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Feature level fusion for enhanced geological mapping of ophiolile complex using ASTER and Landsat TM data

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Abstract. Chromite ore deposit occurrence is related to ophiolite complexes as a part of the oceanic crust and provides a good opportunity for lithological mapping using remote sensing data. The main contribution of this paper is a novel approaches to discriminate different rock units associated with ophiolite complex using the Feature Level Fusion technique on ASTER and Landsat TM satellite data at regional scale. In addition this study has applied spectral transform approaches, consisting of Spectral Angle Mapper (SAM) to distinguish the concentration of high-potential areas of chromite and also for determining the boundary between different rock units. Results indicated both approaches show superior outputs compared to other methods and can produce a geological map for ophiolite complex rock units in the arid and the semi-arid region. The novel technique including feature level fusion and Spectral Angle Mapper (SAM) discriminated ophiolitic rock units and produced detailed geological maps of the study area. As a case study, Sikhoran ophiolite complex located in SE, Iran has been selected for image processing techniques. In conclusion, a suitable approach for lithological mapping of ophiolite complexes is demonstrated, this technique contributes meaningfully towards economic geology in terms of identifying new prospects.

1. Introduction

The Sikhoran ophiolite complex is one of the large ultramafic-mafic complexes situated in Esfandagheh, southeast of Iran. This mafic-ultra mafic complex is exploited for the chromite ore deposit since 1985. Because of the geographically, geologically and the extent of the area a complete sampling and lithological mapping is difficult. Mapping and studing this ophiolit complex is necessary due to exploration new source of chromite ore deposits.The Remote sensing techniques are capable to provide more opportunities for detailed mapping and exploration new source of chromites in the ophiolite complex and also decrease the cost and time consuming [1-4].Remote sensing techniques are appropriate technique for employing in arid and semi-arid regions like Sikhoran ophiolite complex where the rock exposures over the surface and no vegetation disturbance [5-7].

In this paper, we delineated the area of chromites bearing mineralized zone by analyzing the capability of the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) sensor image evaluated along with the Landsat TM image. To achieve research objectives the future –level fusion technique is employed to ASTER and Landsat TM data. In addition to recommend the techniques to the exploration geologists, industrialists and mine owners avoiding their ambiguity on more exploration and exploitation of similar deposits in the arid region by analyzing the capability of the ASTER and Landsat TM data.

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2. Material and methods

2.1. Geologic setting

The Sikhoran ophiolite (57° 01′ 16″ E, 28° 29′ 35″ N) is a part of the Esfandagheh ultramaphic complex, and located in sanandaj-sirjan tectonically zone [8]. The Sikhoran ophiolite complex is composed of series of ultramaphic rocks. Peridotites are the large part of ultramaphic rocks, which is composed of dunite, harzburgite, verlite, serpentine, and a little Lherzolite. The mineralogical components of the predotites rocks are composed of olivine, orthopyroxen, clinopyroxen, chrome spinal and serpentine and magnesite as secondary minerals. In addition dunites and harzburgites as bedrocks of chromite and magnesite have coarse granular texture with evidence of grain boundary migration and annealing. Two generations of minerals observed in these rocks respectively completely deformed and is non-deformed which have been probably recrystallized from ascending melts. In sikhoran ophiolite complex different types of minerals are recognizable and gabbro layers with cumulate textures outspread in this area. Diabasic dykes in this area indicated the last magmatic [9,10]. The earth's surface is well-exposed due to very sparse to nonexistence vegetation cover (Figure 1).

