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### Geological mapping and mineral exploration based on the application of remote sensing (RS) in North Waziristan Pakistan

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#### ABSTRACT

In mineral exploration, remote sensing tools are important and cost effective. Minerals occur in a variety of genetic associations, commercial deposits of minerals are limited in genetic types and modes of occurrences. This forms the basis of modern concept based prospecting and is also responsible for the significant role of remote sensing in exploration. Remote sensing data can help to differentiate metallogenic provinces/belts/sides and mineral guides in a larger terrain. Keeping In view the importance of RS Tools, digitally enhanced OLI Landsat 8 images are applied to find alteration zones and for geological mapping of North Waziristan Pakistan. The territory is rough with sparse vegetation; the exposure of the Waziristan ophiolite, related sedimentary-igneous lithologies and inaccessibility to the area made the utilization of Landsat information helpful in this investigation. Spectral signatures recorded by Landsat 8 data were used to differentiate different rock units and alteration zones. RS tool i.e. band ratios, band combinations, principal component analysis and image classification are helpful in this regard. Final detection of the lithology and alteration zones is based on correlation between classes generated in the thematic map and the referenced geological map. On the basis of the image classification techniques; unsupervised classification, band ratios, five principles lithological units and alteration zones with highest percentage of clay and iron ratio, results are satisfactory with overall accuracy 63.07 % in comparison with referenced geological map using confusion matrix analysis. The results are subject to discussion and need to examine about the utility and confinements of remote sensing strategy on the investigation zone.

#### 1. INTRODUCTION

The aim of the project is to use remote sensing tools in identifying alterations zones for mineral perspective and to create a map of lithology of rocks, sediments and their residuals exposed on the land surface. The new map which would depends on unsupervised classification, colour composites band ratios and principal component analysis expand limited mapping of the ophiolite, approves and enhances past general conclusions and reveals new prospects in the territory. The application of multispectral imaging to the Northwest of Pakistan makes the construction of definite geologic maps economical and efficient. Applying appropriate band rationing and Principal Component analysis (PCA) is part of the analysis which entitles additional lithologic information from the ground. Modified map is verified with referenced geological map published by Geological Survey of Pakistan (GSP), high resolution airborne ortho

photomap and different field reports. For the research purpose, Landsat 8 images are freely downloaded from USGS online repository. Satellite images are processed and analysed using software i.e. Ermapper, QGIS, ArcGIS and Global Mapper. The result of study are satisfactory enough to apply remote sensing as a tool to differentiate lithological units in the study area. Visual evaluation of multispectral images using RS tools i.e. band ratios, PCA and unsupervised classification, we can differentiate between different rock units as usually geological materials are not homogeneous even within specific rock units.

#### 2. METHOD

The study goes in five stages.

1. Creating an updated lithological map with the use of image processing and analysis
2. Highlighting alteration zones.

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3. Rectification of the map obtained by comparison and statistical validation with referenced data.
4. Modification of processing parameters.
5. Final rectification of the map.

The ophiolite belt of Waziristan is having potential for certain type of ore deposits, consisting VMS type of copper deposits, podiform chromite & banded manganese (Jan 1985). The occurrences of these deposits in the ophiolite belt of Waziristan was first reported by Asrarullah of Geological survey of Pakistan, Taher Kheli, Aftab Ahmed (1959), Afzal (1970). A number of principal geological criteria for mineral prospecting, which are helpful in this study, have been setup by McKinstry in 1948 includes: 1-statigraphical–lithological, 2 Geomorphology, 3-Structural, 4-Rock alterations, and 5-Geobotanical, 6-Geochemical and geophysical anomalies (Gupta 1991).

