ABSTRACT

This study centres on the geological and remote sensing examination of the Nagaland-Manipur Ophiolite Belt (NMOB), north-east India, a part of the Western Ophiolite Belt in the Indo-Myanmar Ranges (IMR). The study employs integrated remote sensing and mineral reflectance spectroscopic analyses of rocks and minerals from different segments of the ophiolite belt. For the former, three techniques, namely Principal Component Analysis (PCA) based on the MODIS (Moderate Resolution Imaging Spectroradiometer) data, MODIS-based apparent thermal inertia (ATI), and ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer)-based ATI mapping, have been applied to (a) trace the arcuate pattern of the IMR, (b) geologically map the contact between sedimentary and mafic-ultramafic units in the Nagaland segment of the NMOB and (c) recognise extremely rare lithoassociation of metamorphic sole rocks and contact mantle wedge peridotites from the Manipur segment of the NMOB.

The thermal anomaly mapping based on the PCA on MODIS LST (Land Surface Temperature) and emissivity data reveals the occurrence of three regional-scale, sub-parallel belts, together conforming to the arcuate pattern of the IMR. These findings confirm the effectiveness of the PCA for the geological mapping of accretionary complexes within oceanic subduction systems. The MODIS-based ATI mapping, despite certain limitations, enables demarcations between highly siliceous sedimentary units and low-siliceous mafic and ultramafic units of the ophiolite belt. The ASTER-based ATI mapping of the Tusom CV area, NE Manipur, when integrated with petrological information has led to the recognition of four lithological units, namely (a) mantle peridotites, (b) high-temperature metamorphic sole rocks of mafic granulites, (c) low-temperature metamorphic sole rocks of amphibolites (with or without garnet) and epidote amphibolites, and (d) sedimentary rocks, with an overall accuracy of 70%.

Reflectance spectroscopic study of six different types of ultramafic rocks from the Nagaland Ophiolite Belt reveals that the most dominant olivine absorption features vary from 1038-1049 nm in Ni-poor ultramafic cumulates of wehrlite (Mg#=89, Ni=355 ppm) and olivine websterite (Mg#=90.5, Ni=361 ppm) to 1066-1097 nm in nickeliferous mantle peridotites of dunite (Mg#=87, Ni=3658 ppm) and spinel lherzolite (Mg#=87, Ni=2708 ppm) compositions. Reversal of the 625 nm reflectance maximum

in olivine occurs for Ni concentrations in the mineral between 2200 and 2986 ppm. The low-Ca pyroxene (cf. orthopyroxene) species show characteristic absorption features at 902-926 nm in lherzolite and harzburgite and 918 nm in monomineralic orthopyroxenite. The spectral shift in the absorption band centers towards the longer wavelength (from 902 nm to 926 nm in orthopyroxenes and 1066 nm to 1087 nm in olivines) is explained by increasing Fe^{2+} and Mn (in olivine) concentrations in the minerals. In most rocks, high-Ca pyroxene (cf. clinopyroxene) records absorption features at 643-666 nm and 709-811 nm.

The reflectance spectroscopic analysis of both pure garnet and mixed garnet + pyroxene ± amphibole minerals from three representative samples of metamorphic sole rocks from the Tusom CV area reveals the following key findings: (1) Pure garnet spectra for a known garnet composition of $Prp_{27}Alm_{44}Grs_{25}$ in a representative mafic granulite sample show characteristic absorption bands at 493 nm, 1266 nm, and 1708 nm, consistent with the USGS spectral library data for garnet. (2) When the library spectra of garnet of different compositions are integrated with the garnet spectra investigated in this study, it reveals correlated spectral shifts with garnet solid solution compositions. While the spectral shifts in absorption features near 1300 nm are directly linked with variations in almandine and grossular concentrations in garnet, the same shift near 1700 nm is directly connected to a variation in pyrope contents in garnet. Two polynomial quadratic equations have been derived to relate garnet absorption band centers with specific garnet compositions in terms of their Fe^{2+}, Mg and Ca concentrations. (3) Forty-four synthetic spectra that are produced by linear mixing of end member spectra of garnet, clinopyroxene, and hornblende and of different proportions are used in combination with a variety of spectral matching techniques to derive the compositional information (mineral assemblage and its proportion) from unknown rock spectra of mafic granulites and amphibolites.

Summarising, these findings of reflectance spectroscopy are expected to aid in the interpretation of remotely sensed hyperspectral data from terrestrial and extra-terrestrial bodies, mapping ultramafic cumulate (Ni-poor olivine) and mantle peridotite (Ni-rich olivine) rocks in remote, covered, and unmapped terranes of ophiolitic origin, and in the process, identification of fossil oceanic subduction systems, and finally in the remote sensing-based mapping of metamorphic isograds in unmapped metamorphic terranes.