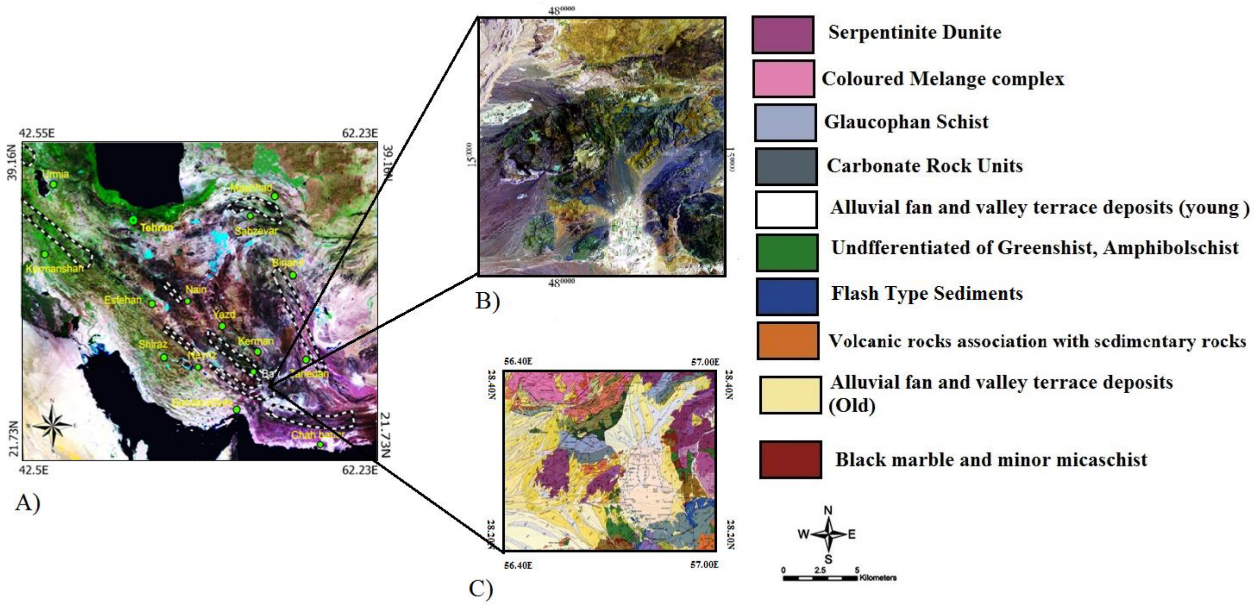
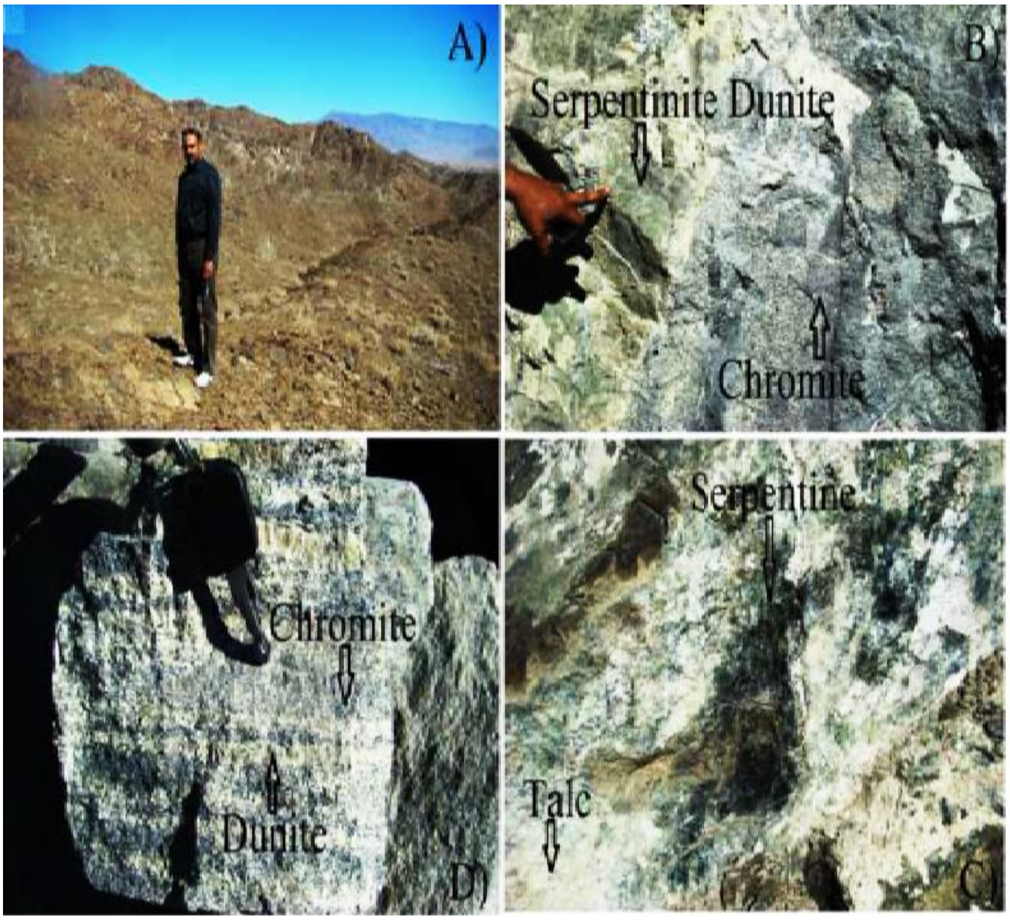


