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Multi Earth Observation data to identify indicators for mineralized zones in parts of Iran

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ABSTRACT
Multi-sensor satellite data such as IRS P6 (RESOURCESAT 1) - LISS IV Mx and LISS III, and IRS P5 (CARTOSAT 1) – PAN A were used for the identification of possible locations of chromite occurrence in a highly inaccessible area having less vegetation cover in the north eastern parts of Iran around Gaft region in the south western portion of Joghatay city. The coarse resolution LISS III data were used mainly for the regional understanding of the geological and geomorphological set up of the area, and the fine resolution PAN A data for delineating the microgeomorphological features. These two data sets were merged and hybrid images were generated in order to obtain the best of spatial and spectral interpretations, particularly for enhancing the minor spectral and spatial components of the lithological units. The existing field data i.e., the coordinates of the mineralized zones, collected using Global Positioning System (GPS) were plotted on the image and studied in conjunction with the multi-sensor data interpretation. The typical spectral signatures observed over known chromite mineralization are correlated with the unknown areas using mainly the lithological controls. The mineralization in this area is mostly controlled by lithology, and wherever these signatures matched, those areas are identified as prospective areas for chromite mineralization.

INTRODUCTION

Satellite images play a vital role in geological mapping especially in updating the geological/lithological contacts, in identification of the geomorphological features and in establishing the regional structural fabric of the area, which are essential for chromite mineralization. Chromite crystallizes into mineral grains within the silicate liquid and because they are heavier than the liquid, they sink to form a cumulate layer at the base of the intrusive. The brown chromite lenses are located inside peridotite in serpentinized form. The degree of serpentinization is more in the vicinity of chromite lenses (Vatanpour 2005). There are two main types of chromite deposits, namely 'Stratiform' and 'Podiform'. Stratiform chromite deposits consist of laterally persistent chromite-rich layers (a few mm to several m thick) alternating with silicate layers. These deposits contain substantial reserves of poor-quality chromite (average 10.7% Cr_2O_3). Podiform chromite deposits consist of pod to pencil-like, irregularly shaped massive chromite bodies and they are predominantly found within dunitic (olivine-rich) portions of ophiolite complexes. The rocks associated with podiform chromites are generally referred to as "Alpine-type" peridotites and they are usually found along major fault zones within mountain belts. The chromite deposits in the Gaft area, Iran are of podiform nature. Their location is generally controlled by lithology and structure, and occur as a primary mineral of ultrabasic igneous rocks, peridotites and their modifications and serpentine.

In the present study, the lithological and structural guides have been interpreted from satellite data and were used in conjunction with the available field data to demarcate possible areas for chromite occurrence.

STUDY AREA

The study area is located in the end of western part of ophiolitic belt locally known as 'Joghatay mountain range' in the north eastern parts of Iran. It is bounded by the latitudes 36° 35′ 00″ N – 36° 39′ 00″ N and longitudes 56° 55′ 00″ E – 57° 03′ 00″ E and is shown in Fig. 1. The area is rugged and devoid of any vegetation. The highest and lowest elevations are 2170 and 1510 metres, respectively. The area receives very little rainfall throughout the year and during winter season i.e. from December to March, snow covers the entire area, as temperature goes down to -10° C.

