DETECTING DIFFERENT BORATE MINERAL ZONES IN THE KIRKA BORATE OPEN PIT MINE BY ASTER SATELLITE IMAGES

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KEY WORDS: Borate minerals, Kırka, ASTER, Remote Sensing

ABSTRACT*:* Borate mirerals are among the most important and strategic mineral in the world. As it will probably be used as energy source in the future, it has a great importance. Turkey has about 70% of world reserves of borate deposits and only Kırka area has approximately 830 million tons of borate reserve. The main aim of this study is to discriminate different borate minerals from the Kırka Open Pit Mine by using ASTER satellite images. Remote sensing is used for this purpose. Borax (tincal), colemanite, and ulexite zoning of borate mineralization is obvious in the Kırka Borate Open Pit Mine. Different remote sensing techniques have been applied to see whether it is possible to differentiate these different mineralization zones. The techniques which were applied in this study are density slicing, band ratio, decorrelation stretch and classification. At the end of the study, it is understood that application of remote sensing techniques for discriminate borate minerals like borax, ulexite and colemanite is going to reach succesful result.

1. INTRODUCTION

Borate mirerals are among the most important and strategic mineral in the world. As it will probably be used as energy source in the future,it has a great importance. Today, it is used in rocket fuel and heat resistant glass industry, especially today's modern industry has found wide use in the field. Turkey has about 70% of world reserves of borate deposits and only Kırka area has approximately 830 million tons of borate reserve. Borate minerals are defined as tincal, ulexite and colemanite in this field. The main aim of this study is to discriminate different borate minerals from the Kırka Open Pit Mine by using ASTER satellite images. Remote sensing is used for this purpose. Common definition of remote rensing is defined as the art and science of obtaining information about an object without being in direct physical contact with the object (Jensen, 2000). Actually remote sensing has detected many objects since the first remote sensing satellite, ERTS-A launched in 1972. The size that the users detected the object was bigger than the football field during those days, we call it spatial resolution. The number of spectral bands which the grandfather satellite had was only four and this property is defined as spectral resolution. We have seen an unbeliveable development in the remote sensing environment since 1972. The people who used the first pioneer's satellite products for their applications and continued to use remote sensing by the new satellites data could understand these enormous developments in the last fifty years more clearly. We could detect only the outer boundary of the big open pit mine during those days. Nowadays, we have opportunity to detect even different lithology boundaries in the same pit.

2. OBJECTIVE OF THE STUDY

The main aim of this study is to discriminate different borate minerals from the Kırka Open Pit Mine by using ASTER satellite images. It is known that, ASTER is a new generation satellite which was launched in December 1999. ASTER covers a wide spectral region with 14 bands from the visible to the thermal infrared with high spatial, spectral and radiometric resolution. The spatial resolution is 15 m in the visible and near-infrared (VNIR), 30 m in the short wave infrared (SWIR), and 90 m in the thermal infrared (TIR). Each ASTER scene covers an area of 60 x 60 km. Location of different borate minerals in the open pit mine has been indicated by GPS. Spectral signatures of these minerals have been interpreted and different reflectance properties for different spectral band intervals have been determined. The interpretation techniques which were used in this study for discrimination of borate minerals are density slicing, band ratio, decorrelation stretch and classification. Comparison of the result image and the ground through data have indicated that, the image obtained by using remote sensing technique from ASTER satellite images has nearly the same borate minerals distribution pattern like the ground seen for Kırka Open Pit Mine.

3. STUDY AREA AND GEOLOGY OF THE REGION

Study area is located in the boundary of Eskişehir Province. Eskişehir is one of the biggest cities of Turkey. Kırka subprovince is located approximately 66 km on the south of Eskişehir. Kırka Borate Open Pit Mine is located very close to the Kırka Subprovince (Figure 1). Kırka Borate Open Pit Mine is one of the famous borate open pit mine on the earth (Figure 2). Kırka Boron Production facilities are located just near of the open pit mine. Construction of the plant began in 1970, production started in 1975. Boron Derivatives Plant have became operational at1984. The plant's open pit mine produces an average of 2.5 million tons of 26 % B_2O_3 raw tincal ore, which is transformed into refined products (Etibor-48) in the plant's facilities with production capacity is approximately 700,000 tons/year (Eti Maden, 2012).

