DETERMINATION OF BOUNDARIES, GEOLOGICAL OUTCROPS AND STRUCTURAL FEATURES OF THE SIVAS TERTIARY BASIN/TURKEY USING LANDSAT TM/ETM+ AND SPOT XS IMAGES

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ABSTRACT:

The Sivas Basin is one of the most well known major Tertiary basins of the Anatolia connected with the evolution of the Neotethyan Ocean. Central Anatolian Thrust Belt contains realms of this ocean and bounds the basin from north. Therefore, realms of the Inner Tauride Ocean are also surrounded the basin from southeast and represented with allochthonous units. Axis of the eastern section of this basin lies approximately in E-W trending between Erzincan and Sivas settlements, This trend turns toward NE-SW between Sivas and Kayseri in west. This roughly huge elliptical basin characterizes within several sedimentary, magmatic and metamorphic occurrences because of varying events during its complex geological history. The basin also exhibits spectacular structural features in regional scale such as foldings and faultings. It is possible to see evidences of these intensive deformations because of NNW-SSE compression regime developing after Miocene. Under this stress regime, Oligocene continental deposits were deformed by decollément gypsum levels.

Sivas Basin also provides easiness of interpretation geologically utilizing multispectral data sets such as SPOT XS and Landsat ETM+ considering that the arid climatic conditions of the region. In this study, image processing methods such as principal component analysis and classification methods were applied to highlight lithological features of the basin. Additionally, DEM analysis was also realized to expose structural features of the basin. These remote sensing studies were supported by field campaigns which were realized during last few years.

1. INTRODUCTION

This study aims to evaluate the Sivas Tertiary Basin geologically using multispectral data sources such as Landsat TM/ETM+ and SPOT images. Image processing techniques were realized with the aid of ER Mapper 6.4 image processing software. SRTM-3 data (ftp://edcsgs9.cr.usgs.gov/pub/data/srtm/Eurasia) which contains the basin overall was used to evaluate the region in terms of structurally.

Sivas Basin is defined as a peripheral foreland basin in terms of evolutionary processes and contains varying metamorphic, magmatic and sedimentary occurrences (Poisson et. al., 1996, Gorur et. al., 1998). The basin represents many spectacular remarks of continental deformation and lies on Alpine-Himalayan tectonic belt (Figure 1) in Turkey's political boundaries. The basin also hides kinematic evidences of ongoing convergence between Eurasian, Arabian and African plates since Late Cretaceous time. Kavak et. al., (1997) and Kavak and Inan (2002) documented that the compressional regime was active in the NNW-SSE direction after post-Pliocene and demonstrated that several lineament systems were connected to this direction by using several satellite image enhancement methods.

The basin presents considerable examples of collision tectonics and contains particularly sediments of shallow marine and continental environment starting from Upper Paleocene-Eocene.

2. GEOLOGIC SETTING

Sivas Basin is surrounded several litospheric fragments and suture zones (Figure 1). First of all, Central Anatolian Thrust Belt (Tatar, 1982) is located on the northern margin of the basin and represents as a suture zone on the northern branch of Neotethyan Ocean which was also known Izmir-Ankara Zone (Brinkmann, 1976). This collisional process was realized on the southern margin of the Eurasian plate and the Apulo-Anatolian block in regional scale (Poisson et. al., 1996). Kirsehir Massif is formed roughly continental basement of the basin (Gorur et. al., 1984). The massif is located in Anatolides-Taurides, as one of the main tectonic units of Turkey (Ketin, 1966). This fragment was composed of mainly metamorphic occurrences and intrusives. On the other hand, Inner Tauride Suture separates Munzur and Bitlis prolongations and bounds the basin from south (Sengor and Yilmaz, 1981). This suture also determines southern branch of the Neotethyan ocean.

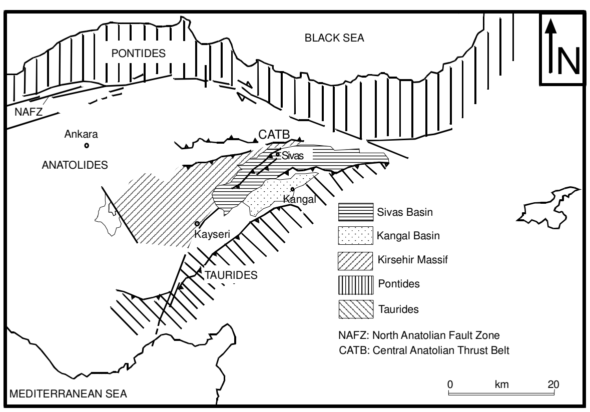

Figure 1. Location map of the Sivas Tertiary Basin (modified from Poisson et. al., 1996).