Seven clear, cloud free Landsat-8 images were downloaded from online repository of the United States Geological Survey (USGS) in tiff format, specifications of the images are shown in Table 1. The study area (Path/row-152/37) is captured by Landsat 8 scenes acquired on 15 May, 2016. Fig. 1 shows the Landsat image of the study area. Following techniques are applied on the satellite imagery. While displaying a color composite, three primary colours i.e. red, green and blue (RGB) for three bands of multispectral images are selected. Fig. 2-3 shows the Colour composites. When combining three colours in different proportions, they create different colours in the visible spectrum. Involving every spectral band (not necessarily a visible band) to an isolated primary colour, resultant will give us a colour composite. Details of band number and their usage is explained in Table 2. Colour visualization will always make it easier to interpret the multispectral images and capture differences between single bands. In LANDSAT 8 OLI scanner; by combining band 4 (red), band 3 (green) and band 2 (blue), resultant color composite image shows closely what would be seen by the human eye. In natural colour composite (Fig. 1) bands are in the visible range and features on the ground appears in their natural colour. Fig. 1 shows iron oxide coloration in the soil, Rocks rich in iron oxide can be seen in dark reddish colour. Recent superior sediments and alluvial fan deposits are in light brown colour. This band combination used for urban studies as well as it provides the most water penetration and bathymetric information. Vegetation types are not easily distinguishable in natural colour composites as we do in false colour combinations. Similarly, natural composite 321 is not good to distinguish shallow water from soil as it in 753 combination. The false colour display assignment can be done in an absolutely random way for any band of a multispectral image so that the colour of a target in the displayed image does not show any resemblance to its actual colour. The resultant image is known as a false colour composite. However, some methods can be more appropriate for the detection of certain features in the image. False colour composite schemes for exhibiting a Landsat 8 OLI multispectral image used in this research are RGB 653 and RGB 543. Fig. 2-3 shows false colour composites. In lithological mapping, RGB color combinations that use bands with

low correlation coefficients are giving us better results due to the spectral diversity in the bands. Lithology interpretation is based on the following remote sensing tools:

- I. Colour composites
- II. Band ratios- Clay, iron-oxide, NDVI and its derivatives.
- III. Unsupervised classification (ISO CLASS)

Geological colour Composite in fig. 2 shows RGB 653 which creates an enhanced image with strongly green vegetation, bluish water and light to dark brown rock or soil. Limestone and shale are most probably pinkish or light in colours. RGB 753 and 652 are alternatives of this combination. Quaternary fan deposits are visible in light brownish-greyish colour, dark brown colour could be dunite and wherlite.

Fig. 3 shows RGB 543 In a tropical setting, it replicate a conventional Infrared aerial image with red vegetation and grayish to bluish rock or soil. It focuses on the boundaries between barren and vegetated land. Equivalent in L5/7 to this band is RGB 432. Chlorophyll content in leaves is different in different types of vegetation which results different shades of red in every plant. That's why 543 composite images are very convenient in determining the extent of vegetation cover and in the classification of vegetation in remote sensing. Band rationing is very simple and powerful technique in the remote sensing; Fig. 4, 6 & 7 shows band rationing images. Different band ratios like NDVI used by (Bannari 1995), iron oxide, clays ratio and principle component (PCS) (Mudrov 2010) could give us better understanding of the geology. Basic idea of this technique is to emphasize or exaggerate the anomaly of the target object as used by (Abrams 1983). In Fig. 4 band ratio is created with b7/b6 in red, b6/b5 in green and b2/b3 in blue. It is clear from the image that geology is giving map like appearance with small relief in topography. Rocks composed of clay mineral are in blue shades, light reddish colour could be of chert and light yellow colour could be of Limestone. Clay ratio in Fig. 6 is produced through the combination of band b6/b7. Clays, carbonates and micas can produce the light grey to white zones in greyscale images. In pseudo color, clay with red colour is showing maximum value which is 1.65. It can be due to the reason that hydrous minerals as said by (Knepper 1975) or alteration zone have high absorption as compare to band 7. Fig. 7, Iron oxide ratio is created through band b4/b3 combination. Iron oxide ratio increases the existence of iron bearing minerals which can be the reason of strong absorption in b4 and alteration in iron oxide, also it causes strong absorption in band 3 and higher reflectance in band 4. Oxides of iron seems to be reddish with higher values i.e. 1.357.

