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DETERMINATION OF THE ORE ENRICHMENTS IN HINZIR MOUNTAIN (TURKEY-KAYSER□-AKKI□LA) BY USING LANDSAT 7 ETM+ AND QUICKBIRD DATA

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ABSTRACT

The aim of this study is to demonstrate the capability of the Landsat 7 ETM+ and Quicbird satellite images in determining unknown ore deposits/enrichments by using different remote sensing techniques and geographical information systems. Altered areas in connection with the hydrothermal solutions were determined by using the mentioned satellite data as preliminary study before fieldwork. The lithological units and altered areas of the study area can successfully be differentiated and mapped by application of various image processes and enhancement techniques. Band combination, principal component analysis, Crosta technique application, band rationing, decorrelation stretching and various filtering techniques were applied to the satellite data. As a result of RS-GIS studies and field works for grounds truth, iron ore deposits were found in Karcaömer and Tipitutan areas. Additionally, many hydrothermal ore/ mineral enrichments locations were detected along the SW-NE striked fault which cuts the mountain two main parts from Manavus to Çukuryurt village. Also, some rich copper outcrops were found in Boyunbağı-Cehennemdere area. The results of ^{34}S analysis of the sulphide minerals, such as sphalerite, fahlerz and arsenopyrite minerals show ocean water originated hydrothermal solution's values, whilst the occurrences of some chalcopyrite enrichments point out granite originated hydrothermal fluid existence. It is postulated that the unexposed granite pluton should be located beneath the whole lithological units of the study area. Evaluation of the iron rich areas, total magnetic intensity and gravity maps of the study area in GIS environment support this postulation.

As a result, the origin of the fault controlled ores/ mineral enrichments in the region could have been caused by granite and/or ocean water originated hydrothermal solutions as two different processes. Nevertheless, before reaching the final conclusion, some more detailed research and analyses should be made in more ore/mineral enrichments outcrops.

INTRODUCTION

Hınzır Mountain is located in almost central Turkey, just northeast of Kayseri city and covers about 200 sq km (Fig.1). Limestones and dolomites are the main lithologies, whilst some outcrops of calcsilicate hornfelses located along the main SW-NE strike fault which mainly cut the mountains into two parts (Fig.2). Some transported blocks of metamorphic rocks were seen in Boyunbağı region. Additionally, ophiolithic rocks were seen located under the carbonate rock and crop out in very lower levels of the mountain, such as in Manavus and Çukuryurt dere region (Fig.3).

Some known geological studies on Hinzir Mountains and environs are as follows; Özkan (1956); Lebkuchner (1957); Demirtaşlı (1967); Yoldaş (1972); Özgül et al. (1973); Altıner (1981) and Özer et al. (1984). Neither reports nor published literature were known about these newly discovered mining deposits and /or mineral enrichments areas until this study. Nevertheless, these two areas were seen as illegally operated mines by local people. Most probably, lack of easy passage ways on the mountains and heavy snow coverage on upper level of the mountains except 2-3 months in a year might obstruct detailed field work in the study area. Therefore remote sensing and geographical information system (RS-GIS) techniques are preferred to apply to the study area in advance of field work.

It is well known that satellite images have been used to determine geological features of continental areas since the establishment of the ERTS project in 1972. Furthermore, satellite images and digital elevation models obtained from them have been used quite successfully in the understanding of geomorphology and the geological features that control it, and especially in the definition of young dip-, oblique- and strike-slip faults responsible for active surface-shaping processes and locating of the fault controlled hydrothermal ore deposits and/or enrichments.

GEOLOGY OF THE HINZIR NAPPE

Hınzır Mountain is considered as a Nappe in pre-Early Cretaceous times (Özer et al., 1984). Crystallized limestones and dolomites are the main lithologies of the mountains and representing Carboniferous (?) - Early Cretaceous age interval. Permian lithologies are represented by dark grey colored medium-thick layered rarely dolomitized crystallized limestones on the lower levels, whilst white-gray colored dolomitized limestone on the medium level and Brachiopoda shell, worm traces and Mizzia containing medium-thick layered dark colored crystallized limestones are on the top of the series. The Permian aged lithologies in the study area are covered concordantly by 400 meter thick Triassic (according to stratigraphic level) crystallized limestones. These units are overlaid by the Jurassic-Cretaceous grey-black colored, medium-thick layered, folded and crystallized limestones, which contain some reddish colored lamellibranches in the upper levels.