One of the most detailed studies to expose the tectono-stratigraphic setting and evolutionary development of the Sivas Basin was realized by Poisson et. al. (1996). The authors claimed that the basin has continental basement rather than an oceanic crust. According to them, décollement Oligocene gypsum levels determine tectono-stratigraphic evolution of the basin. The basin elongates roughly in NE-SW direction. Decollément gypsum levels in evaporitic rocks dip gently toward the continent and it is possible to see remarkable examples of these levels on satellite imagery in white tones such as Landsat ETM+ images (Figure 2).

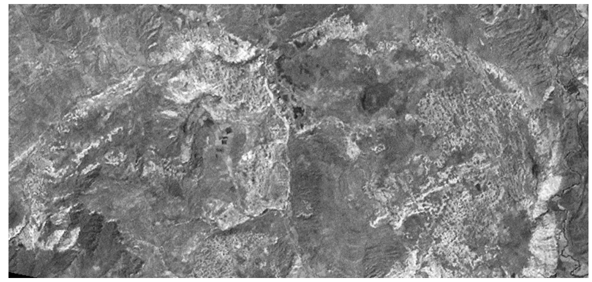

Figure 2: Décollement gypsum levels on band 5, Landsat ETM+ image are highlighted in white.

2.1. Field studies

In this study, field-based data were formed with the aid of fault kinematic studies collected from the southern parts of the basin. These measurements were evaluated Carey method (Carey, 1979). According to this method, the generally active minimum principal stress axis (σ3) for this region is in a vertical direction and compresses a strike in a NNW–SSE direction (Figure 3).

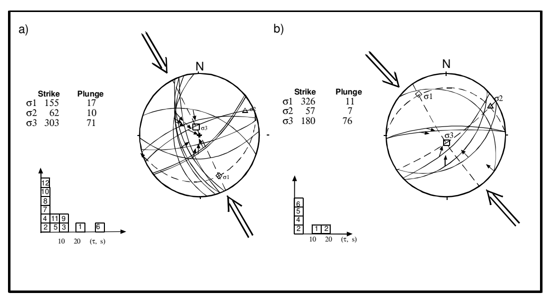

Figure 3: Fault measurement results. (Lower hemisphere stereographic projections of striated fault planes measured in the field. σ1, σ2 and σ3 are respectively the maximum, mean and minimum paleostress axes. Histogram shows that the distribution of deviation angles between predicted slip vector (τ) and the computed slip vector (s))

3. IMAGE PROCESSINGS

Gypsum karst is also a geomorphologic phenomenon which affects intensively Oligocene Hafik formation gypsum deposits in Sivas Tertiary Basin (Gunay, 2002). Eastern parts of Sivas Basin which where outcropped over large areas are under this geohazard risk. Also, some collapse lakes such as Hafik, Todurge, western and eastern Lota are located eastern part of the basin. All lakes were formed by collapsing gypsum occurrences in this region (Figure 4) similar to other worldwide examples such as in Florida/USA.

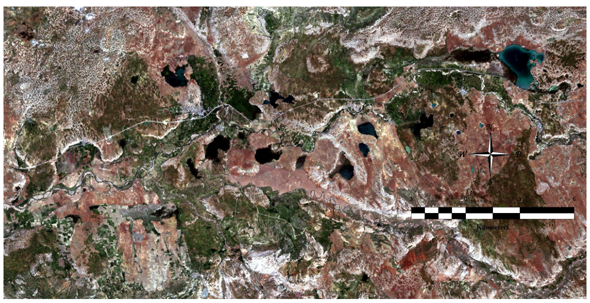

Figure 4: Collapse lakes in the eastern section of Sivas Basin on Landsat TM 3,2 and 1 bands.

In this study, image processing procedures were realized Brovey transform, principal component analysis (PCA), and unsupervised classification methods.

3.1. Image fusion

Because of availability of 15 meters panchromatic spatial resolution feature of Landsat ETM+ system, Brovey transform was chosen as one of the most robust fusion methods.