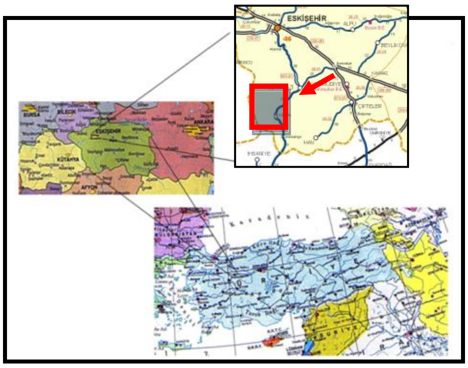

Figure 1. Location map of the studied area.

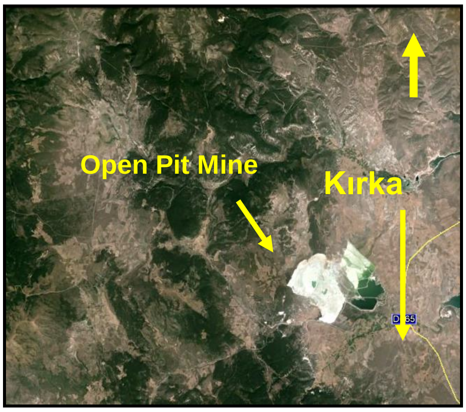

Figure 2. Kırka Borate Open Pit Mine is seen on the Landsat 7 satellite image (RGB/321).

3.1 General Geology of the Region

General geology of the region is originated during Neogene time (Figure 3). The most of the region was covered by tuff at that time and the age of the tuff is determined as Miocene age. These tuffs are the main products of the volcanic activities during this time. These are seen as pure white colored in the field. Tuffs are overlaid by claystone, marn and tuff intercalation, and named as Sarıkaya Formation. The borate mineralization is seen in this litology. The white colored limestone with thin clay layers in it overlies the borate occurrence (Yalçın and Baysal 1991).

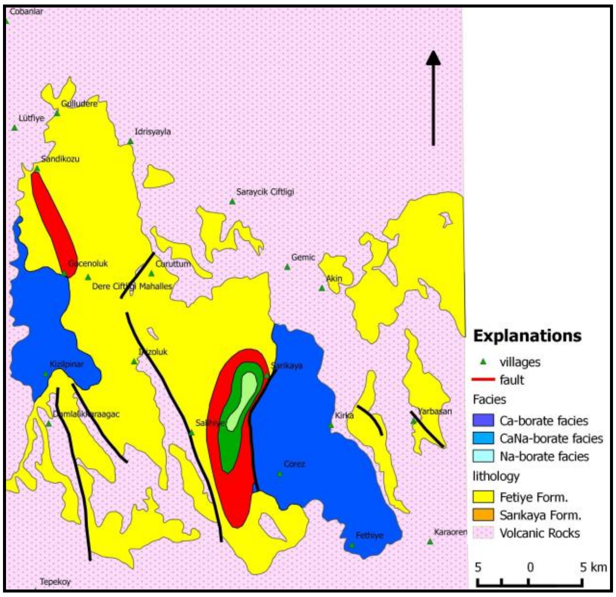

Figure 3. Regional geological map of the studied area (Yalçın and Baysal 1991).

3.2 Tectonic Lineanements of the Region

It is known that, the borate mineralization in the area had been occured during Middle and Upper Miocene time due to the settlement of borate minerals to the shallow lakes from the water which came from the active volcanism. The volcanism and the tectonics which affected the region during those days must be known. Direction of mineralization zones and the extend of the mine can be determined by using these data. There is a close relation with the tectonics and occurence of the borate mine.

