ABSTRACT

The Precambrian basement rocks of north east of Hajjah, Yemen represent the southwestern extension of Nabitah belt, a part of the Arabian shield. They comprise of a succession of metamorphosed volcanic and volcano-sedimentary rocks produced in an arc environment. These rocks are intruded by syn and post-tectonic granite, gabbro and granodioritic intrusions. Precambrian basement rocks are unconformably overlain by sedimentary rocks; Wajid Sandstone, Akbra Shale, Kohlan Sandstone, and Amran limestone. Visible near infrared (VNIR), short wave infrared (SWIR) and thermal infrared (TIR) of multispectral remote sensing have become potential tool for mapping hydrothermal alteration zones. Application of remote sensing and GIS-based spatial data integration for mapping of hydrothermal alteration zones is still not fully employed in the activities of the Geological Survey of Yemen. This thesis involves analysis of multispectral (Landsat-7 ETM+ and ASTER), Google Earth data, SRTM, laboratory spectral reflectance, chemical analyses and petrography in mapping the hydrothermal alteration zones in the north east of Hajjah. The results of the chemical analyses show anomalies of Au, As, Ni, Cu, Zn, Sb and the petrological study shows intensity of alteration, deformation features, replacement of mineral composition and recrystallization. Empirical Line Method (ELM) was applied to eliminate the atmospheric effects with respect to ASTER and ETM+ data. The accuracy of the atmospheric correction was also evaluated from three targets: vegetation cover, Amran limestone, and Akbra shale rocks of the surface reflectance, and the result exhibits not much difference before and after calibration; ASTER image is more effective especially in the SWIR region. The Laboratory reflectance spectra of Precambrian basement exhibited alterations such as sericitization, oxidation, clay minerals, serpentinization and carbonatization. Silicified alteration is not distinguishable in the regions of VNIR and SWIR of the electromagnetic spectrum, because of lack of diagnostic spectral absorption features in silica in this wavelength.
Although the arsenopyrite and pyrite are widespread in the entire area, their features did not appear in the VNIR and SWIR regions because they exhibit trans-opaque behaviour and often lack distinction in these regions. Optimum Index Factor (OIF) with its resulting 56 and 364 band colour combinations of ETM+ and ASTER data, respectively have been used to reduce the time and simplify the selection of suitable band colour combination for identifying and discriminating different rock units. It also facilitates the large amount of ETM+ and ASTER data more flexible, useful, and easy to use. Principal component analysis (PCA) and band ratio techniques proved to be very powerful and efficient for mapping hydrothermal alteration zones and different rock units: in the band ratios 5/7 and 3/1 of ETM+ and their equivalent 4/6 and 2/1 of ASTER data proved successful in mapping altered clays and iron oxide. Band ratios 5/7 of ETM+ and 4/6 of ASTER revealed to be more suitable method for mapping the altered clay when compared to PCA technique. Result of Normalized Differences Vegetation Indices (NDVI) revealed that the vegetation cover is sparse in the area and it shows the high effectiveness of the application of remote sensing in geological studies. Lineaments extracted manually from Google Earth, enhanced panchromatic band of ETM+ and DEMs exhibited that the dominant trends of lineaments are displayed in NE-SW and NW-SE directions adhering to the main directions of the Gulf of Aden and Red Sea. Lineaments extracted manually were more satisfactory and accurate than the lineaments extracted automatically. Comparative values obtained from SRTM DEM after filling the gaps and DEMs of contour lines for different elevation points showed that they are close to each other. Lineaments are more concentrated in the Precambrian basement rocks and the alteration zones are exceptionally, highly associated with these concentrations. It is, therefore, deduced that the study area is geodynamically active.

**Keywords:** Yemen, Hajjah, Precambrian, hydrothermal alteration zones, geochemistry, petrology, ASTER, ETM+, SRTM, DEM, Google Earth, spectral reflectance, ELM, lineaments, PCA, band ration and OIF.