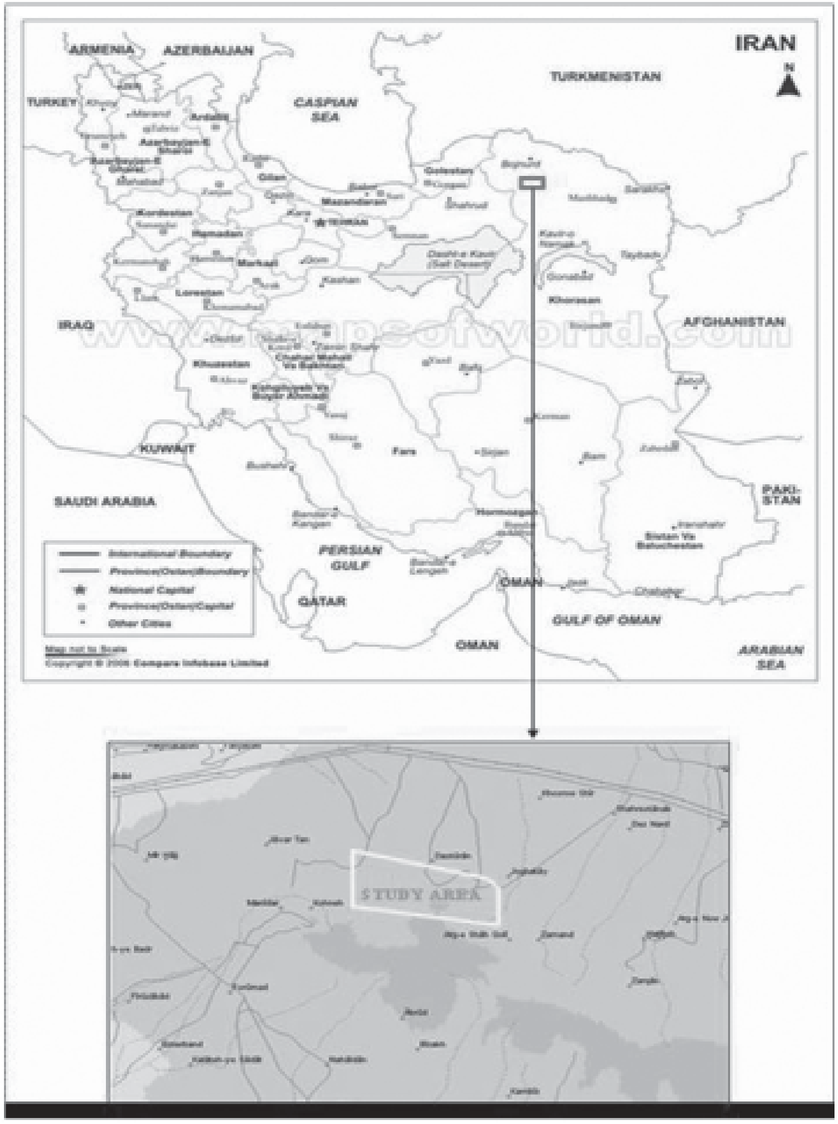

Figure 1. Location map of the study area (source: www.mapsofworld.com).

GENERAL GEOLOGY

The study area comprises of ophiolitic zone belonging to Sabzevar ophiolitic sequence. This zone is famous for its chromite deposits of ‘podiform’ type, which are scattered in the form of chromite lenses in the subsurface and are associated with mafic and ultramafic igneous rocks (e.g. peridotite, dunite, harzburgite) containing high concentration of magnetite. The ophiolite massif is surrounded by andesitic volcanic rocks, marly limestone, green to purple coloured silt stone and red marl. Chromite ore occurs as lenses and disconnected bodies within the ultramafic rocks comprising of serpentinite, peridotite, dunite and harzburgite. They are worked by both opencast and underground methods. Small ore bodies have been worked near the surface without any systematic mine development. The central part of massif is composed of mainly harzburgite and enstatite dunites with subordinate pyroxenites. The peripheral parts of the massif are composed of banded gabbro, gabbro norites within serpentinised dunites and minor harzburgites. The harzburgite unit forms the basement to the cumulate rocks. Chromite ore bodies usually occur within the dunite pockets inside the harzburgites (Sengupta 2006).

METHODOLOGY

IRS P6 - LISS III (23.5 m resolution having four bands in the spectral region of visible, near infrared and shortwave infrared), IRS P6 - LISS IV Mx (5.8 m resolution having four bands in the spectral region of visible and near infrared) and IRS P5 – PAN A (2.5 m resolution panchromatic) data sets were geo-rectified with the help of topographical maps. LISS III data, being a coarse resolution data with a wider swath, were used for understanding of the regional geomorphological and geological set up of the area. The spatial and spectral components were highlighted in PAN A and LISS IV, respectively because of the obvious reasons of the sensor capabilities. Hence these two data sets were merged and a hybrid image was generated using digital image processing techniques in order to obtain the best of spatial and spectral interpretations. Later using the existing geological map as the reference, interpretation was done on the hybrid image for the lithological and the geomorphological features as well as for identifying their contacts and the geological structures (Inzana, et. al. 2003). This was done using the photo-interpretation techniques especially image and the geotechnical elements. The field data pertaining to the existing mining locations i.e., the Global Positioning System (GPS) locations of the known chromite occurrences were plotted on the image. The typical image and geotechnical elements observed over known mineralization were correlated in the unknown areas and favourable locations for chromite were identified (Kusky & Ramadan 2002). The following flow chart (Fig.2) describes the methodology followed in a sequential order.

