Analysis of potential field anomalies in Pasinler-Horasan basin, Eastern Turkey

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Abstract: *This study was carried out in the Pasinler-Horasan basin (Eastern Turkey), where sedimentary rocks of the Neotectonic period (from Eocene up to present day) outcrop and exhibit considerable oil and coal potential. This basin extends approximately in the E-W direction, is surrounded by the Pontides to the north and the Bitlis Mountains to the south and its basement is of pre-Miocene age. In this study, the tectonic structure of the Pasinler-Horasan basin was examined by using gravity and magnetic data. A full horizontal derivative map was computed from the gravity data. The power spectrum method was applied on the Bouguer gravity data of the region. The estimated average sedimentary basin thickness and Moho depth are equal to 4.7 km and 42.9 km, respectively. The average Curie point depth was also calculated as 18.4 km from magnetic data, which indicates a magnetic body within the lower crust (LC).*

Key words: *Pasinler-Horasan basin, eastern Turkey, tectonic and crustal structure, gravity and magnetic data*

INTRODUCTION

Previous regional studies in the Pasinler-Horasan basin in Eastern Turkey focused on the exploration for oil and coal (Fig. 1, Akkuş, 1965; Pelin, 1981; Kerey and Bozkuş, 1984). Following the occurrence of earthquakes, seismicity studies were performed in this basin (Koçyiğit, 1983; Şaroğlu and Yılmaz, 1987). The neotectonic evolution of the region was investigated by Bozkurt (2001) and Koçyiğit et al. (2001).

Gravity and magnetic maps give useful information concerning the thickness of sedimentary basins (Hinze, 1985). Gravity data acquired at 0.5 km point intervals and aeromagnetic data gridded at intervals of 2.5 km were provided by the General Directorate of Mineral Research and Exploration (MTA). Lithological boundaries related to lateral changes in density and fault locations can be determined by computing the horizontal derivatives of the gravity anomalies (Blakely and Simpson, 1986; Blakely, 1995; Bundalo et al., 2002). Horizontal gradients related to shallow structures exhibit high values and form relatively short lineaments.

The average depth of underground masses can be calculated from gravity data using the power spectrum method, which is a statistical technique (Spector and Grant, 1970; Mishra and Naidu, 1974; Cianciara and Marcak, 1976; Maden and Gelisli, 2001). The Curie point depth can also be computed from the magnetic data using the same method (Bhattacharyya and Leu, 1975; Byerly and Stolt, 1977; Okubo et al., 1985; Blakely, 1988; Okubo et al., 1991). This is the depth at which the dominant magnetic minerals exhibit crustal temperatures to the Curie point and it reflects the thermal structure of the region. Partial melting of the lower crust contributes to its present thermal structure. According to previous studies, the Curie point depth depends on the geologic context. The Curie point depth is shallower than about 10 km at volcanic and geothermal areas, ranges between 15 and 25 km at island arcs and ridges, is deeper than 20 km at plateaus and deeper than 30 km at trenches (Tanaka et al., 1999).

In this paper the tectonic structure of the Pasinler-Horasan basin was studied using the gravity and magnetic data. Average sediment thickness of the basin and Moho depth were calculated from gravity data. Also, the average depth of magnetic sources was determined.

GEOLOGY AND TECTONIC FEATURES

The area of interest around the structurally developed Pasinler-Horasan basin is shown in Figure 1. The basin consists of Neotectonic sediments and is surrounded by pre-Miocene rocks. The Pasinler-Horasan formed as a unique one in the beginning of the Neotectonic period. Later it was divided into subareas due to volcanic activity and deformations (Şaroğlu and Yılmaz, 1987). Normal faulting in Pliocene developed a graben. Terrestrial clastic rocks with different

volume percentages were deposited in the basin. Arc shape step-fault uplifted ophiolitic rocks, which cover the southern slopes of the graben. Locally developed horst and grabens do not affect the main structural style, although they are commonly observed in the basin. A fault zone, trending in the NE direction, is located to the south. Previous studies (Koçyiğit, 1983; Şaroğlu and Yılmaz, 1987) indicate compression from Middle Quaternary up to present day due to northward movement of the Arabian Plate.

