Application of remote sensing techniques in alluvial sampling design for exploration of placer deposits in the semi-arid areas

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Abstract:

Alluvial sediments are important for exploration of gold, diamond, ilmenite, etc. It is important to search for such kind of deposits by using ground sampling. The important question is that, where to collect samples? One has to have a comprehensive knowledge of the regional geology, the type of expected source rocks, the geomorphic and climatic factor and the type of deposits considered for exploration. By refereeing to the geological maps, one can not classify the alluvial deposits based on their source rocks. They are usually classified according to their type (silt, clay, gravel, sand etc.) or according to their age (quaternary, Recent etc.). As the alluvial deposits are composed of different assemblages of minerals, it is possible to map the alluvial deposits based on their source lithologies by using multispectral satellite images. In the arid and semi-arid types of climate it is much easier to separate different alluvial deposits according to their source lithologies. In this study Both ASTER and ETM+ data are used to show that the source lithologies and the spatial distribution of their alluvial deposits can be clearly mapped by different image processing techniques. Once this is done, the sampling design should be very cost effective. Shahre-e-Babak and Kahnouj areas which are located in Kerman province in Iran are chosen as test areas to show the capability of remote sensing technique for the exploration of alluvial deposits.

Key words: Alluvial sediments, geochemical sampling, remote sensing, ASTER, ETM+

Introduction:

Rocks that compose the earth's crustal layers are subject to denudation following weathering. This causes loose materials in the supergene zone to be formed whose

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physical properties differ very much from those of the parent bed rock. The resistant minerals can withstand weathering and the less resistant ones are decomposed to the new minerals. The alluvial sediments are rich sources of gold, uranium, thorium, zirconium, titanium, mercury etc. A primary lithological halo, secondary auresole and dispersion flow, owing to their large dimensions and occurrence close to the ground surface are easier to detect compared with a concealed ore body. Therefore the discovery of a deposit is made possible by geochemical methods of search for its primary and secondary halos and dispersion auresoles and flows (Solovov, 1987). Figure 1 shows a typical concealed ore body and its dispersion flows.

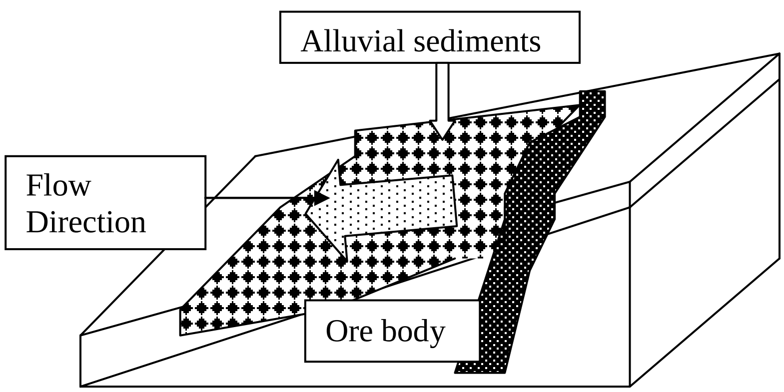

Figure 1: Block diagram of supergene dispersion due to presence of an ore body and a natural topographic gradient.

Alluvial fans are most common in, and characterized of, regions with arid and semiarid climate, although some fans occur in more humid environment as well. In arid regions the material in these fans is derived from erosion of the adjacent mountains, then transported by infrequent but torrential floods down steep-gradient streams towards the basins.

Traditional sampling in the alluvial sediments are consisting of systematic or random sampling from the alluvium which are usually time consuming and not accurate. The sampling design is based on the geological maps in this method. As we know, the alluvial sediments in the geological maps are mainly classified either based on their ages or types . If the source rocks of the alluvial deposits are known, the sampling design can be set more efficiently and accurately. Remote sensing can play an important role in sample collection by reducing the area under the investigation through directed sampling. Knepper et al., 1994; Navai and Mehdizadeh-Tehrani, 1994 have reported the application of remote sensing on exploration of aggregates and placer deposits.

Remote sensing instruments measure reflected or emitted radiation in the visible, near-infrared, thermal infrared, or microwave portion of the electromagnetic spectrum to obtain information about the earth's surface from a distance. Satellite images have long been used as an effective exploration tool that can be used on detection of associated hydrothermal minerals, associated structural elements and lithological mapping (Drury, 2001; Gupta, 2003; Jensen, 2000). The spectral resolutions of the new remote sensing data such as ASTER and ETM+ data can help in differentiation of varieties of lithological units. The semi-arid type of environment is a paradise for application of remote sensing data for lithological mapping due to poor vegetation cover. The aim of this work is to use satellite data (ASTER and ETM+) for mapping lithological units and their derived alluvial materials.