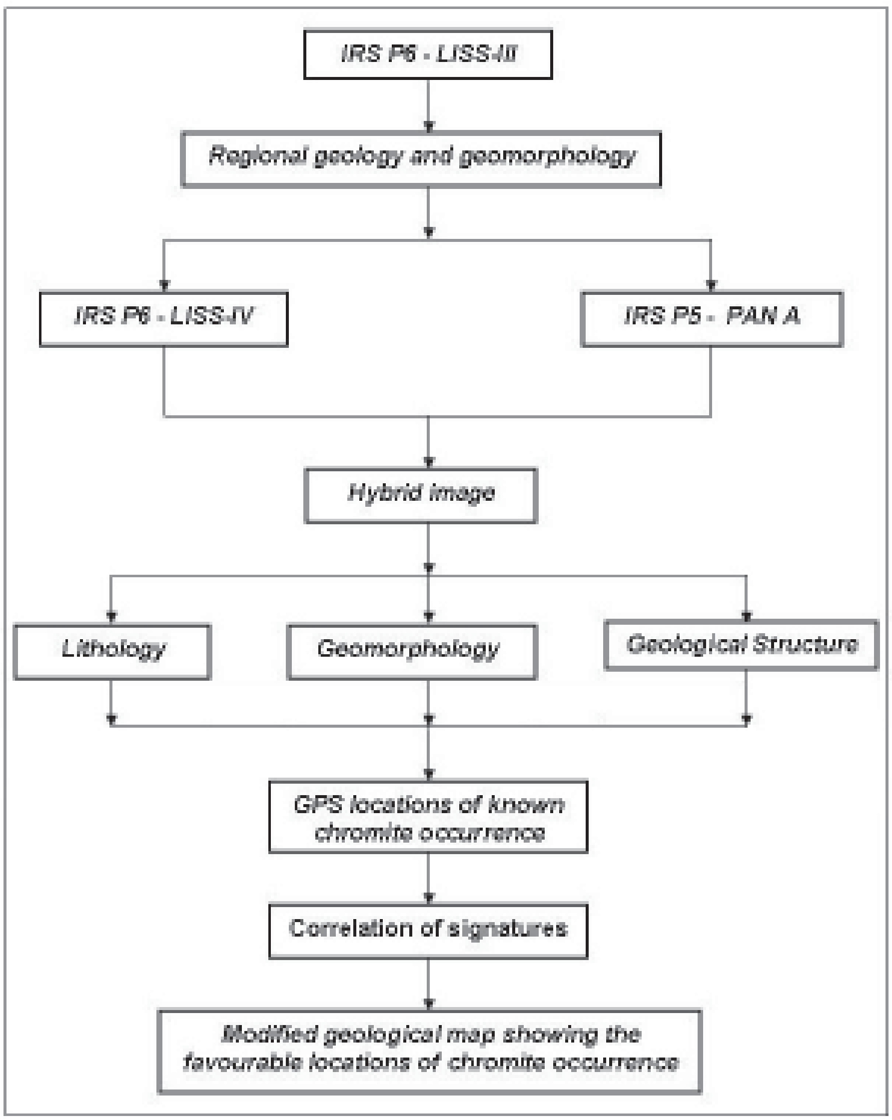

Figure 2. Methodology Flow chart.