Sedimentary rocks of Eocene to Quaternary age outcrop in the study area (Fig. 2). The basement in Pasinler-Horasan region is composed of ophiolitic rocks. The Kağızman ophiolitic complex is unconformably overlain by an Upper Eocene sedimentary package, which is in turn overlain by Upper Lower-Middle Miocene sedimentary rocks. The youngest sedimentary rocks were formed during the period between Late Miocene to Pliocene. Quaternary alluvium covers all these rocks. Due to frequent variations in lateral and vertical facies and faulting, thickness of sediments changes within the basin.

INTERPRETATION OF THE FIELD DATA

The gravity data used, provided by the MTA, were acquired at 500 m intervals and with 0.01 mGal precision. Gravity values were tied to MTA and General Command of Mapping base stations related to the Potsdam 981260.00 mGal absolute gravity value, which is accepted by the International Union Geodesy and Geophysics in 1971. Latitude correction was applied, according to the 1967 International Gravity Formula. Bouguer reduction and topographic correction, to a distance of 167 km, were calculated, assuming a terrain density of 2.40 Mgm^{-3}.

The Bouguer gravity map of the Pasinler-Horasan basin (Fig. 1) shows closed anomalies in its middle west and north east part, due to the low density sedimentary units. The horizontal derivative of gravity anomalies is maximum over the boundaries of geological structures like horst or graben, masses extending horizontally and vertically, fault blocks and volcanic intrusive bodies (Blakely, 1995). Fault zones associated with the formation of the basin, can be determined by computing horizontal gradient of the gravity anomalies (Fig. 3). Thus, the boundaries of buried vertical structures are imaged. The partial derivatives of the horizontal gradient were computed, using finite differences. Additional faults appear on the computed map besides those in

Figure 1. The known faults (straight lines) and the inferred faults (dashed lines), shown in this figure, are approximately parallel. To the north, continuous lineaments exist in the NE direction, while to the south there is a lineament in the E-W direction. This lineament is not continuous in the Çobandede-Söylemez line, probably due to volcanism. Lineaments appear again in the NE direction, south of the Horasan-Kepenek line. These lineaments indicate the boundaries of the geological structures and volcanic uplift areas. The gravity derivative map assists in basin modelling study.

The power spectrum method computes the thickness of the sedimentary basin and of the crustal Moho depth (Spector and Grant, 1970), by taking 2-D Fourier transformation of the Bouguer anomaly. On the power spectrum curves, amplitude decreases with increasing wavenumber. The power spectrum analysis reveals three distinct linear segments (Fig. 4). The slope of the segment to the left determines the thickness of the sediment basin (h3=4.7 km), which is defined with less precision. From the segment to the middle the depth to the UC-LC interface is calculated (h2=12.8 km). The segment to the right exhibits the steepest slope, which corresponds to the mean continental Moho depth (h1=42.9 km). These depths are in agreement with the ones computed by Mindevalli and Mitchell (1989).