Lineanement analysis must be one of the first step for the exploration stage of the mining project. Determination of the tectonic activities of the region and discontinuities in the rocks due to tectonic movements will be primary parameters for the open pit mine design. Landsat 7 satellite image were used to find the main directional extends and distribution of lineanements. The band combination of the image is RGB/741. Lineanement properties of the Kırka Borate Open Pit Mine region have been determined on this image (Figure 4).

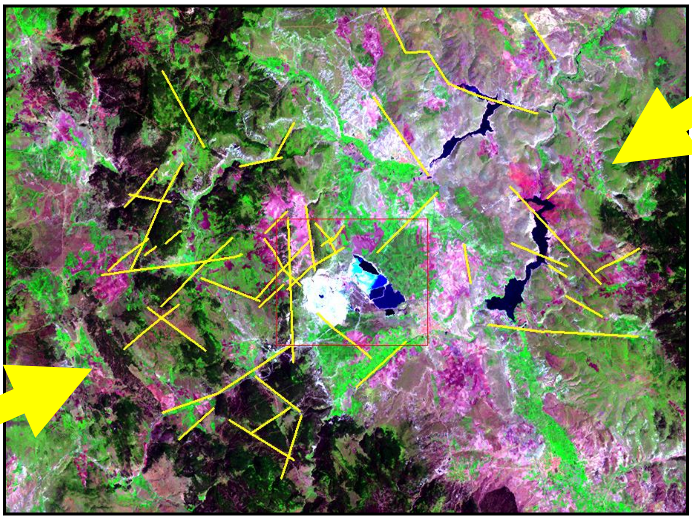

Figure 4. Lineanements of the studied area on the Landsat 7 image (RGB/741)

Azimuth of each lineanements were calculated and used as input for Rose Diagram (Figure 5). The result has shown that two different lineanement directions, named as L1 and L2 were dominant in this region. L1 is numerous than the other has NE-SW direction and L2 is less common than the first one has NNW-SSE direction. Due to this situation, it is evaluated that the main tectonic force had been acted in the region is compression and direction is NEE-SWW.

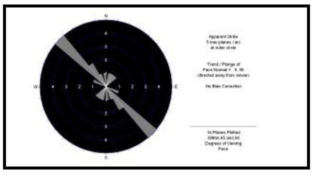

Figure 5. Azimuth of lineanements pole results of the studied region on the Rose Diagram.

3.3 Borate Mineralization in the Kırka Open Pit Mine

The borate minerals are minerals which contain a borate anion group. Many borate minerals, such as borax, colemanite, and ulexite, are salts: soft, readily soluble, and found in evaporite contexts (Wikipedia, 2013).

Zoning of borate mineralization is obvious in the Kırka Borate Open Pit Mine. Mineralization exhibits a symmetrical zonation in a lateral sense; it is comprised of: a central body of Na borate (borax), an intermediate zone of Na–Ca borate (ulexite), and a marginal zone of Ca borate (colemanite) (Figure 3). This mineral zonation is also developed in a vertical sense, although it is somewhat asymmetrical because of the presence of a discontinuous Mg borate horizon overlying the central body of borax (Helvacı and Orti, 2004).

4. METHODOLOGY

Remote rensing is defined as detecting an object without getting contact with it. Detecting and deriving object need information about this object by making some measurement at a distance from the object (Swain and Davis, 1978). Today, the the most frequently measured unit in remote sensing is electromagnetic energy reflecting from the object of interest. Although remote sensing is divided into active and passive remote sensing, we will use passive remote sensing in this study. The reflected electromagnetic energy from the open pit mine and surrounding areas is obtained and these data were used by remote sensing methodology to get accurate result.

It is known that, key concept of remote sensing depends on observed spectral differences in the energy reflected or emitted from feature of interest. This principle is the basis of multispectral remote sensing, the science of observing features of varied wavelength in an effort to derive information about the features and their distributions (Campbell, 1996). The term “spectral signature” has been used to refer to the spectral response of a feature, as observed over a range of wavelengths (Parker and Wolff, 1965). These curves are characterized by reflectance peaks and absorption bands caused by electronic and vibrational processes within their crystal lattice.