Figure 1. Location of ophiolite complex (A), Overview of ophiolites (B), Geology map of study area.

Based on the petrology studies the Sikhoran harzburgites have been made by partial melting of subcontinental lherzolites with minor percolation of later melts. Mineral chemistry shows this complex is likely a part of mantle diaper. Firstly, the diapir is partially melted and resulting melts form transition zone and layered gabbro and secondly the partial melting, ultramafic sills and isotropic gabbro were formed and move upward. These could have reacted with host peridotites and formed chromite bearing dunites. It is possible that in early Kimmerian orogenic phase, the Sikhoran ophiolite rock units were metamorphosed up to amphibolite facies [11]. Figure 2 shows the overview of the study area.



Figures 2: The panoramic view of the peridotiets rocks (A); The layer of Chromite and Serprntinit dunite (B); Serpentine and Talc (C) Chromite and dunite veins (D).

2.2. Remote sensing data

The ASTER data used in this study were obtained from the Earth and Remote Sensing Data Analysis Center (ERSDAC) Japan, and consist of a cloud-free level 1B scene that were acquired on February 15, 2007 in the study area. The level 1B data product measures radiance at the sensor, without atmospheric corrections, and were produced from the original level 1A format by ERSDAC. The 1B format data also has been applied for both geometric and radiometric corrections. The images have been pre-georeferenced to UTM zone 40 North projections with WGS-84 datum. The Landsat TM image was obtained through the U.S. Geological Survey Earth Resources Observation System (EROS) Data Center (EDC). It is a cloud-free image (0% cloud cover) that collected on February 25, 2008 for the study area.

2.3. Image processing methods

2.3.1. Preprocessing of ASTER and ETM$^+$ Data. The crosstalk correction was performed on ASTER SWIR subsystem, aimed at removing the effects of energy overspill from band 4 into bands 5 and 9 [12]. We have performed this correction by Cross-Talk correction software available from www.gds.aster.ersdac.or.jp. Atmospheric correction was applied by Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLAASH) algorithm on VNIR and SWIR of ASTER subsystems [12]. Geometric correction has been applied to Landsat TM datasets using ACRES software. It has included the application of pre-defined models to reduce the effects of earth rotation.

2.3.2. Image processing methods used. To discriminate the location of high-potential areas of Chromite mineralization in a regional scale and also determining of suitable technique for lithological mapping the feature level fusion is used in the study area. . In addition this study has applied spectral transform approaches, consisting of Spectral Angle Mapper (SAM) to distinguish the concentration of high- potential area of chromite and also for determining the boundary between different rock units. This method has not reported in scientific literatures for ophiolite complex lithological mapping, thus it is applied to ASTER and Landsat TM data in this study. Over flowchart illustrating the different of the research and suggested techniques is described in figure 3. It is included mainly of four steps. First correction step including data gathering and atmospheric and geometrical correction. Then the second step involved coarse classification. In this step, the spectral angle mapper (SAM) was used for both ASTER and Landsat TM data. On the third step, based on SAM results the futures involved different minerals and rocks were extracted. And in step four the geological map using the feature level fusion technique was prepared. Finally the results compared to laboratory analysis and field investigations.