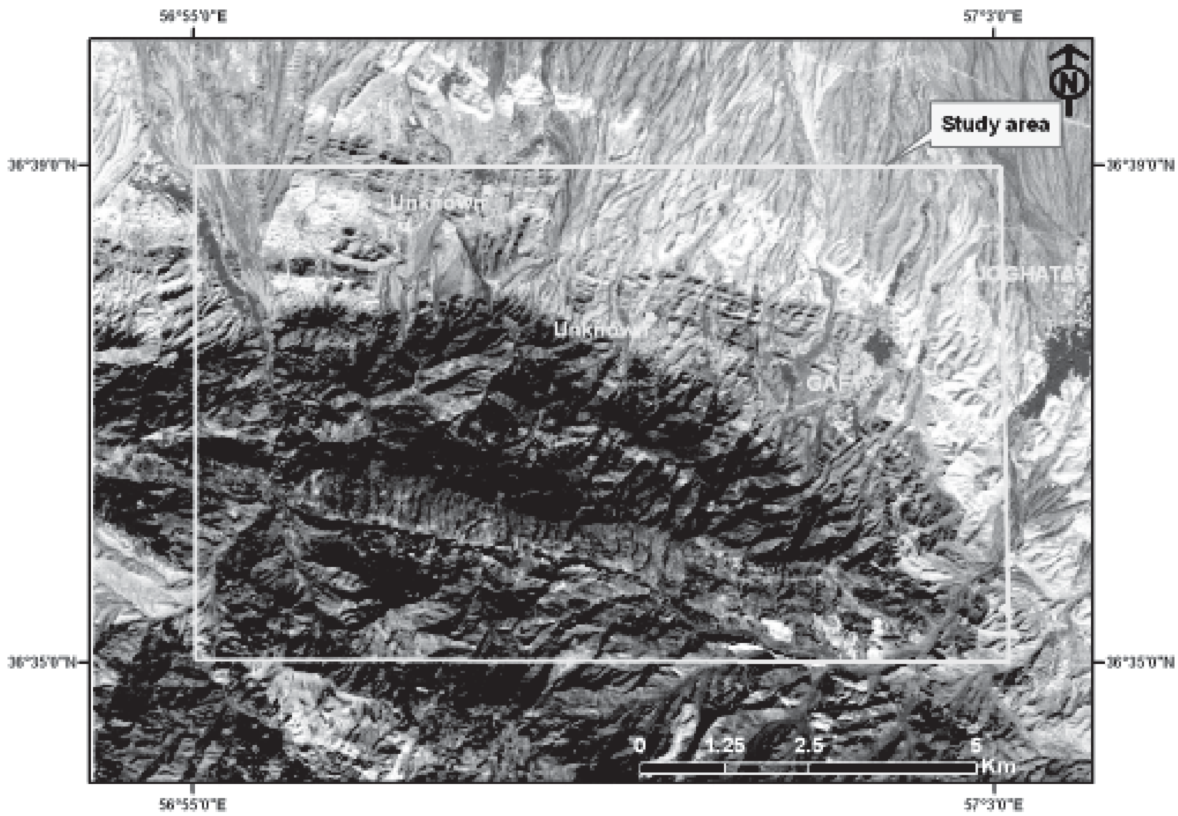

Figure 3. Satellite image of the study area.

