Integration of Radar Sat-2 and Landsat Etm+ Images for Mineral Exploration in The Central Part of Libya

Dr. Younes Ajal Abulghasem
Dept. of Geology -Faculty of Sciences
Aljabel Alghrabi University

Abstract:

The area of study located in the central part of Libya is situated at a potential iron ore mineralization zone. In order to identify the alteration zones and mineralization characteristics of the intrusions, iron ore deposit is a belt of upper-Devonian sedimentary formation including iron ore bearing layers, which extend over about 160 km, in ENE-WSW direction, on the northern border of the Murzuk Basin.

This study examines the integration of Radar Sat-2 and Landsat ETM+ images to discover any probable extensions of iron ore deposits.

Landsat ETM+ images proved to be useful in surface mapping of lithologic and structural features in that area. Radar Sat-2 images reveal fluvial features beneath a surface cover of the desert sand. These features are not observable in Landsat ETM+ images of similar resolution.

In this work, the Supervised Classification, Principal Component Analysis (PCA), band, and Intensity-Hue-Saturation techniques is used for merging Radar Sat_2 and Landsat TM images to enhance the interpretation of geological features.

The data fusion produced a new data set of images showing enhanced subsurface structures such as foliation, faults and folds that control the distribution of the Banded Iron Formation and placer deposits in Quaternary paleodrainages in the study district. The study demonstrates the utility of merging optical and radar remote sensing data for exploring mineral deposits in arid regions.

Keywords*: Landsat ETM+, Radar SAT-2, Intensity-Hue-Saturation, Supervised Classification, Iron Ore .*

1.Introduction.

Iron ore deposit is a belt of upper-Devonian sedimentary formation, including iron ore bearing layers, which extends over 160 kms, in ENE-WSW direction, on the northern border of the Murzuq basin, in the province of Sabha Figure 1 The western and eastern ends of the iron ore bearing layers are covered by more recent formations, which completely cover the ore outcrops, [1] (Sterojexport 1977).

The study area is situated in the province of Sabha, Libya, bounded by latitudes 27° to 28° N, and longitudes 12° to 16° E. The territory covers an area of nearly 60,000 sq. Km.

The study area lies to the south of the Gargaf arch, an E-W trending anticline, built up of a Precambrian core and Cambrian to Devonian clastic sediments with Lower Carboniferous Rocks at its southern limb, striking about 85° with 1-3° dip towards the south. Paleozoic formations containing iron-bearing oolitic layers are reported to occur in several areas beside the Wadi ash Shati.

The iron bearing horizons are mostly confined to the Middle and Upper Devonian Awaynat-Wanin formation. In the Shati valley, the Upper Devonian formation consists of 140 meters of gray, tan and brown, fine to medium grained, well-rounded and well-sorted cross bedded sandstone. It is interceded with thin beds of quartzitic sandstone, varicoloured claystone and siltstone and contains several intra-formational conglomerates.

The main objective of data fusion in remote sensing is to create an integrated composite image to improve information sharing and greater intelligibility. This data has geospatial details about earth's surface and information on the ground for substantial assessment of land resources and mineral exploration.

The data fusion of visible-infrared (VIR) and radar images is to produce additional information and increase the amount of data that can be extracted from the individual input images.

Radar image contains the details beneath the surface coverage while maintaining the basic colour content of the original VIR data. Image fusion can be on three different levels of processing, the pixel level, feature level and decision level according to the stage where the fusion takes place. In this work, a pixel based image fusion from different sensors, namely Landsat ETM+ and ERS-2 was performed using the Intensity, Hue, and Saturation (IHS) transformation procedures.

The fusion can enhance the subsurface structures such as foliation, faults and folding that control mineralization of iron ore deposit in the study area and reveal the fluvial features which are not observable in Landsat ETM+ images.