Unsupervised classification (ISO CLASS) is created (Fig. 5) with 70 number of classes using different classification parameters; results are verified visually and statistically with reference data, colour composites and band ratios. Unsupervised classification is executed using Iterative Self Organizing Data Analysis Algorithm Technique (ISODATA) as used by (Tou & Gonzalez 1974). In this classifier we don't use training samples data as a base for classification. Instead, these classifiers involve algorithms. Undefined pixels are analyzed by these

algorithms in the image and collect them into number of classes established on the natural clusters or grouping present in the image values. Geological referenced map is reclassified in ER mapper using algorithms written under Table 4 and shown in Fig. 8. Five major lithologic units are marked on the referenced geological map, which are discussed under section 4 stratigraphy and Table 3. Thematic map with unsupervised classification is shown in Fig. 9. This map is showing 5 lithologies which are giving quite satisfactory results when we compared with referenced geological map. Fig. 10 shows referenced geological map prepared by Geological Survey of Pakistan.

Error (Confusion) Matrix (Awad, N.M.A., 2011) allows for quantitative estimation of the overall accuracy of classification. The correct classifications results are presented diagonally from upper left to lower right corner. Table 4 and 5 shows confusion matrix analysis. The values (Tables 3) which are not found in the diagonals are considered as errors said by (Congalton 1991; Congalton 1999). The ISO classified image with 70 clusters or classes shown in Fig. 5, each represented by a different color. Each class was labeled and identified as geology or non-geology with the help of high resolution ortho photomap and geological referenced map using ARCGIS and QGIS online imagery. The confusion matrix was generated through ER mapper. Confusion matrix between referenced geological map and the classified multispectral image with 70 classes was created to check the accuracy of the classification as shown in Table 4 and 5.

There was confusion between classes and just 5 classes were showing satisfactory results out of 16 which are shown in Table 3. As far other lithologies are concerned, there was confusions in following set of lithologies; JZEF, TKF, JVV, JWV, QRS, KML, JZF and QTG (See Stratigraphy). After calculation of confusion matrix, highlighted maximum numbers in rows and columns (Table 4, 5). In this way we reduced the classes and just 5 classes were retained. For the second time, image was reclassified using algorithm shown in Table 5 with just 5 classes which are giving satisfactory results. Geological referenced map is also reclassified using 5 corresponding lithologies. After reclassification of both images, confusion matrix analysis giving us 63.071 % overall accuracy with kappa statistics 0.521 as used by (Jensen 2005).

### 3. RESULTS AND DISCUSSION

The purpose of the study is to generate a revised map of the rocks revealed on the surface in geologically complex area and to identify VMS type deposits using RS tools. Geological referenced map was having 20 major lithologies; JUM, QFD, JPS, JUM, JWV, QFD, QTG, JSD, DOLORITE DYKE, KML, JVV, JG, QRS, JPG, ZEF, TKF, JAF, JZF, TRF and QAL (See Stratigraphy). Study shows that on a broad scale, the use of 70 classes in unsupervised classification produced more precise distribution of lithology. The result of study are satisfactory enough to apply remote sensing as a tool to differentiate lithological units in the study area. Visual evaluation of multispectral images using RS tools i.e. band ratios, PCA and

unsupervised classification, we can differentiate between different rock units as usually geological materials are not homogeneous even within specific rock units. Within the ophiolite complex different igneous rock types like gabbroic rocks, ultramafic rocks, and the sheeted dike complex can be differentiated on the basis of spectral ratio, false color composites and PCs.

The reference data used in this study was the geological map of North Waziristan on the scale 1:50,000. For further studies and to minimize uncertainties caused by vegetation, complex geologic history and local landscape evolution events, it would be valuable to use other data (field data, geophysical data) for reference purposes. Different systems like Landsat allows efficient, consistent data collection for geological studies. Combination of more information and with the help of higher resolution data, like high resolution spectral data, spatial and morphometric datasets, we can get better geological view of the area. Keeping in view the complex geological history of the area, I suggest that a combination of remote sensing with sampling on ground and geophysical data; magnetics and gravity could produce more accurate results. Information could be changed due to geomorphic processes and different factors; erosion and deposition, so evaluating the accuracy of unsupervised classification, results of Landsat 8 OLI data through error matrix and kappa hat shows that remote sensing using digital image processing techniques can generate moderate to high level results in lithological mapping especially in arid regions.

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