2.3.3. Data fusion techniques. Data fusion as a general technique is useful to combine data from different multiple sources to enhance the potential value and to produce data with better visible representation. This method employs different applications such as identification, classification, identification and object detection (Zhang 2009). In addition image fusion techniques increase interpretation abilities for data with different characteristics such as variations in spectral, spatial resolution which gives more complete information and detailed view of the observed features. Generally data fusion techniques in remote sensing divided into different levels including: pixel/data level, feature level, and decision level [13,14]. An illustration of the concept of pixel- level fusion is the combination of the raw data from multiple sources into data with a single resolution which are expected to be more informative and synthetic than either of the sets of input data or which reveal the changes between datasets acquired at different times [14].

Using feature- level fusion need to extraction of different features such as edges, corners, line and texture parameters from various types of data and then combination these into new feature maps which may be used for additional processing instead of the original data. This is particularly important when the number of available spectral bands becomes so large that it is impossible to look at each band separately [13]. The characteristics of specific source data have a major role to determine and extracting features. Hence may be various if the datasets employed are heterogeneous. Usually in remote sensing this type of image fusion requires pixel- level registration of the available data. Feature maps are resulted as preprocessing for satellite data separation or change detection.

For example features involve edges, corners, lines and texture parameters are distinguished and integrated in a fused map which may use for image separation or change detection. The definition of decision-level fusion is a combination of the results from multiple algorithms to yield a final fused decision. When the results from different algorithms are expressed in confidences (or scores) rather than decisions, it is called soft fusion; otherwise, it is called hard fusion.

3. Results and discussion

3.1. Feature fusion technique on ASTER and Landsat TM

The Multisensory image fusion technique is well executed in the geology investigations and a widely employed technique for lithological mapping [13]. Clearly known that the use of Multisensor data will enhance the interpretation abilities of the images. Geological features that are not able to visible in the single data are distinguished from integrated. Using feature- level fusion need to extraction of different features such as line and texture parameters and etc from various types of data and then combination these into new feature maps which may be used for additional processing instead of the original data. This is particularly important when the number of available spectral bands becomes so large that it is impossible to look at each band separately [13]. On the other hand spectral angle mapper (SAM) was used for ASTER and Landsat TM data for detection in different lithologies and rock units and also for regional mapping. For apply SAM to detect minerals the default value 0.10 was employed for threshold angle of each end member mineral. In addition in this study the spectral absorption of minerals in VNIR +SWIR bands of ASTER and Landsat TM was used to distinguish defined end member.

Due to the different characteristics of spectral features, the spectral angle mapper techniques (SAM) employed on ASTER and Landsat TM images to extraction features separately. And then the geological map based on spectral angle mapper results is prepared (Figure 6). The result showed that the Colored mélange complex including ophiolite component, volcanic rocks, keratophyre, radiolarian cherts and plagic limestone in association with Eocene sedimentary rocks, the Mafic and ultra-Mafic rock unit , the Gloucophan & Amphibolite schist and Quaternary sediments distinguished in ASTER data as dark blue, light blue, brown and white Color respectively (Figure 4). And also the result of SAM technique on Landsat TM data showed that Harzburgite with minor Dunite, Dunite & Serpentine and Alluvial fan and valley terrace deposits as green, yellow and red color were detected respectively (Figure 5). In the next step we tried to generate a geological map based on feature- level fusion technique of ASTER and Landsat TM data. To achieve this objective we used ENVI, ERDAS and Arc GIS softwares. And also to evaluate the results, the final geological map checked with true geological map. The produced map showed that this technique is suitable for geological mapping of ophiolite complex in regional scale. This study recommended the application of the methods used for exploration the new chromite ore deposits and lithological mapping of the ophiolite complexes especially in arid and semi-arid regions and also un-accessible and remote areas (Figure 6).