As is well known, 1, 4 and 7 th bands represent visible, near and middle infra-red regions of electromagnetic spectrum. Due to this basic fact that, their RGB combination display which were composed of respectively 7,4 and 1 bands emphasize differentiation between lithological contacts combining with spectral information content (Drury, 2001).

This method is evaluated the most photo-interpretative method according to the other types of data fusion techniques such as high-pass filtered, multiplicative, principal component analysis based and IHS (intensity, hue and saturation) methods (Carter, 1998; Bretschnider and Kao, 2000).

This transformation algorithm (ER Mapper, 1998) was used for RGB display in this study as below:

Red= band 7/ (band 1+ band 4+ band 7) + Landsat ETM+ panchromatic band
Green= band 4/ (band 1+ band 4+ band 7) + Landsat ETM+ panchromatic band
Blue= band 1/ (band 1+ band 4+ band 7) + Landsat ETM+ panchromatic band

A healthy differentiation based on visual interpretation between exposing lithological units of Sivas Basin with the aid of combining spatial and spectral enhancements was provided by Brovey transform in this study (Figure 5). Although vegetation is an undesirable component in image processing studies, it has been very helpful geologically to derive structural features in this study. In Figure 5, dark blue colour shows realms of Inner Tauride Ocean and characterizes allochthonous ophiolites. Figure also shows a remarkable fold-thrust belt that was developed between Lower-Middle Eocene Bozbel formation, which was composed of laterally graded flysch, tuffites and volcanic intercalations and Late Cretaceous ophiolitic mélange rocks. Bozbel anticline, which was described firstly by Kurtman, (1973), elongates in NWW-SEE direction compatible with boundary of southeastern parts of the basin.

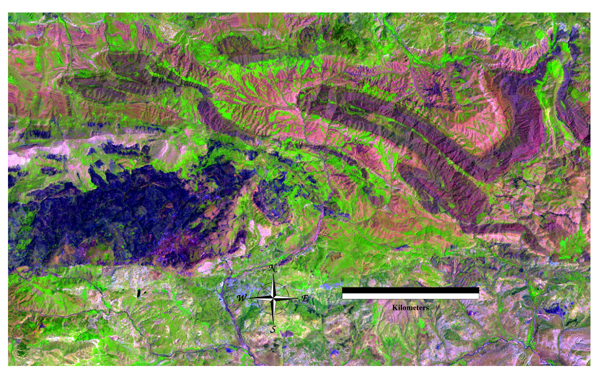

Figure 5: Spectacular fold expressions on Landsat ETM+ 7,4, 1 (RGB) combination with Brovey transform displays southern parts of the Sivas Basin.

3.2. Principal Component Analysis (PCA)

PCA, which was also known as Karhunen-Loéve (Sabins, 1996) method is a linear transformation technique in image processing studies and reducing data redundancy method between spectral bands. In this analysis, PCA transformation was applied to SPOT XS image of the Sivas Basin.

As is seen clearly in Figure 6, this spectral enhancement mode provides satisfactory results to differentiate geologic units of the region. Spectral differences in RGB display indicate also observing of regional structural features. These elongations approximately in NE-SW trending also determine the southern boundary of the Sivas Basin (Figure 6).

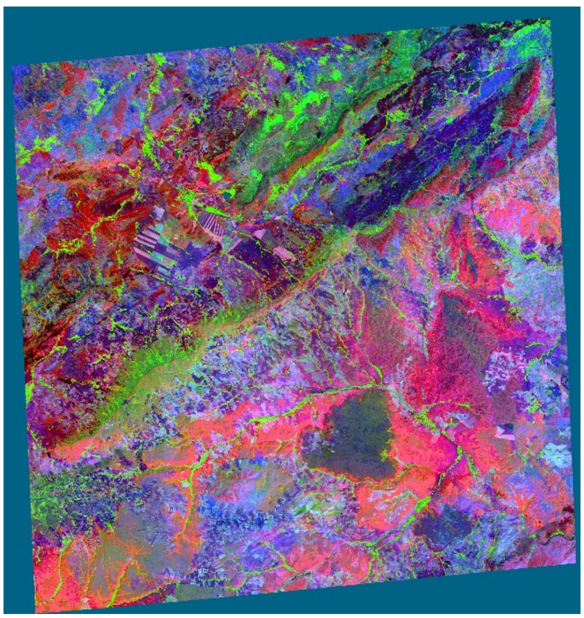

Figure 6: PCA (123) components on a full-scene SPOT XS image.