Ophiolithic rocks outcrops in Manavus and Çukuryurt dere areas, which are the lowest levels of the study area, whereas some randomly distributed metamorphic blocks are located in Boyunbağı region. The metamorphic rocks were most probably transported and included in the Hınzır Mountain limestones during the nappe movement.

One of the important findings of this study is Zebra dolomites outcrops, which have never been mentioned previously in any literature. These rocks were seen in many places as having direct contact with many hydrothermal veins. The detailed investigation on zebra dolomites is prepared as the subject of other paper.

The other important output of this study is the determination of the calcsilicate hornfelses, which outcrops along the SW-NE strike fault and most probably have been formed by interaction of carbonate rocks with the hydrothermal solution, which originated from unexposed granitic pluton.

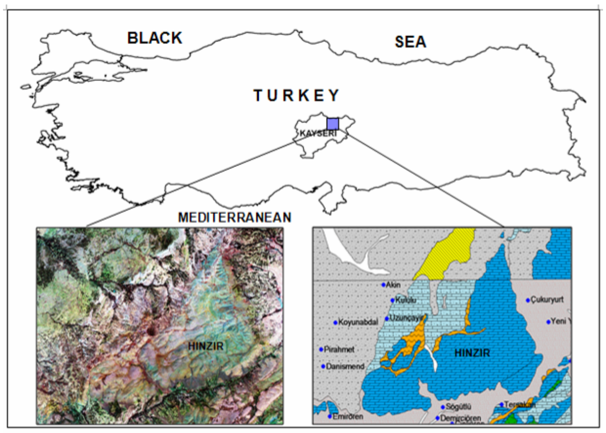

Fig.1: Location of the study area.

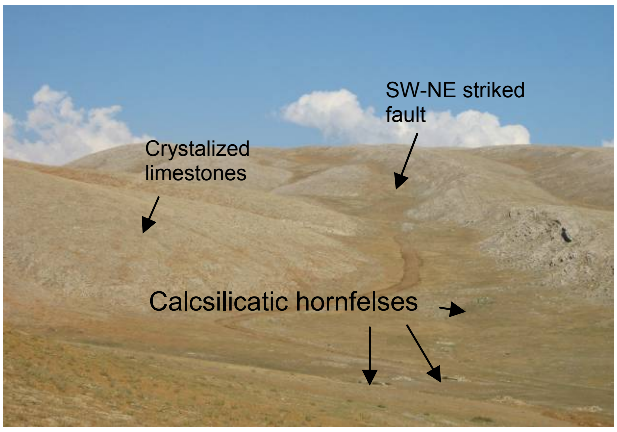

Fig.2: General outlook of the SW-NE strike fault.