It is mentioned that there are three different borate mineralization zones in the open pit mine. These are Na-borate (borax) in the central zone part, Na-Ca borate (ulexite) in the intermediate zone and Ca-borate (colemanite) in the marginal zone. Different remote sensing techniques have been applied to see whether it is possible to differentiate these different mineralization zones. The techniques which were applied in this study are density slicing, band ratio, decorrelation strecth and classification.

These different zones were detected in the field and GPS coordinates of these locations were obtained. ASTER image and GPS system coordinates were selected as the same system. These coordinates were used as a check point after the the techniques were applied. Spectral signature of three borate minerals were obtained and spectral wavelength of each minerals were selected for the applications (USGS, 2007).

Figure 6. Spectral signatures of different borate minerals and location of ASTER bands (USGS, 2007).

4.1 Density Slicing Technique

Band 4 of ASTER satellite was selected as the band used for this technique (Figure 6). The spectral difference within and between the wavelength of borate minerals are obvious. Spectral data of these different minerals were calculated by pixel calculation on the Band 4. These data were used for density slicing and the result map is obtained. There is very close relation with the field data and the obtained result (Figure 7). Pink and red colored areas correspond to Na-Borate (borax-tincal) and light and dark green color areas correspond to Na-Ca Borate (ulexite and colemanite).

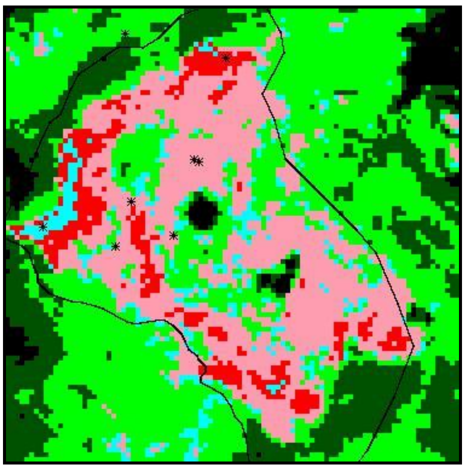

Figure 7. Density Slicing map of the Kırka Open Pit Mine (star symbology indicates GPS readouts).

4.2 Band Ratio Technique

Band ratio technique was applied by using two different ASTER to detect different minerals. Band4/Band3 were used in this technique (Figure 8). Na-Borate (tincal) is seen in the middle and Ca-Borate (colemanite) zone surrounds it.

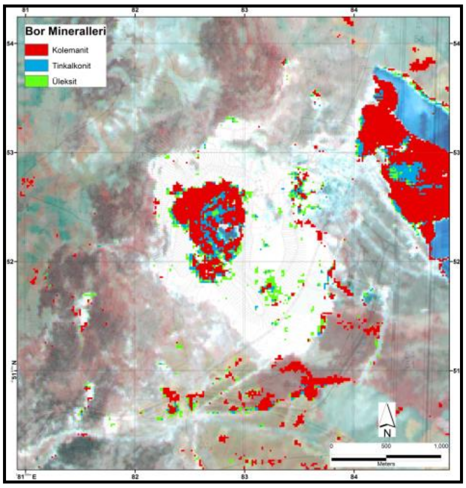

Figure 7. Band ratio (Band4/Band3) result of the open pit mine.

4.3 Decorrelation Stretch Technique

Shortly, the technique called as Dstretch, is a kind of transformation technique. It has been used in remote sensing to enhance multispectral images. Generally it is applied to the rock and soil types. After application it is seen that, Na-Borate areas are pink, ulexite and colemanite areas are yellow and limestone and soil overlies the borate deposit as green colored (Figure 8)areas. It is more likely to resemble the real situation.