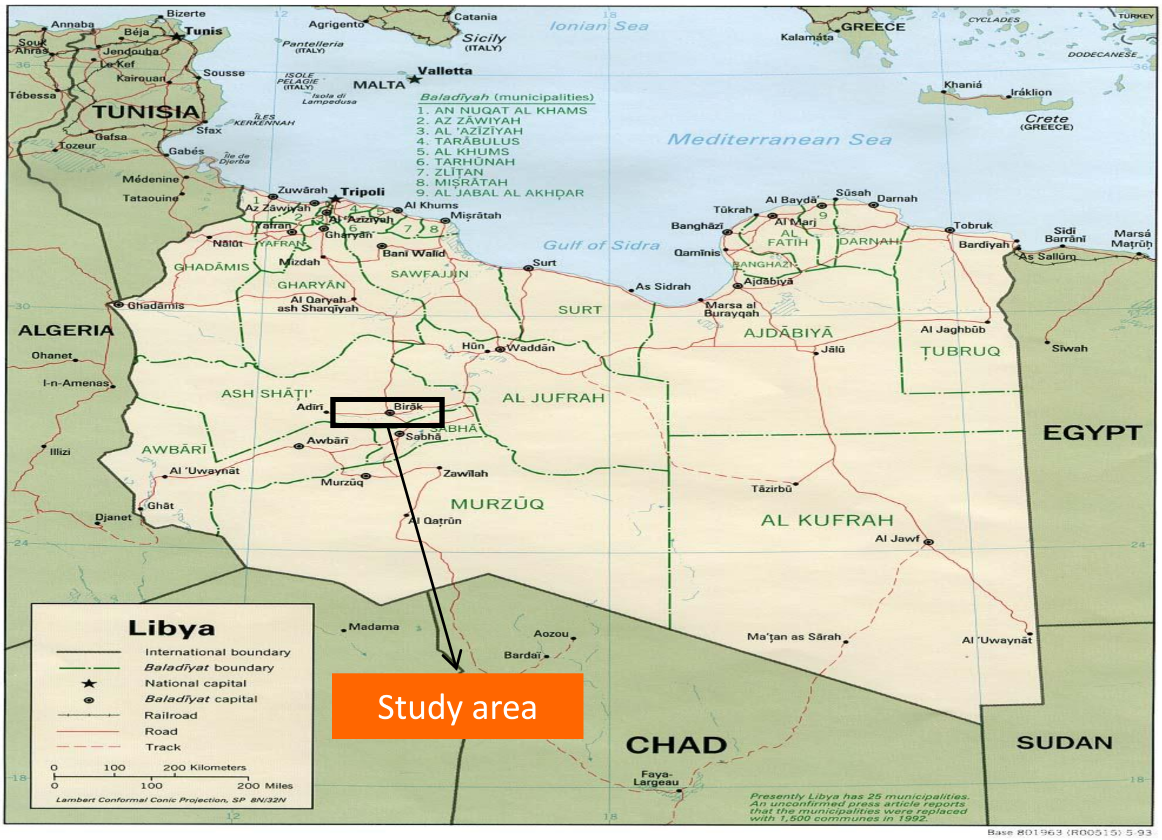

Figure 1: Location of the Study area

2. Methodology:

The methodologies applied in updating the geological map of the research area involved several steps. The literature review was the first step in deriving information about the general geology of the study area. This was followed by data preparation and pre-processing of remotely sensed images (Landsat ETM+, ERS-2). Pre-image processing such as radiometric corrections and image enhancement were employed in order to clearly visualize the image. During the image processing, all images were geo-referenced into one projection system. Images were subseted to the bounding coordinates of the research area. Appropriate band combinations were chosen for lithological and structural interpretations.

The Enhanced Thematic Mapper Plus (ETM+) instrument onboard this spacecraft is an eight-band multi spectral scanning radiometer, capable providing of high-resolution imaging of the Earth's surface. It detects spectrally filtered radiation in the visible, near infrared, middle infrared and thermal infrared bands of the Earth lit by the sun in a band 183 kms wide, when in orbit at an altitude of 705 kms. Nominal ground sample distances or "pixel" sizes are 15 meters in the panchromatic band, 30 meters in the 6 visible, near and midinfrared bands and 60 meters in the thermal infrared band.

Mosiacking methods were carried out using ERDAS Imagine 8.4 software to join three images of ETM+ (188-41,187-41 and 186-41) and produce one image covering the study area. The same steps were applied on ERS-2 images (17611-3051, 6818-3051, 18570-3051, 19300-3051, 18527-3051, 17611-3069, 6818-3069, 18570-3069 and 18527-3069) covering the investigated area. One image covering the area of study was produced and used for more analysis. Sub-setting is useful by working with large images. It is the process of “cropping” or cutting out a portion of an image for detailed processing. Both Landsat ETM+ and Radar ERS-2 images were subseted to produce identified image extended from 12° to 16° lat and from 27° to 28° long.