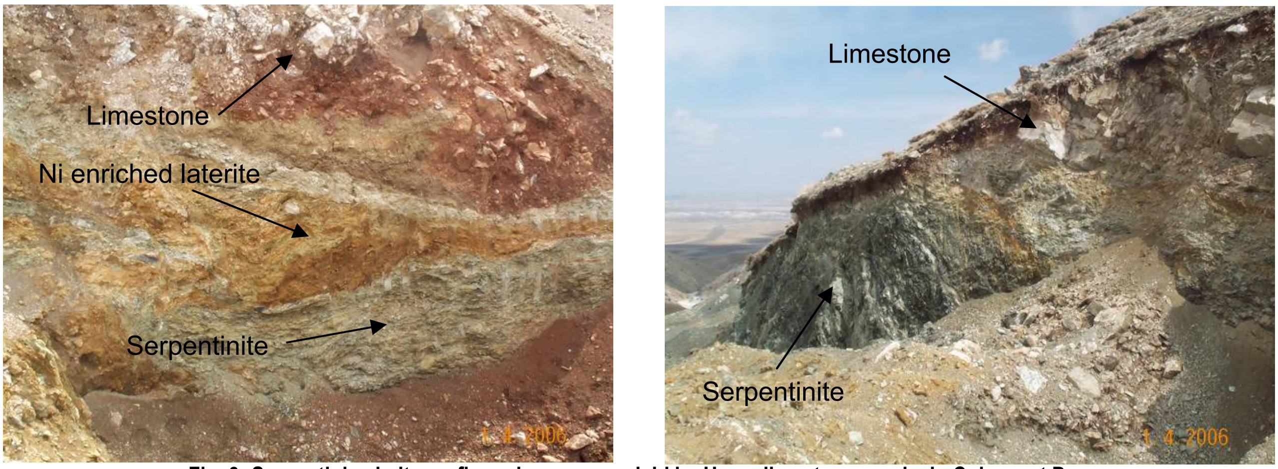

Fig. 3: Serpentinized ultramafic rocks were overlaid by Hınzır limestones rocks in Çukuryurt Dere.

REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEM (RS-GIS) DATA AND METHOD

In the present study, a Landsat 7 ETM+ image taken on 13 June 2000 was used. This image covers about an area of ~ 180 km² through UTM zone 37 and numbered "175-34" by Landsat. Additionally, 19.06.2006 and 24.06.2006 dated Quick bird data were used and rectified with the 100.000 scaled J36 and K36 numbered topographical maps and GPS points, which were taken during field work. All data were evaluated in TNT Maps 6.9 and Arc GIS 9.1 (Arc Map and Arc Scene) environment. The study area was prepared and discussed from the standpoint of RS-GIS, and some 3D views were prepared as SRTM data in order to understand more clearly the tectonic features of the study area (Fig. 4). Additionally, some geophysical data, such as gravimetric and the total magnetic field maps of the study area were evaluated in GIS environment with the satellite data (Fig. 5).

Landsat data have been used for number of years in arid and semi-arid environments to locate areas of iron oxides and/or hydrous minerals (Abrams et al., 1983; Kaufman, 1988; Sabins, 1999; Tangestani and Moore, 2001) which might be associated with hydrothermal alteration zones. The host rocks that contain ore deposits of hydrothermal origin always show the result of interaction with the hydrothermal fluids that change the mineral and chemical composition of the rock and cause the deposition of the ore and related hydrothermal minerals (Rutz-Armenta and Prol-Ledesma, 1998).

Principal Component Analyses is often used as a method of data compression. It allows redundant data to be compacted into fewer bands. The transect, which corresponds to the major (longest) axis of the ellipse, is called the first principal component of the data. The direction of the first principal component is the first eigenvector, and its length is the first eigenvalue. A new axis of the spectral space is defined by this first principal component. The points in the scatter plot are now given new coordinates, which correspond to this new axis. Since, in spectral space, the coordinates of the points are the data file values, new data file values are derived from this process. These values will be stored in the first principal component band of a new data file. The second principal component is the widest transect of the ellipse that is perpendicular to the first principal component. The variance of single band expresses the spread of its values about the mean. A measure of the joint variation of two bands is known as their covariance. When covariance is positive, bands are positively correlated, when negative an inverse relationship is

present. When the covariance is zero, the two bands are completely independent of each other (Loughlin, 1991; Drury, 2001; Lillisand et al., 2004).

