LITHOLOGICAL MAPPING OF NIDAR OPHIOLITE COMPLEX, LADAKH USING HIGH-RESOLUTION DATA

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Introduction: Ophiolites represents fragments of oceanic crust overlying the mantle. Their characteristic mineralogy, spatial and temporal inter-relations are closely associated with the complex mantle dynamics in Earth history. Nidar Ophiolite complex (Lat: 32°45'N - 33° 35'N & Long: 78°E - 79°E) located towards SE of Ladakh and exposed well along the Indus Suture Zone. They represent the remnants of the Neo-Tethys ocean that existed between Indian and Eurasian continental plates during the Mesozoic-Cenozoic Eras. Most of the earlier studies for the Indian ophiolites including Nidar have pertinently been dedicated towards field characterization and analytical techniques. The present study has attempted to identify, map and spectrally characterize the various lithounits of the region based on high-resolution remote sensing data from various missions.

Dataset used and Methodology: We have used high-resolution data from multiple sources to discriminate between lithologically dissimilar rock units utilizing either single band images, their composites or ratio images and derived spectral indices consequently. The approach has been utilized for differentiating the lithology based on their spectral character manifested in the image in the form of colour or tonal variations. The differentiated ophiolite rocks are, thus, easily interpreted due to their direct relationship between image colour and spectral response of lithounits in different bands. For the interpretation of iron, carbonate and mafic phases, LANDSAT-8 OLI data have been used. Different bands were selected as per the reflectance spectroscopic signatures of the rocks. Spectral indices have been generated for the discrimination of characteristic lithology using ASTER emissivity data (TIR) bands as well. ASTER-TIR bands have globally been employed for for detection and discrimination of quartz, carbonates and mafics (based on vibration of the SiO_4 tetrahedra in olivine, pyroxene and plagioclase group of mineral species) [1]. In addition, for spectral analysis,PRISMA data have been downloaded in .he5 format, (hierarchical data format)[2]. The L2D data tile was georeferenced and stacked in ENVI software (© Harris Geospatial Solutions, Inc) to capture spectral variability present in the image. Several image classification techniques were subsequently applied. Initially forward MNF transformation was performed on 233 bands of preprocessed image to reduce the dimensionality of the data and isolate noise fraction. The first 10 eigen bands

containing most of the spectral information were selected next to generate pure pixels using Pixel Purity Index method. The selected purest pixels using n-dimensional scatter plot were used to determine the endmembers which were ultimately used for spectral analysis from the resampled ASTER mineral library.

Results and Discussion: Geological map (Figure 1) and false colour Composite images generated from Landsat-8 OLI images. The composite images were analysed to identify the compositional characteristics of the region based on diagnostic absorptions in specific wavelength range in VNIR and SWIR region. The ophiolite terrain with lithological assemblages highlighting iron, carbonate and silicate-suits were identified based on their reflectance and absorption characteristics.
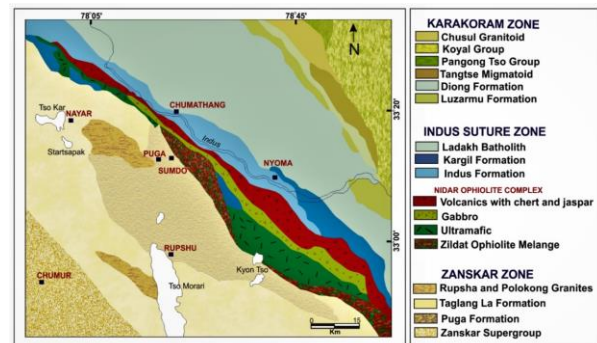

Figure 1: Geological Map of the Nidar Ophiolite Complex (Modified after [3]).

Quartz, carbonates, mafic/ultramafic rocks, and their altered derivatives reveal strong emissivity absorption features in TIR region, which promotes the 8-14 μm range to be therefore the most suitable for lithological mapping of mafic–ultramafic rocks [4]. The results generated using ASTER TIR bands for Quartz Index (QI) Map, Carbonate Index (CI) Map, Mafic and Ultramafic Index map (MI) (e.g., Figure 2) clearly discriminates the igneous and quartz-rich sedimentary rocks and also the mafic, ultramafic and carbonate lithological assemblages. For lithological identification using PRISMA data color composition of 0.9μm (red), 1.4μm (green) and 2.2μm (blue) (Figure 3) was selected that manifests ultramafic in green, mafics in light green, volcanics and volcanoclastic sedimentaries appears in shades of blue and the granitic terrain, both in the north (LB) and south (TMC), in light. The main components of these upper mantle and lower crustal lithology are