2.1 Supervised Classification Techniques:

Common classification procedures can be divided into two major groups subdivisions based on the method used: supervised classification and unsupervised classification. In the supervised classification, analysts mentioned in the imagery homogeneous representative samples of the different surface cover types (information classes) of interest. These samples are referred as training areas. The selection of appropriate training areas is based on the analyst's knowledge of the geographical area, and their knowledge of the actual surface cover types presented in the image. This means the analyst is "supervising" the categorization of a set of specific classes. The numerical information in all spectral bands for the pixels comprising these areas is used to "train" the computer to recognize spectrally similar areas for each class. A computer uses a special program or algorithm (of which there are several variations), provide numerical "signatures" for each training class. Once the computer has determined the signatures for each class, each pixel in the image is compared to these signatures and labeled as the class it most closely "resembles" digitally. Thus, in a supervised classification it should be identifying the information classes which are then used to determine the spectral classes which represent them [2] (Canada’s Centre for Remote Sensing 2008) .

Image classification is a very important method in the interpretation of remote-sensing data. The computer-assisted classification of an image automatically categorizes all pixels of an image into land cover classes [3] (Poovalinga.B et al. 2009). The selected bands (7, 4, and 2) have been used in the image-supervised classification technique namely maximum likelihood classifier (MLC) to classify lithological units. Geologic maps for Idri and Wadi Ash Shati published in 1984, [4] were used as reference ground data.

2.2 Principal Component Analysis:

Principal component analysis (PCA) has been called one of the most valuable results from applied linear algebra. The “principal component analysis transformation," is a multivariate statistical method used to compress multi spectral dataset into few PC images in which spectral difference between materials become apparent in PC image than individual bands [5] (Gillespie et al. 1986; Sabins 1987). Principal components are commonly calculated using the covariance matrix obtained from the input multi-spectral data whereby the corresponding eigenmatrices are also determined.

According to Canas and Barnett (1985) a standard colour composite image (any tree band display) contains 73% of the available image variance, whereas the principal composite image contains 97%. In order to involve all the bands into a RGB display, a PCA is performed [6]. By this way, most of the information is compressed into new channels. In this study, PC images are prepared to use three visible (R,G,B) and three infrared bands of available sub-set of Landsat ETM+ mosaic. The first three PC images contain 98.33% of the information of the six Landsat-TM bands.

2.3 Intensity-Hue-Saturation (HIS) Analysis:

IHS transformation is a process in which a band RGB composite is decomposed into intensity (I), hue (H), and saturation (S) components and after manipulated then it is transformed back to the RGB-space for interpretation. Intensity represents the brightness hue signifies the dominant wave length, and saturation is related to purity of a colour [7] (Sabins 1987). The advantage of this technique is its ability to effectively separate intensity and spectral information from standard image, and the possibility to convert IHS elements back to RGB -space. The resulting enhanced colour images are easier to interpret, as the spectral information (hue) is not changed during transformation. IHS transformation was applied to Landsat band 5, 3, and 1. For contrast enhancement saturation and intensity images stretched separately and both intensity and saturation stretched simultaneously by keeping hue image unchanged in both transformations. In both transformations, the different lithological units have similar colour as in the false-colour composite of Landsat bands 7, 3 and 1 with insignificant saturation and intensity improvement.

2.4 Data Fusion:

Merge is a free image merging application, which allows users to make use of its image merge feature for overlaying two images. Images may be in any relative position prior to saving the finished file. Merging images in various ways is one of the major features of this freeware image merger. If any two images are of different sizes, it is not a problem; merge can resize, reshape, scale and position all images. Many methods have been proposed for the merging of high spectral and high spatial resolution data in order to produce multispectral images having the highest spatial resolution available within the data set.

The general procedure for merging panchromatic information into the multispectral bands is to transform the original multispectral image into a new coordinate system in which one of the axes represents intensity [8] (Pellemans et al. 1993). The IHS is perhaps the most commonly used merging method. It consists of a numerical procedure developed to convert a three-bands (R,G,B) display into its fundamental physiological (IHS) elements of human colour perception [9] (Buchanan & Pendergrass 1980). As a result of applying the transformation an intensity component is obtained, which groups the information that is common to the three bands, which in turn is mainly related to the illumination changes caused by ground relief effects. The hue and saturation components contain the spectral information, corresponding to the reflectivity of the surface.