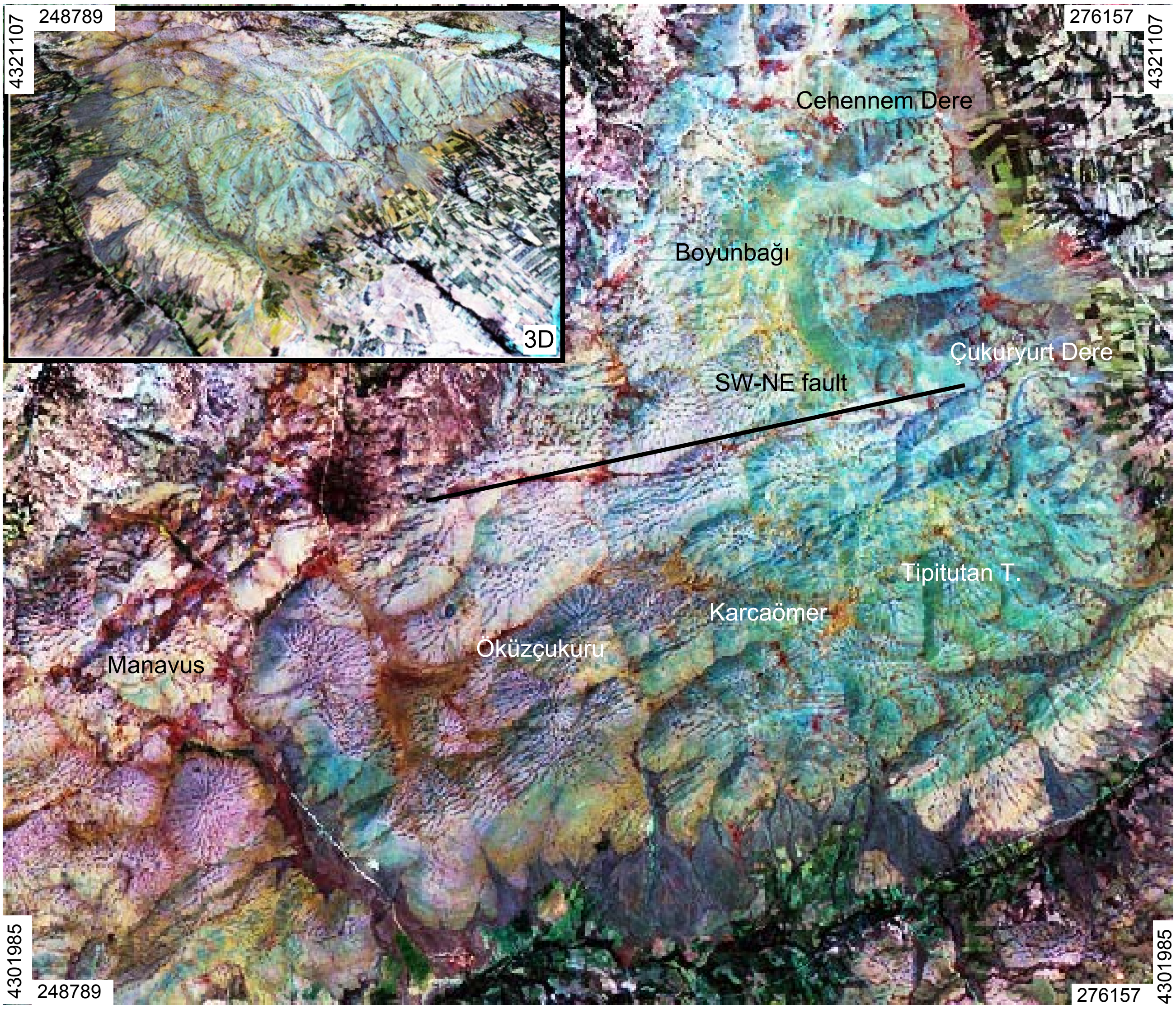

Fig. 4: Landsat +7 ETM 531 Composite of 2D and 3D views of the Hınzır Mountain.