The areas under investigation have a mountainous topography, but there is a sharp decrease in the elevation, where alluvial sediments are formed. The climate is typical of continental and semiarid, with vegetation cover consisting of low shrubs and bushes with occasional trees in the mountains, along the streams and near settlements.

Geology

a- North of Shar-e Babak area

Cretaceous sediments are mainly flysch that are the oldest lithology in the area. Eocene volcanic rocks are subdivided into the Bahr-e-Aseman complex and the Lower Razak, Middle Razak and Upper Razak complexes. These rocks are represented by pyroclastics, pyroxene trachyandesites, pyroxene andesites, trachyandesites, trachybasalts, tuffaceous sediments, basaltic rocks and andesites. The sedimentary rocks in the volcanic-sedimentary complex are mainly sandstone and, less frequently limestone. The Neogene sediments consist mainly of loosely consolidated, unsorted and poorly stratified conglomerate and sandstone overlying the Eocene volcanic-sedimentary rocks. Calcareous terraces and recent alluvium are the main sedimentary units formed in the Quaternary (Dimitrijevic , 1973).

b-South of Kahnooj City

The area located just 25 kms south of Kahnooj City is covered by alluvial deposits which are rich in TiO_2 . Band-e Ziarat mountains with north south trend have a length of about 50 kms and a width of 15 kms. The gabbroic mass that forms the core of this mountain belongs to the ophiolitic formation of Early Paleocene to Early Cretaceous is suggested to be the source rock. The tectonic activities along with physical weathering have given rise to the formation of vast alluvial deposits in the form of alluvial fans along the eastern and western flanks of Band-e-Ziarat Mountain. The sediments located on the western side of Band-e-Ziarat Mountain are rich in ilmenite (up to 12%)(Kousary, 1983).

Data and methodology

ETM+ subscenes (path 161, Row 39 dated 8/4/2002 for north of Shahr-e-Babak and path 159, Row 41, dated 21/7/2002 for Kahnooj area) and ASTER data for north of Shar-e-Babak area (summer of 2001) are used for the present work. Image processing was aimed at enhancing the contrasts related with lithologies. ENVI and ERMapper soft wares are used for processing the images.

Data analysis and discussion

The striking features of the lithologies and their derived alluvial materials are the similarities between their spectra (Figures 2 & 3). By comparison of the spectra derived from the images, one can come to the conclusion that it is possible to relate the alluvial sediments to their parent lithologies.

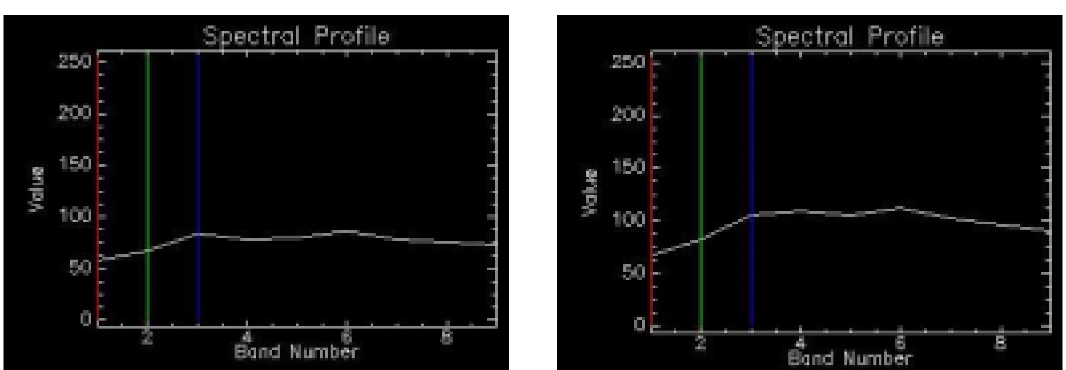

Figure 2: Reflectance and absorption profiles of flysch (left) and the derived sediments(right) . The DN profiles are plotted from the