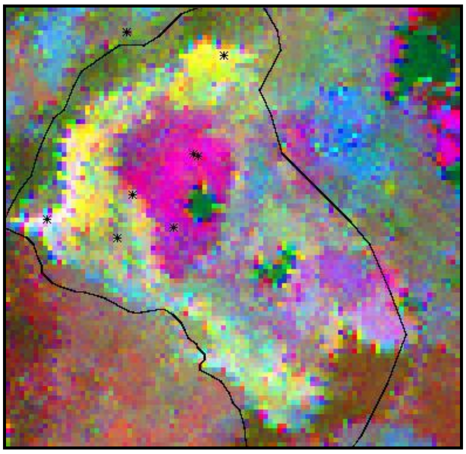

Figure 8. Decorrelasion Stretch Technique result of the studied area.

4.4 Classification Technique

The true mineralization zone boundaries wasn't known at the begining of the study. Due to this, unsupervised classification technique was used for the studied area. After application, it is understood that K-Means classification algorithm gave the most real situation (Figure 9). The ASTER bands used in this technique are RGB/458).

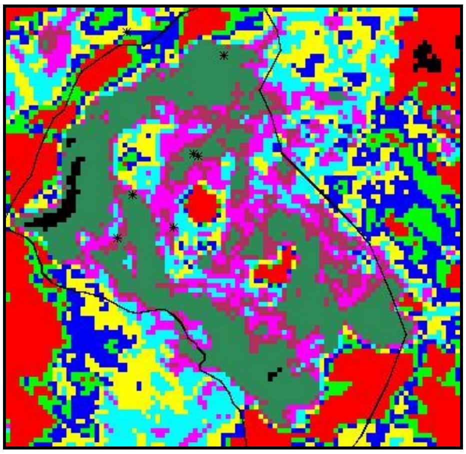

Figure 9. Unsupervised classification (K-Means) of the studied area.

5. CONCLUSIONS AND RECOMMENDATIONS

At the end of this study it is understood that;

- Remote sensing can be applicable for the discrimination of borate minerals, like tincal, ulexite and colemanite,
- The ASTER satellite image can be applicable for this kind of discrimination due to wide spectral region with 14 bands.
- In this study it is understood that, the main tectonic force which acts this region is compression and the force direction is NEE-SWW. This data have effected the open pit design of the mine. Lineanement analysis must be done at the beginning of mine explorations especially for tectonic dependence type mineralizations.
- Some remote sensing techniques have been applied for the discrimination of borate minerals. These are density slicing, band ratio, decorrelation strecth and classification. It is seen that, density slicing, decorrelasion stretch and K-Means unsupervised classification techniques gave more real result.

It is recommended that;

- Remote sensing techniques must be applied and some results must be received before beginning open pit mine design, like Kırka region.
- Lineanement analysis by using satellite images must be used as a first step in every mine exploration studies, especially to detect the major tectonic stress direction of the region.
- These remote sensing techniques must be applied to other borate mineralization deposits in Turkey and other countries to check the correctness of the methodology.

References

Campbell, J.B., 1996, Introduction to Remote Sensing, The Guilford Press, New York, pp. 13-14.
Eti Maden, 2012, http://en.etimaden.gov.tr/kirka-boron-works-72s.htm
Helvacı, C. and Orti, F., Zoning in the Kırka Borate Deposit, Western Turkey: Primary Evaporatic Fractionation or Diagenetic Modifications, The Canadian Mineralogists, Vol.42, pp.1179-1204.
Parker, D.C. and Wolff, M.F., 1965, Remote Sensing, International Science and Technology, Vol.43, pp. 20-31.
Jensen, J.R., 2000, Remote Sensing of the Environment, an Earth Resource Perspective, Prentice-Hall, Inc., Upper Saddle River, pp.xii.
Swain, P.H. and Davis, S.M., 1978, Remote Sensing: The Quantitative Approach, McGrawHill, Inc., pp. 1-18.
USGS, 2007, Digital Spectral Library, http://speclab.cr.usgs.gov/spectral-lib.html.
Wikipedia, 2013, http://en.wikipedia.org/wiki/Borate_minerals
Yalçın, H. and Baysal, B., 1991, Kırka (Seyitgazi-Eskişehir) Borat Yataklarının Jeolojik Konumu, Dağılımı ve Oluşumu, MTA Dergisi, vol. 113, pp. 93-104.