3.3. Classification

An unsupervised classification has been applied to differentiate geological units to Landsat TM image of the study area. To determine numbers of the spectral classes, 1/500.000 scaled geological map of the region has been considered. Figure 5 shows this relationship. But this method has not satisfactory results as PCA method because of proximities in spectral differences of the geologic units of the region.

But, presence of a distinctive basin (Kangal) which were made up of mainly by younger Neogene deposits and plateau basalts in yellow and pink tones is observed clearly in the lower parts of the images.

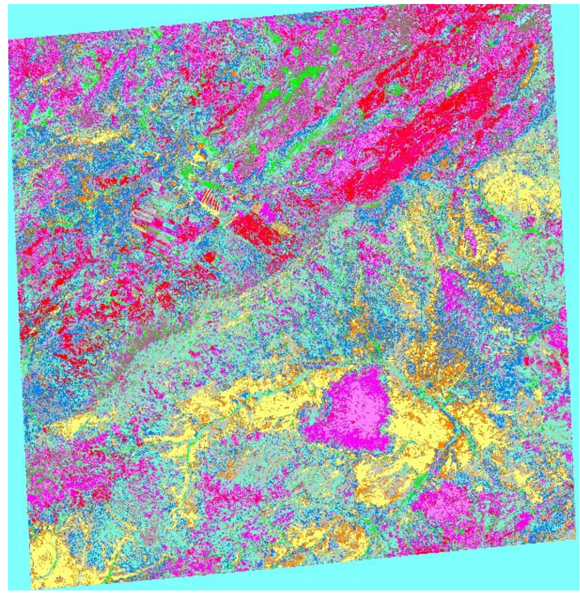

Figure 7: Unsupervised classification result of SPOT XS image.

4. DEM ANALYSIS

In this study, DEM analysis was chosen as a robust assessment tool inferring structural features. High-resolution digital elevation data sets derived from radar systems has been most reliable public sources to evaluate any region structurally. Topographic analysis efforts in geosciences have been supported using digital elevation models (Pollard, 2002). As is well known, visualisation techniques support and facilitate interpretations as well as evaluation of data quality, and thus enhancement of the model itself.

In this study, we will use two different SRTM-3 (N39E036 and N39E037) data of Sivas Basin. Observed orientations of the structural features of the Sivas Basin can be seen in Figure 8. The Kizilirmak River floor, which transects the basin obliquely in NE-SW direction, is parallel to the general trends of the basin. Although no considerable seismic data could be found in historic earthquake database, some authors claim that this river floor can be represented as an active fault (Inan, 1993; Kocyigit and Beyhan, 1998).

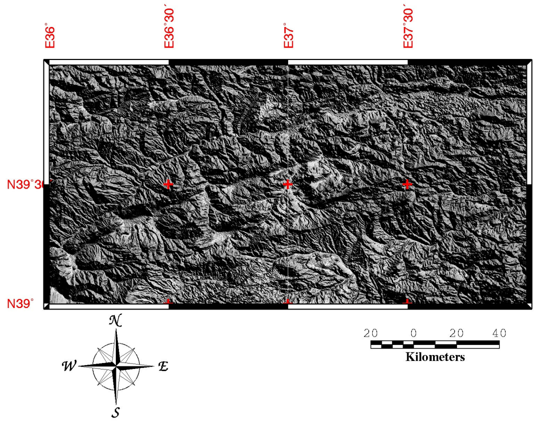

Figure 8: SRTM-3 data is helpful to asses

Conclusions

Tectonically, Sivas Basin has been developed on the Alpine-Himalayan belt with the complex interactions of Eurasian, Arabian and African plates. Remarkable marks of this collisional process were observed roughly in N-S direction within the Oligocene Hafik formation, which was composed of mainly massive gypsum deposits after Upper Miocene. Deformational behaviour of décollement levels are proofed the presence of thin-skinned deformation along their contacts within horizontally Mio-Pliocene sediments.

Brovey transform, which was also known a useful image fusion method, may be very useful spatially in lithological differentiation studies combining with panchromatic band in Landsat ETM+ images. On the other hand, public use digital elevation data such as SRTM-3 and their evaluations in planar and three-dimensional modes aid structural evaluation efforts in geosciences and clench the results of directional edge enhancement processes.

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