The main objective of data fusion in remote sensing is to create an integrated composite image to improve information sharing and greater intelligibility. This data has geospatial details about earth's surface and information on the ground for substantial assessment of land resources and mineral exploration. The data fusion of visible-infrared (VIR) and radar images is to produce additional information and increase the amount of data that can be extracted from the individual input images. Radar image contains the details beneath the surface coverage of the respective Radar Sar data while maintaining the basic colours content of the original VIR data. Image fusion can be on three different levels of processing, the pixel level, feature level and decision leve,l according to the stage where the fusion takes place. In this work, a pixel based image fusion from different sensors, namely Landsat ETM+ and ERS2 was performed using the Intensity, Hue, and Saturation (IHS) transformation procedures. The fusion can enhance the subsurface structures such as foliation, faults and folding that control mineralization of iron ore deposit in the study area and reveal the fluvial features which are not observable in Landsat ETM+ images.

Using the technique of IHS fused image is multiple, but based on one principle: the replacement of one of the three components (I, H or S) of a set of data with another image. In most cases, the channel intensity will be replaced. Changing the intensity - the amount of bands- by a higher spatial resolution value and reversing the IHS transformation leads to the composite bands [10] (Chavez et al 1991) .

3. Results and Discussion:

3.1 Supervised Classification Technique:

Image classification analysis is the most common analysis of multispectral remotely sensed data in order to produce thematic maps that provide a representation of the spatial distribution of a particular theme [11] (Foody & Mathur 2004). Multispectral classification is useful to obtain information on land cover and surface properties. It helps to translate continuous variability of image data into map patterns that provide meaning to the user. The computer-assisted classification of an image automatically categorizes all pixels of an image into land cover classes.

The selected bands (7, 4 and 2) have been used in the image-supervised classification technique namely Maximum Llikelihood Classifier (MLC) to classify lithological units. Geologic maps for Idri and Wadi Ash Shati published in 1984 were used as reference ground data. supervised (M L C) method carried out in this study since this classifier considers the shape, size and orientation of the cluster as well as variability within the cluster. Training sets for seventeen classes of lithological units were used based on the available field observation datasets and geological map of the area.

Input bands determined in the above mean digital numbers values for lithological units were used. Bands (7, 4, and 2) in R.G.B of the study area for Landsat ETM+ images were used in the classification. Pixels were initially selected from the image that represented land cover (different types of rocks).

Seventeen different rock types were classified and confirmed with ground truth verification based on the geological map of the area and field trip. The results of image classification show that the iron ore body (appears in red colour on the map) extends towards the west and northwest of the known iron ore deposit (Wadi Ash Shati) and new areas of iron ore detected by supervised classification that these area carrying the same DN value with the existing iron ore body. The results of supervised classification shown in Figure 2.