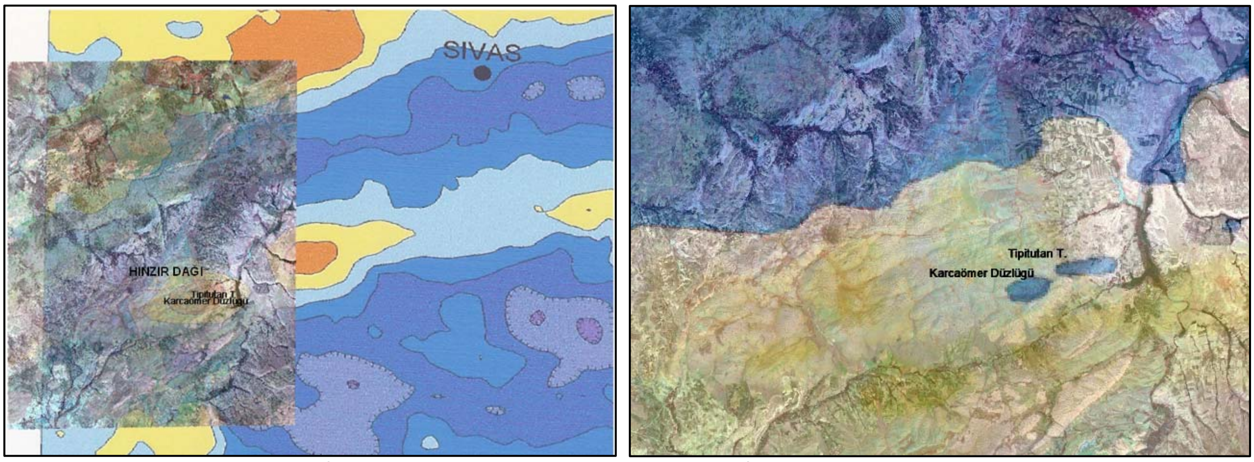

Fig. 5: Evaluation of the Landsat image with the gravity maps (left) and total magnetic intensity maps (right) in GIS environment in the study area.

The principal component analysis is widely used for alteration mapping in metallogenic provinces (Abrams et al., 1983; Kaufman, 1988; Loughlin, 1991; Bennett et al., 1993; Tangestani, 2000; Tangestani and Moore, 2001). Crosta technique is also known as feature oriented principal components selection. Through the analysis of the eigenvector values it allows identification of the principal components that contain spectra information about specific minerals, as well as the contribution of each of the original bands to the components in relation with spectral response of the materials of interest. This technique indicates whether the materials are represented bright or dark pixels in the principal components according with the magnitude and sign of the eigenvectors loadings. This technique can be applied on four and six selected bands of TM data (Crosta and Moore, 1989; Rutz-Armenta and Prol-Ledesma, 1998; Tangestani et al., 2002 and 2004).

The lithological units and altered areas of the study area were successfully differentiated and mapped by application of various image processes and enhancement techniques, such as band combination, principal component analysis, Crosta technique application, band rationing, decorrelation stretching and various filtering techniques to the satellite data. Application of some techniques on Quick bird images has given more reliable data because of their higher resolutions. Especially the location of the hydrothermal interaction with the host rocks (mainly carbonates) was detected very easily in decorrelation stretching and PCA processes on Quick bird data (Fig. 6). On the other hand, Landsat images have some advantages over Quick bird data because of their 7 band facilities. For instance, clay analysis and Crosta techniques can only be made by using Landsat data (Fig. 7). Additionally, the possibility of band combination and band rationing variety on Landsat 7 data are much more than Quick bird data.