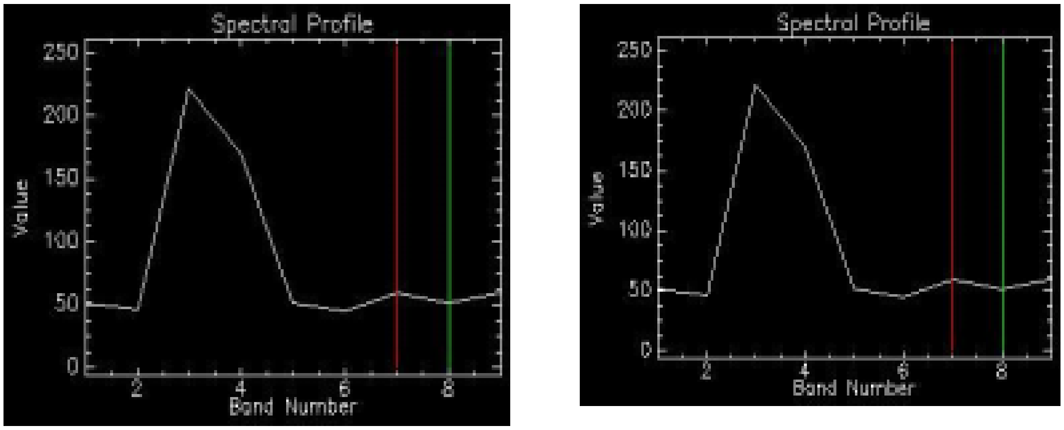

Figure 3: Reflectance and absorption profiles of the Eocene volcanic rock(left) and the derived sediments(right) . The DN profiles are plotted from the ETM+ bands. Here the first band is on the right and band 7 is on the left side of the diagram.

In order to enhance the spectral differences between different alluvial sediments in the ETM+ images for the north of the Shar-e-Babak area, varieties of image processing techniques such as false color composites of thermal, band7, band8(pan); band7, band4, band1; band5, band3, band1; color composites of band ratios 5/7, 5/4, 3/1; 5/7, 3/2, 4/3; 5/7, 3/1, 4/5; principal component analysis; RGB to HSI transformation are tried out. The examination of these images showed that only false color composites of Band 7, band4, band1 ; and RGB to HSI transformation of band5, band3 and band1 are useful for differentiating different alluvial sediments(Figure 4). The band ratio images are useful for enhancing the areas rich in clay and iron oxide minerals. The color composite of thermal band, band7 and band8(pan) is also useful for relating the alluvial sediments to their source rocks, especially those sediments which are dark in color. As the thermal image in the data used here is acquired during the day, the darker rocks especially those volcanic rocks with basic composition are brighter in thermal images.

Different image processing techniques were applied on ASTER images. Principal component technique was found to be useful for enhancing the lithological variations. False color composite of PC1, PC2 and PC3 (in red, green and blue) shows different lithological units and their derived sediments in different color. As shown in figure 5, it is possible to find out the source rocks of the alluvial sediments.

Similar image processing techniques are applied for the Kahnooj area (Figure 6). and-e-Ziarat Mountain are

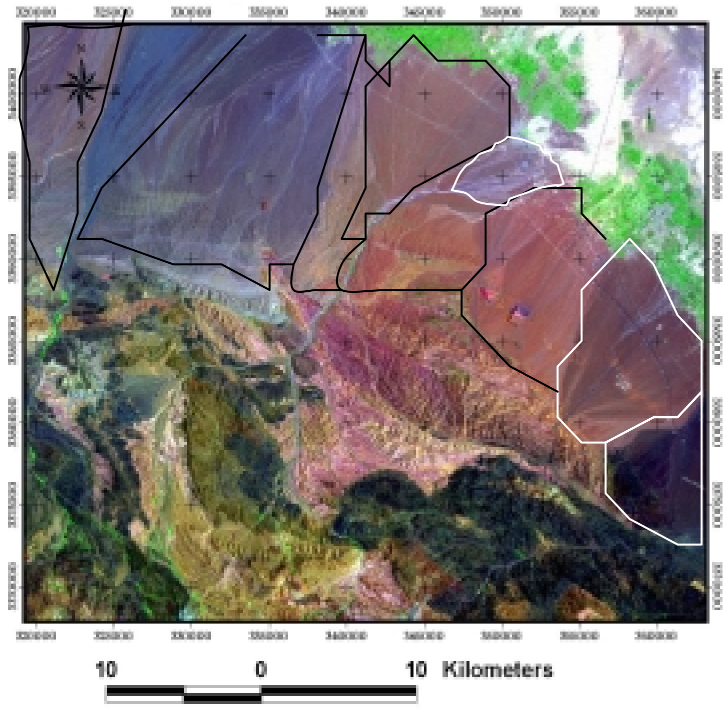

Figure 4: ETM+ image that covers northeast part of Shar-e-Babak City. Different alluvial sediments are marked in the image.

rich in ilmenite. Out of all the image processing techniques that tried on these images, the color composite of bands 5, 3, 1 in red, green and blue respectively was found to be a good image for separation of different alluvial sediments. The FCC of thermal band, band7 and band pan in red, green and blue showed that the extent of the derived alluvium from gabbros can be defined.

Referring to figures 4, 5 and 6 it is possible to classify alluvial sediments and fin out the source rocks. If a source rock is assumed to be a potential target, by examination of the processed satellite images, the spatial distribution of its alluvial sediments can be determined. The geographical coordinates of the samples can then be determined on the geometrically rectified images. Based on this method the sampling from the alluvial sediments that do not have any exploratory potential is avoided. The drawback of this method is that, it can be utilized mostly in the arid and semi-arid environments. The areas which are under a constant deposition of wind- blown materials are also may not be suitable for application of this method.