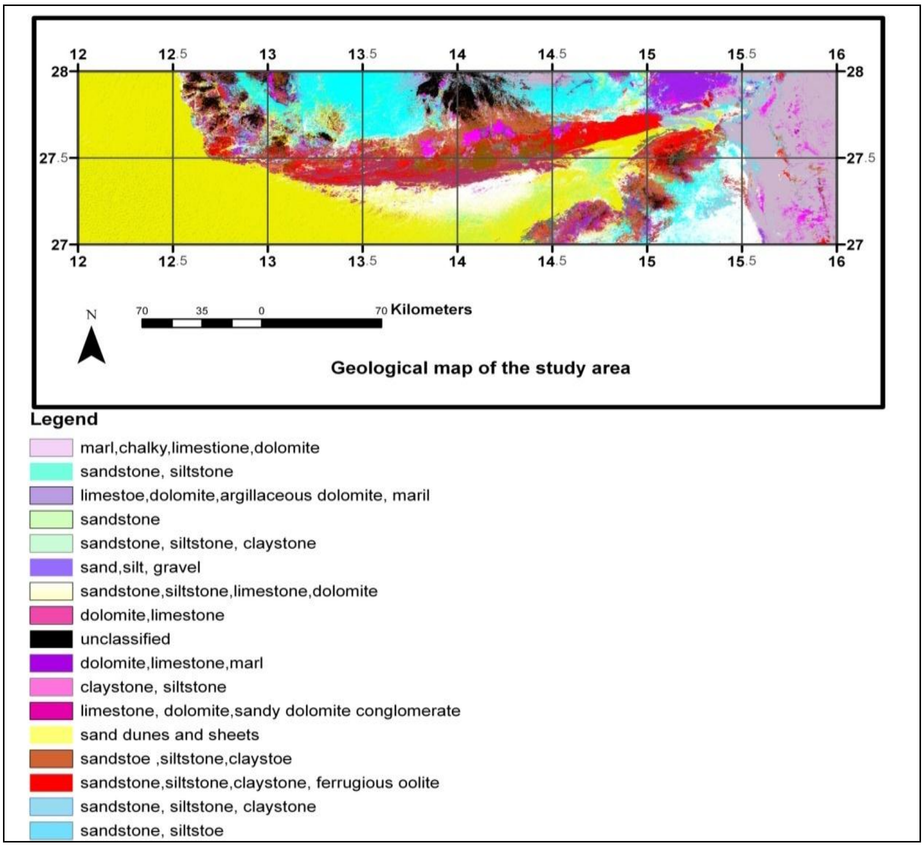

Figure 2 : Classification map of the study area

3.2 Principal Component Analysis (PCA)

In this study, PCA was performed on 7 bands covering VIB, VNIR and SWIR. PC 1, with 75% variance, contains geologic and topographic information and that accounts for high correlation between the input bands. The PC images were prepared using three visible (VIS) and three infrared bands of available sub-set of Landsat ETM+ mosaic. The first three PC images contain 98.33% of the information of the six Landsat-ETM+ bands. PC1, PC2, and PC3 display for lithologic contrast and the rest of the PC (PC4 to PC7) appear to be less informative in terms of lithologic discrimination but the iron ore body still appears very clear as shown in figure 3. RGB composite of PC1, PC2 and PC3 have better colour contrast. It allowed best lithologic discrimination and the iron ore belt appears very clear in yellow colour on the map (Figure 3). Landsat ETM+ image can be widely used to generate exploration targets in Wadi Ash Shati area using the wavelengths characterized by iron absorption.

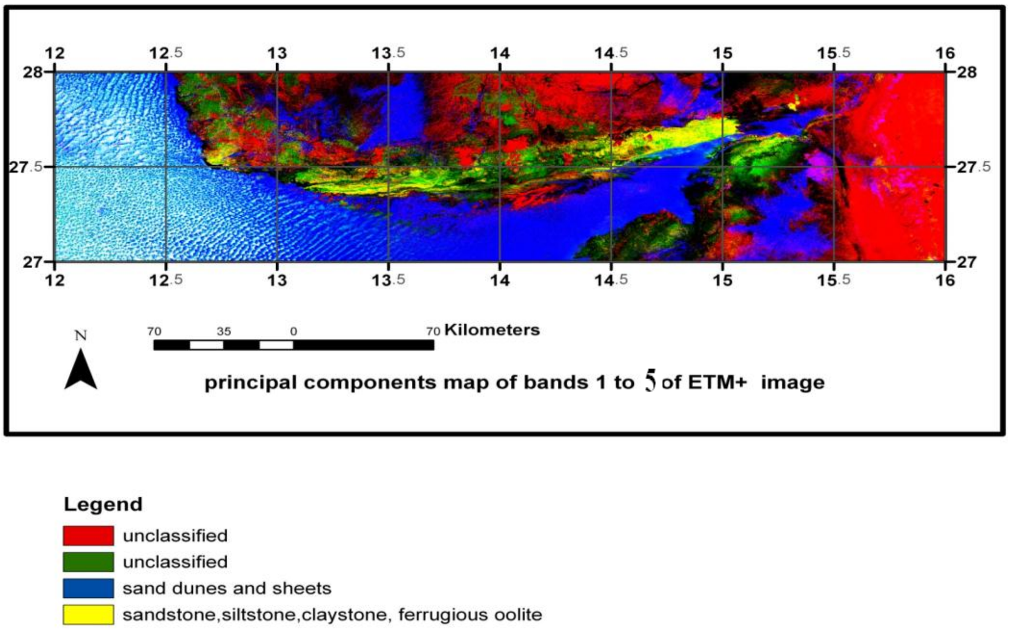

Figure 3 : RGB colour composite of PCA 1, 2 & 3 of the study area

3.3 Intensity-Hue-Saturation Analysis (HIS)

This procedure led to an excellent spectral discrimination and interpretation of the study area. In this study, a method was presented by which transforming the spectral information of a three-channel composite to intensity-hue-saturation the iron ore belt mapping can be easily achieved. The hue component has been proven to be very useful for iron area mapping, because the spectral behavior of the iron category pixels is well differentiated from other land-cover, land-use categories.