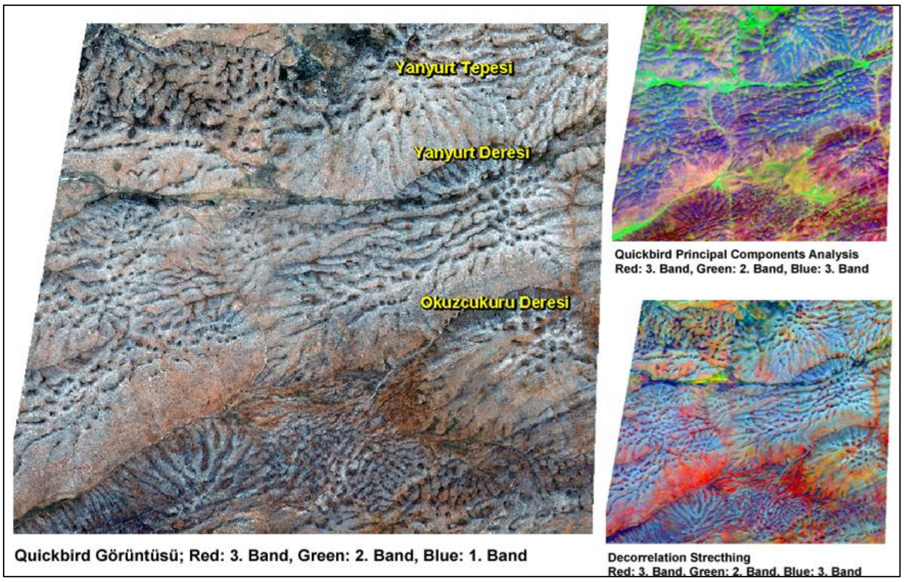

Fig. 6: Quickbird RGB composite, Principal Components Analysis and Decorrelation stretching images of the SSE-NNW strike fault region in the study area.

Clay, Iron and iron oxide analysis were made on the band 1 of Landsat ETM+ data. Iron oxide analysis is found to be very helpful to locate especially in Tipitutan, Karcaömer, Öküzçukuru and Boyunbağı regions in the study area (Fig. 7).

PETROGRAPHY, GEOCHEMISTRY AND ISOTOPE STUDIES

Petrogaphy, geochemistry and isotope studies are not the main topic of this paper and the details of these subsections will be presented in different paper. Nevertheless, summary of these studies is as follows; according to the petrographical investigation; iron ores in Tipitutan and Karcaömer areas are hematite (Fig. 8). Sphalerite, fahlerz, galenite, pyrite, phyhotite, arsenopyrite, millerite, linneite and chromite (!) are the detected minerals in the hydrothermal bodies, while some chalcopyrite and gold are present in some locations, especially in Çukuryurtdere and Cehennemdere (Fig. 9). Kuvars, Kalsit and dolomites (especially zebra textured) are the main gang minerals. The presence of chalcopyrite needs higher crystallization temperature than the other determined minerals. Therefore, it is believed that at least some of the occurrences caused by unexposed granite originated hydrothermal solutions instead of surface originated hydrothermal enrichments. ^{34}S analysis was performed in some samples taken from the hydrothermal bodies located in Çukuryurtdere. As known that surface or ocean waters originated hydrothermal solution never reaches enough temperature which might cause chalcopyrite enrichments. For many logical reasons, besides evaluation of gravimetry, total magnetic intensity in GIS environment, determining some chromite minerals in the hydrothermal bodies are considered as another proof for unexposed granite occurrences. It is believed that there is mantle originated granite plutons occurred under the ophiolitic rocks and this granite originated by hydrothermal solutions on leached ophiolites and thus acquired some chromite crystals before taking place in hydrothermal bodies, which are located in faulted limestones in the study area. This data are considered another strong proof that the ophiolitic rocks are located prior than Hınzır nappe location in the region. There are many places which can be seen that ophiolites are covered by the Hınzır limestones. Lisvenitization of the ultramafic rocks in Manavus area is very obvious and this process is considered another strong proof for hydrothermal leaching

occurrence in the study area (Fig. 10). Therefore, one km long iron and chlorite rich silicified dike should be investigated in detail.