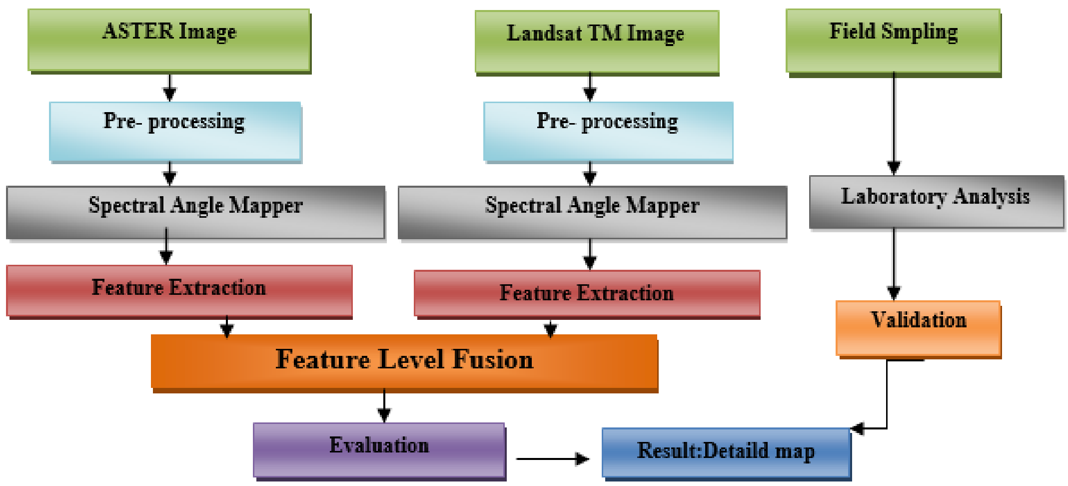


Figure 3. The flow chart of process and methods.

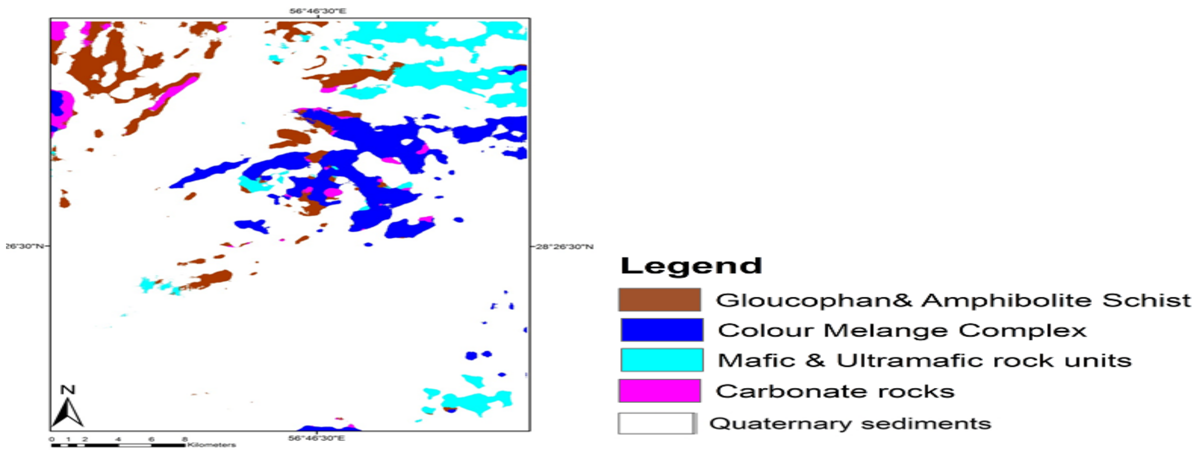


Figure 4: SAM result using ASTER data.