As shown In the Figure , the iron ore belt (dark-blue colour) can be easily distinguished from the surrounded rocks in the area. Among the original spectral channels of Landsat-7, ETM+, the spectral information contained in TM4, TM7, and TM2 proved to be the most valuable in mapping iron ore areas.

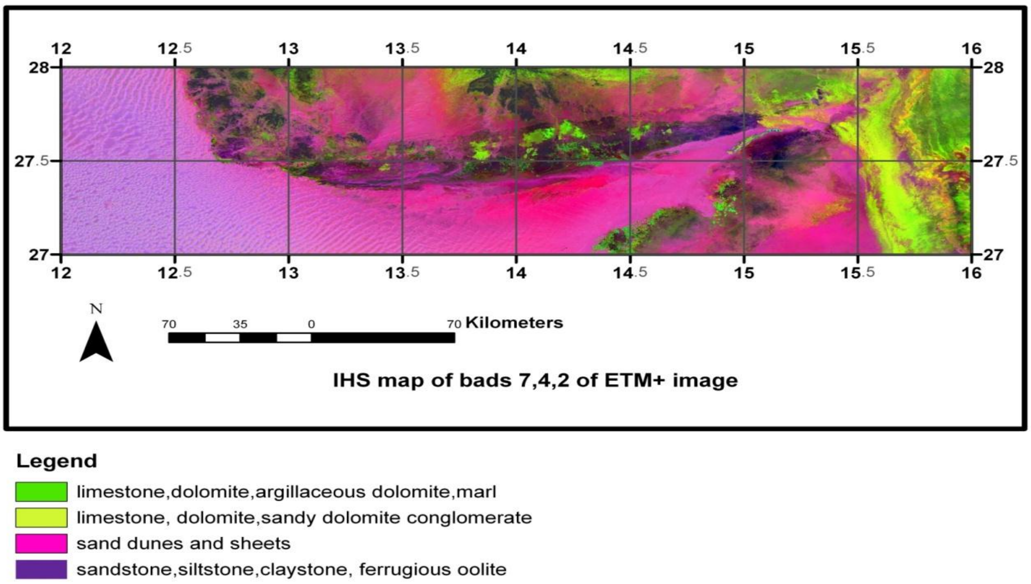

Figure 4 : IHS colour composite of TM (7, 4 & 2)

3.4 Image merging:

Data used in this study area were Landsat ETM+ scene (Path: (186-188) Row: 41) 28.5 m resolution, and RADARSAT ERS-2 scene, 28.5 m resolution. These images were processed using the ERDAS Imagine, version 8.7 software.

IHS method is applied to three bands at a time, whose fusion output is displayed in either true or false colour. Therefore, three selected bands from the Landsat scene; 7 (2.08 - 2.35 µm), 4 (0.76 - 0.90 µm) and 2 (0.52 - 0.60 µm) were used to contain most of the information about the surface geological features of the study area

This procedure led to an excellent spectral discrimination and interpretation of the study area. The most important finding of this study is the appearance of features beneath the sand surface on the fused Landsat ETM+ and ERS-2 images.These features are not observable at all on the Landsat ETM+ image of similar spatial resolution therefore; new geological and structural information was achieved with regard to the drainage pattern, lithological and structural features.

The output fused image brought up the buried iron ore in the study area which was covered by sand dunes within (0.5. to 1) m thickness and the aridity of the sand and soils permitted radar subsurface penetration and capturing of the feature in the returned signal.