igneous with olivine, pyroxene and plagioclase as dominant phases representing the ultramafic and mafic rocks (peridotite, pyroxenite, dunite, gabbro, basalt) and quartz and K-feldspar for felsic and associated sedimentary rocks (granite, andesite, diorite, sandstone, conglomerate, shale, grit). The identified ultramafic, mafic and volcanic lithounits of NOC are dominated by olivine, pyroxenes and plagioclase feldspar. Presence of olivine is detected by a broad absorption near 1.03 µm [5] Pyroxenes, identified with two absorption bands near 1 and 2 µm, respectively [6]. The alteration products of ultramafic and mafic igneous rocks are mainly chlorite, epidote, non-diagenetic calcite, iron oxides/ hydroxides, and iron-rich clay minerals. Serpentinized minerals have absorption near 2.3 µm and a minor absorption near 2.1 µm due to Mg-OH. Presence of low temperature serpentine relevant here as it is often associated with condition favourable for synthesis of organic compounds at micro-level and hence serves as a proxy for microbial activity. The presence of olivine in dunite is, hence, confirmed by the detection of serpentine (narrow Mg-OH absorption feature). The reflectance spectra Fe, Mg-OH (chlorite, epidote) and carbonate (calcite, dolomite) have typical absorption features at 2.3 µm to 2.4 µm [7]. Along with carbonates, epidote and chlorite are also present among the main altered mineral phases identified in igneous and metamorphic terrains. Presence of muscovite and illite are also ubiquitous in granitic terrains recognized by absorption features located between 2.1 µm to 2.2 µm due to Al-OH strech. The results generated from multispectral Landsat OLI and ASTER data for band ratioing, compositional indices and spectral characterization done using PRISMA data delineates well the ophiolite mafic and ultramafic & associated rocks in this region. The dominant phases in the ultramafic and mafic rocks that are the principal representatives of the upper mantle and lower crustal lithology, have been identified along with associated sedimentary rocks with various altered phases.
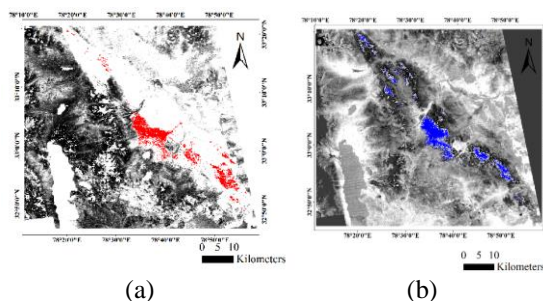

(a)   (b)

Figure 2: Thresholded pixels of (a) Mafic index(MI) and (b) Mafic-ultramafic index generated from ASTER-TIR based lithological indices for the Nidar region.
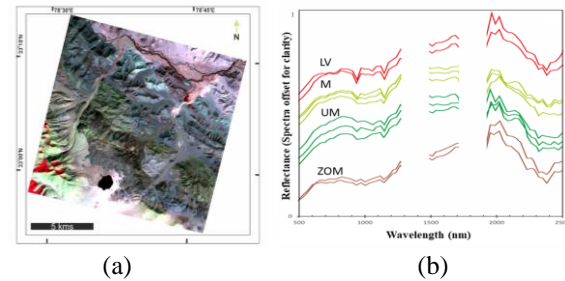

(a)   (b)

Figure 3: (a) Colour composite image from hyperspectral data of PRISMA sensor, displaying various lithounits in the region distinctively (b) Reflectance spectra acquired from PRISMA data for the various lithounits of the study area.

Conclusions and Future work: The present study has attempted to identify, map and spectrally characterize the various lithounits of the region based on high-resolution remote sensing data from various missions. At present very limited work exists on the use of hyperspectral remote sensing for exploration of ophiolites and had not been fully explored. The approach followed here can be an effective operational tool for exploration of new ophiolites that also have economic significance. Remote sensing and especially hyperspectral imaging spectroscopy provides means of obtaining a better insight into the nature and evolution of crust of terrestrial planets in conjunction with geochemical studies. Nidar ophiolites with characteristic mineralogy and associated low-temperature aqueous geochemical signatures provide easily accessible areas that can serve as good analogs for planetary crustal rocks especially for martian crust. The study area, thus, could also serve as potential terrestrial analogues site for Mars displaying mineralogical and microbiological implication for life.

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