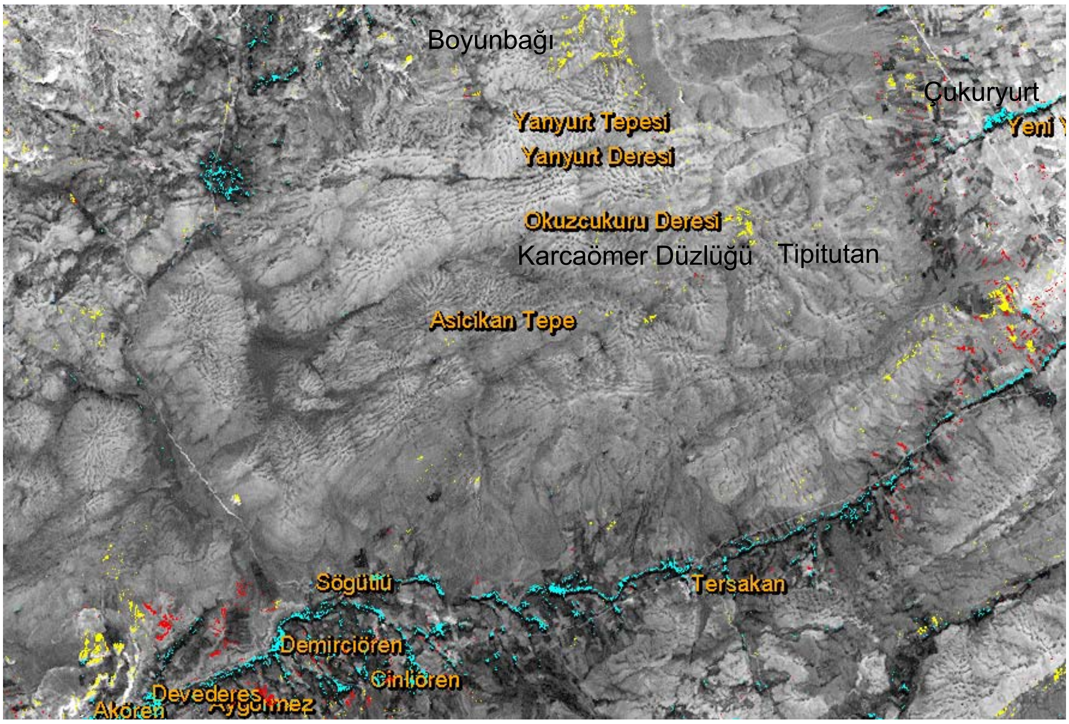

Fig.7: Clay (blue coloured), iron oxide (yellow colored) and iron (red colored) analysis on Landsat 7 ETM+ band 1 for the study area.

Fig. 8: Lisvenitized serpentinite in Manavus region.

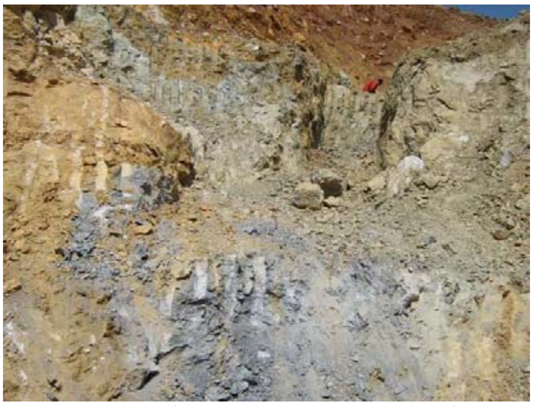

Fig. 9: The photos of the hydrothermal deposit in Çukuryurt dere.

Fig.10: The Photos of the Karcaömer iron ore deposits.

CONCLUSIONS

The ore enriched altered areas and the related lithological units of the study area were successfully defined and/or located by application of various image processes and enhancement techniques, such as band combination, principal component analysis, Crosta technique application, band rationing, decorrelation stretching and various filtering techniques to the two different satellite data.

The origin of the fault controlled ores/ mineral enrichments in the regions is thought to have been formed either by granite and/or ocean water originated as hydrothermal solutions in two different processes. The 25 km long SW-NE strike fault is the main location of the detected hydrothermal bodies. Location of the iron ore rich areas coincided with the higher level of gravity and total magnetic intensity areas in the study area in GIS environment, which might point out also to the occurrence of unexposed granitic pluton beneath the studied units.

Zebra dolomites were seen in many places as having direct contact with many hydrothermal veins. The other important output of this study is the determination of the calcsilicate hornfelses, which outcrops along the SW-NE strike fault and most probably to have been formed by interaction of carbonate rocks with the hydrothermal solution, which originated from unexposed granitic pluton.

Before reaching the final conclusion, some more detailed research, excavations, drillings and analysis should be done in more ore/mineral enrichments outcrops.

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