Summary and conclusions:

Alluvial deposits are economically important for exploration of gold, diamond,

ial sediments based on

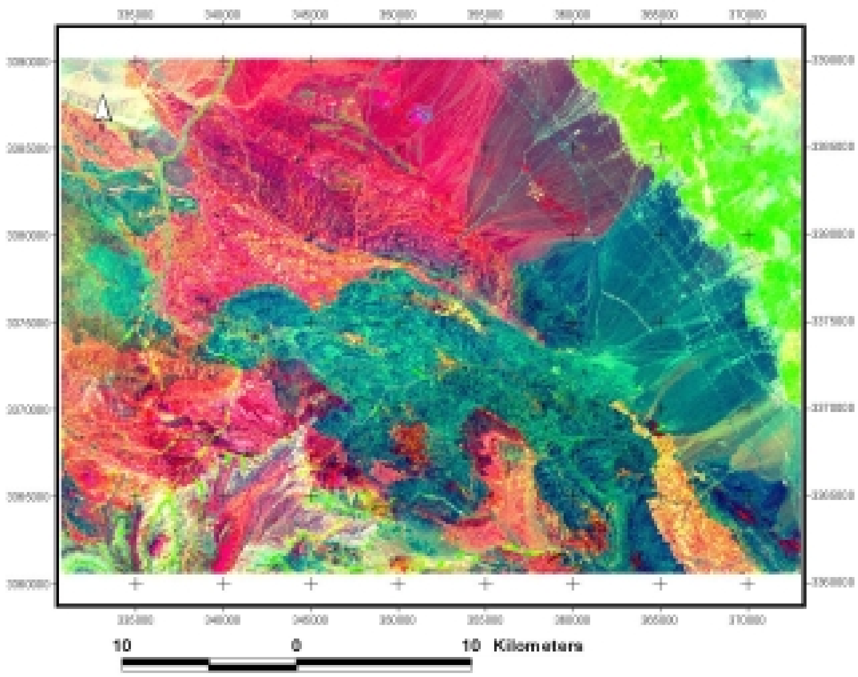

Figure 5: False color composite of PC1, PC2 and PC3 in red, green and blue of ASTER data. The image covers an area northeast of Shar-e-Babak City. The alluvial sediments can clearly be related to their source lithologies.

their composition and their source rocks. By refereeing to the geological maps, one can not classify the alluvial deposits related to their source rocks. They are usually classified according to their type(silt, clay, gravel, sand etc.) or according to their age (quaternary, Recent etc.). Multi-spectral remote sensing systems can classify different alluvial sediments based on spectral characteristics of their mineralogical compositions.

Two areas are selected to demonstrate the capabilities of ASTER and ETM+ data for mapping the alluvial sediments in arid areas of southern Iran. The analysis of ETM+ showed that FCC of bands 7-4-1, 5-3-1 and 6-7-pan are very useful for enhancing different alluvial sediments. The analysis of ASTER data showed that principal component transformation is useful for the lithological mapping. FCC of PC1-PC2-PC3 showed a good image enhancement for separation of different alluvial fans and recognition of their source rocks.

Acknowledgements

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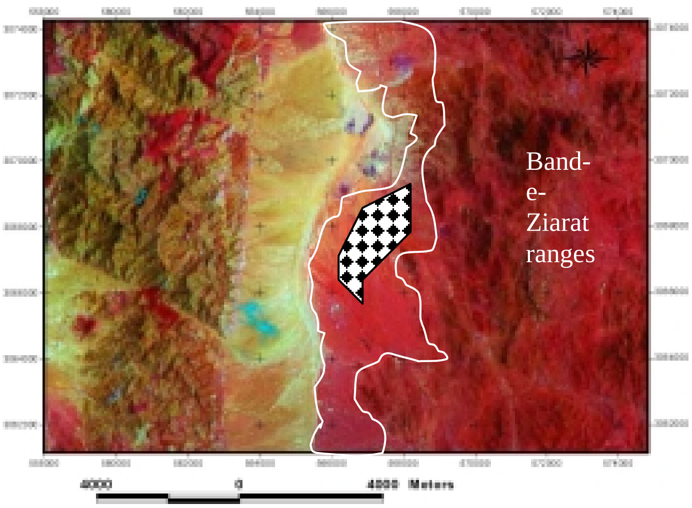

Figure 6: ETM+ image of Kahnooj area. The ilmenite deposit in the area is present in the alluvial sediments(marked area).The alluvial sediments derived from the gabbros are marked in the figure.

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