn, and Sr and flat REE patterns, indicating diverse formation conditions. Sr isotope ratios (0.73761–0.70614) provide additional insights into magnesite's relative ages and fluid sources. By integrating spectral, geochemical, and isotopic data, this study highlights the environmental and geological processes driving magnesite formation.

The findings emphasize role of ultramafic rocks in natural CO_2 sequestration, with implications for carbon capture and storage strategies in mitigating climate change. The outcomes of this research have advanced the scientific understanding of magnesite genesis in southern India and in natural carbon dioxide sequestration processes.