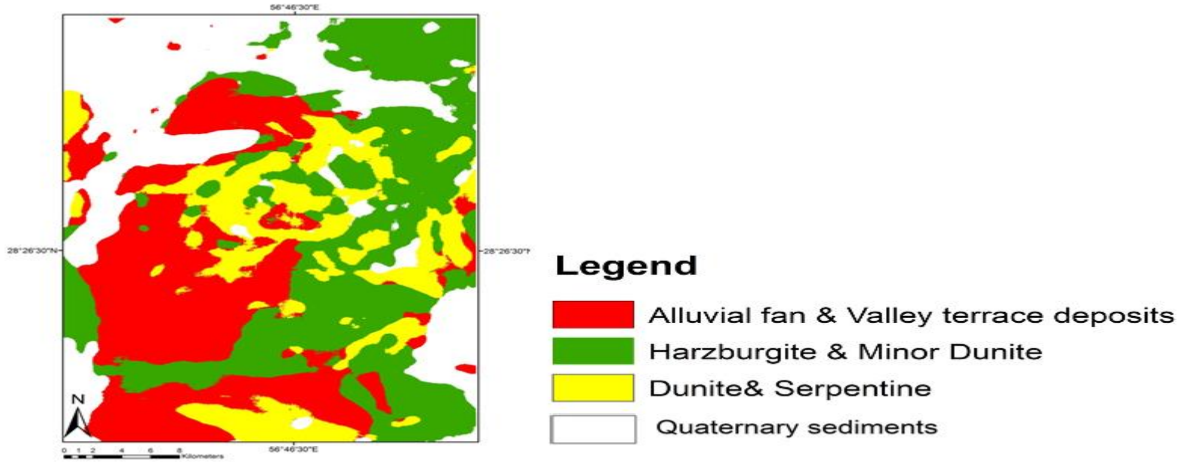


Figure 5. SAM result using Landsat TM data.

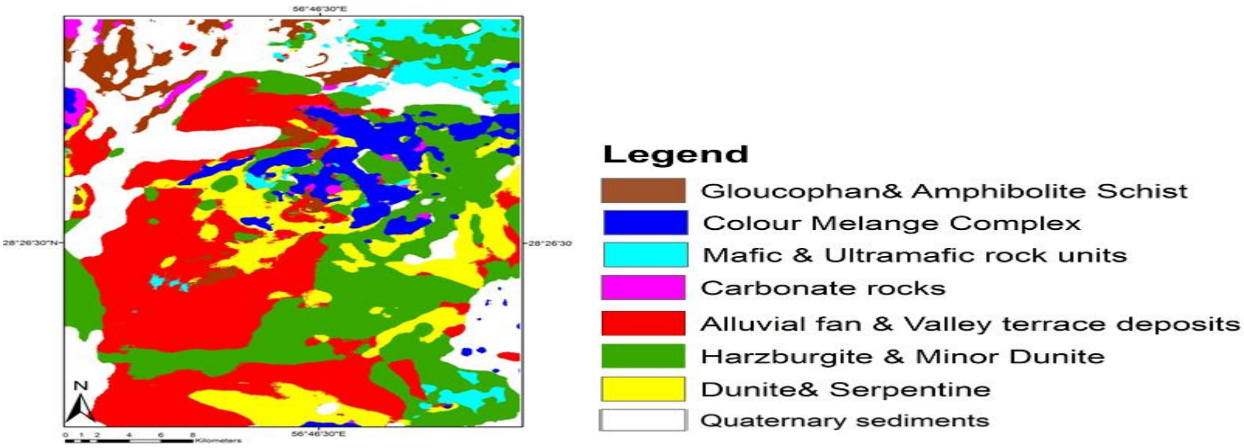


Figure 6. The geological map of study area using feature – level fusion technique on ASTER and Landsat TM.

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