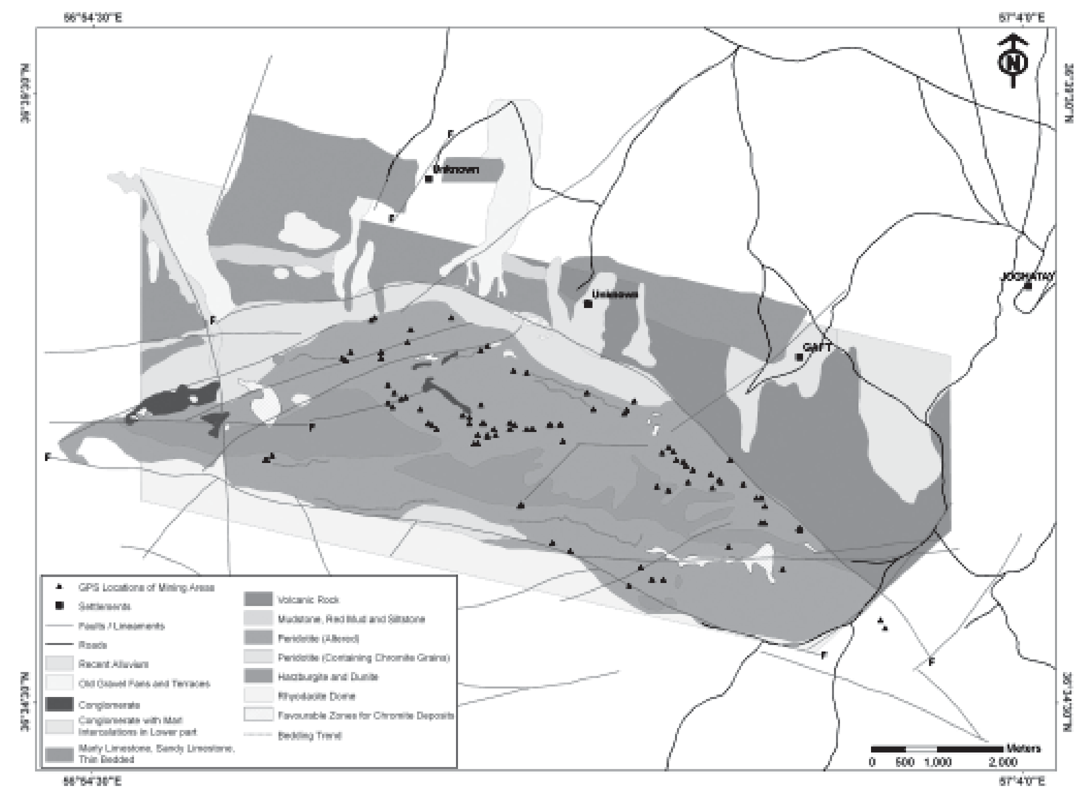

Figure 4. Updated geological map showing the prospective zones for possible chromite occurrence.

RESULTS AND DISCUSSION

The hybrid image (Fig.3) was interpreted for lithology; geomorphology and structure based on the image characteristics and geotechnical elements with reference to the existing geological map. This image has brought out the drainage pattern more effectively and also has shown prominently the lithological and geomorphological contacts as well as the structural features. Hence, essentially in the present work, the lithological boundaries of the existing geological map were modified using satellite data, as chromite occurrence was mostly seen in ultrabasic rocks. Since this area was devoid of vegetation cover, satellite data was extremely useful to identify such controls based on the image signatures, as described hereunder: harzburgite and dunite were identified based on the dendritic drainage pattern with a dark green tone. Geomorphologically, it was interpreted as a structural hill with less altitude or relief; peridotite (altered) rock formations possess parallel and sub-parallel drainage with a light green tone. Geomorphologically, it was interpreted as a structural hill with medium altitude or relief; volcanic rock possesses coarse drainage texture with light brown tone. Geomorphologically, it was interpreted as a piedmont zone; peridotite (containing chromite grains) rock formations possess parallel and sub-parallel drainage with a light brown tone. Geomorphologically, it was interpreted as a structural hill with high altitude or relief; rhyodacite dome has got a circular drainage pattern with light red color. Geomorphologically, it was interpreted as a residual hill with domal structures; mudstone, red mud and siltstone have got a parallel drainage with grayish white tone. Geomorphologically, they were interpreted as structural hills with trend lines and altered ridge-valley topography; marly limestones, sandy limestones, thin bedded formations contain a drainage, which was bifurcating with fan type drainage pattern with whitish tone. Geomorphologically, they were interpreted as piedmont zones with prominent alluvial fans; conglomerate with marl intercalations in lower part was the formation which has a bifurcating drainage with parallel to sub-parallel trends with grayish white tone. Geomorphologically, it was interpreted as piedmont zone; Conglomerates have dendritic drainage pattern with reddish white tone. Geomorphologically, they were interpreted as denudational hills; in Old Gravel Fans and Terraces, the drainage was radial and bifurcating with light grey tone. Geomorphologically, they were alluvial fan zones; and the recent alluvium possesses bifurcating drainage with radial pattern and white tone. Geomorphologically, it was interpreted as piedmont zone.

The structural features (faults / lineaments) and the 'bedding trends' were also interpreted based on the dislocations of the rock beds, the linearity of the spectral signatures, etc. The locations of the known chromite occurrence were, then, plotted on the modified geological map prepared based on the satellite data interpretation. It was observed that most of the chromite deposits were controlled by peridotite and secondary faults.

Two major areas of possible chromite occurrence, one in the western part of the study area cutting across by two NE – SW trending parallel lineaments and bounded in the south by E – W trending fault, and the other in the south eastern portion of the area along E – W trending lineament were demarcated in the peridotite formations. Other two locations in the northern side of the western and eastern (to the south west of Gaft town) portions of the study area, respectively, in the peridotite formations were also identified as prospective for chromite (Fig. 4).

CONCLUSIONS

It was observed that most of the chromite deposits were controlled by peridotite and secondary faults. The typical image elements observed over known mineralization were correlated in the unknown areas and thus the possible favourable locations for chromite occurrence were identified. The study has essentially brought out the role of satellite remote sensing in identifying the lithogical, geomorphological and structural guides for demarcation of the possible locations of chromite occurrence. As the area has sparse vegetation cover, the satellite spectral signatures could be directly correlated with the various lithologcical units. Most of the area was inaccessible and hence this study was extremely useful to identify the possible chromite mineralized zones.

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