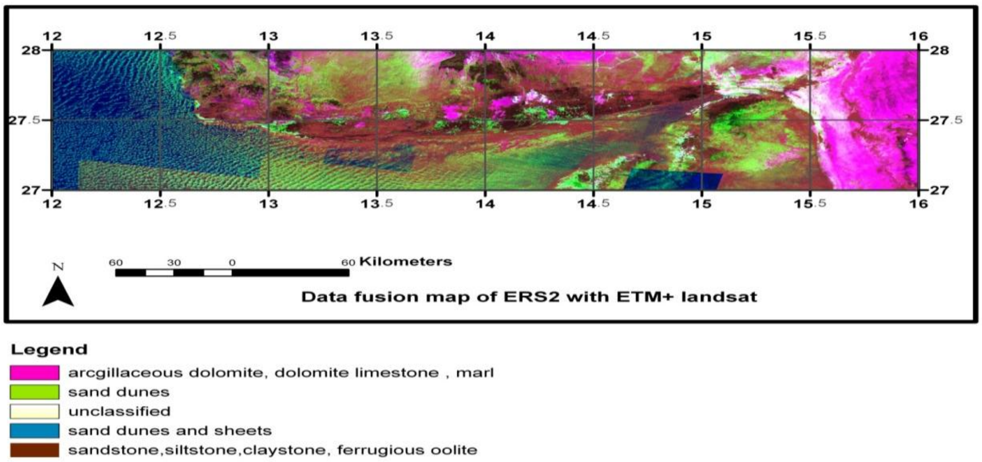

Figure 5 : Interpretation from Landsat ETM+ / ERS-2 fused image

Conclusions :

This study showed that remote sensing techniques provide an efficient tool for geological mapping. Different processing techniques were applied to the Landsat ETM+ and Radar images to discriminate and delineate the lithological units and regional lineaments moreover, remote sensing has proven a valuable aid in exploring mineral resources.

During the processes of image interpretation, geological maps were used as a base map to extract information on major lithologic units. Multispectral image enhancement and interpretations were important in identifying and delineating lithological units, including iron ore deposit in the study area. A wide variety of digital image processing techniques were applied such as the Supervised Classification, Principal Components (PC) analysis, Intensity Hue Saturation (IHS) transformation and data fusion with Radar Sat-2 data.

The composite colour of Principal Components (1,2,&3and7,5&4), and the IHS (7, 4, 2) enabled to determine the iron ore body in the study area and **discover new areas of occurrences of iron ore** .

The fusion of ETM+ and ERS-2 were based on the use of IHS transformation with the output fused image improves visual detection of iron ore covered under sand dunes sheets, and wadi alluvium, was make it undetectable in Landsat ETM+ data. This study demonstrates the importance of using proposed remote-sensing technique (merging Landsat ETM+ and Radarsat data) in mineral exploration to detect the covered mineral deposits in the area of Wadi ash Shati and surrounded areas.

References:

- *Buchanan, M. D., & Pendergrass, R. 1980. Digital image processing can intensity, hue and saturation replace red, green and blue? Electro-optical systems designs 12 (3):29-36.*
- *Canas, A., & Barnett , M. 1985. The generation and interpretation of false-colour composite principal component images. International Journal of Remote Sensing 6:867-881.*
- *Canada's Centre for Remote Sensing 2008 .*
- *Chavez, P. S., Sides, S. C., &Anderson, J. A. 1991. Comparison of three di€ erent methods to merge multiresolution and multispectral data: TM & SPOT pan. Photogrammetric Engineering and Remote Sensing 57:295- 303.*
- *Foody, G. M., & Mathur, A., 93, . 2004. Toward intelligent training of supervised image classifications: Directing training data acquisition for svm classification. Remote Sensing of Environment 93:93-107.*
- *Geologic maps for Idri and Wadi Ash Shati published in 1984*
- *Gillespie, A. R., Kahle, A. B., &Walker, R. E. 1986. Colour enhancement of highly correlated images Decorrelation and HSI contrast stretches. In Remote Sens. Envir. New York, NY.*
- *Poovalinga.B, Rajendran.S, A. T., M. K. 2009. Visualizing Uncertainty-How Fuzzy Logic Approach can help to Explore Iron ore Deposits. Indian Soc.Remote Sens. 37:1-8.*
- *Pellemans, A. H., Jordans, R. W., &Allewijn, R. 1993. Merging Multispectral and Panchromatic Spot Images with Respect to the Radiometric Properties of the Sensor. Photogrammetric Engineering and Remote Sensing 59:81-87.*
- *Sterojexport 1977. Clays investigation of Wadi Ash Shat. Tripoli Industrial Research Center.*
- *Sabins, F. F. J. 1987. Remote Sensing Principles and Interpretation. Edited by ed, n*