The MTA conducted an aeromagnetic survey in Turkey during 1978–1989. Aeromagnetic data were collected along flight lines spaced at 1–3 km profile intervals, at an elevation of 600 m above ground level. The flight direction was perpendicular to the regional geologic formations and tectonic structures (Aydın and Karat, 1995; Ateş et al., 1999). MTA gridded the data with 2.5 km intervals. The magnetic map shows high amplitude and high wavenumber anomalies in the region under investigation (Fig. 5). The high amplitude anomalies lying in the NE direction may originate from the metamorphic rocks in the basement. Okubo et al. (1985; 1989) suggested a method to compute the depth to the bottom (Zb) of deep magnetic sources from the spectral analysis method (Spector and Grant, 1970). The depths to the top boundary, Zt and the centroid Zo, of magnetic sources are determined from the slope of the log power spectrum. Then, the depth Zb and the Curie point depth are calculated from Zt and Zo (Okubo et al., 1989).
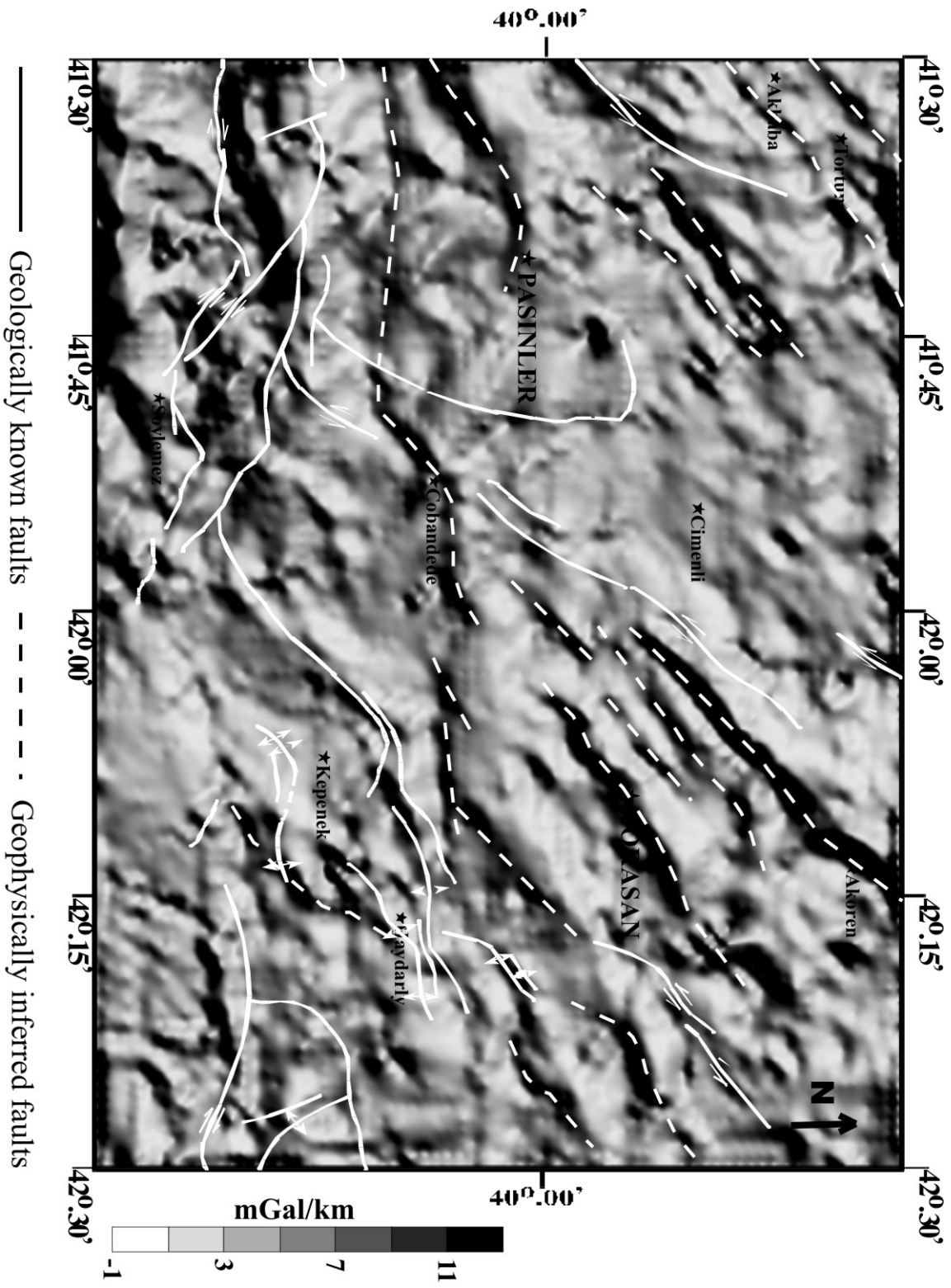
FIG. 1. Simplified geological and the Bouguer anomaly map of the Pasinler-Horasan basin. The Bouguer anomaly was computed using 2.4 Mgm-3 as reduction density. The contour interval of the Bouguer map is 10 mGal. The location of the investigated area is shown in the inlet map.

FIG. 2. Generalized stratigraphic column of the Pasinler-Horasan basin (modified after Aksu, 1994).

FIG. 3. Grey scale image of the full horizontal derivative Bouguer gravity in the Pasinler-Horasan region.

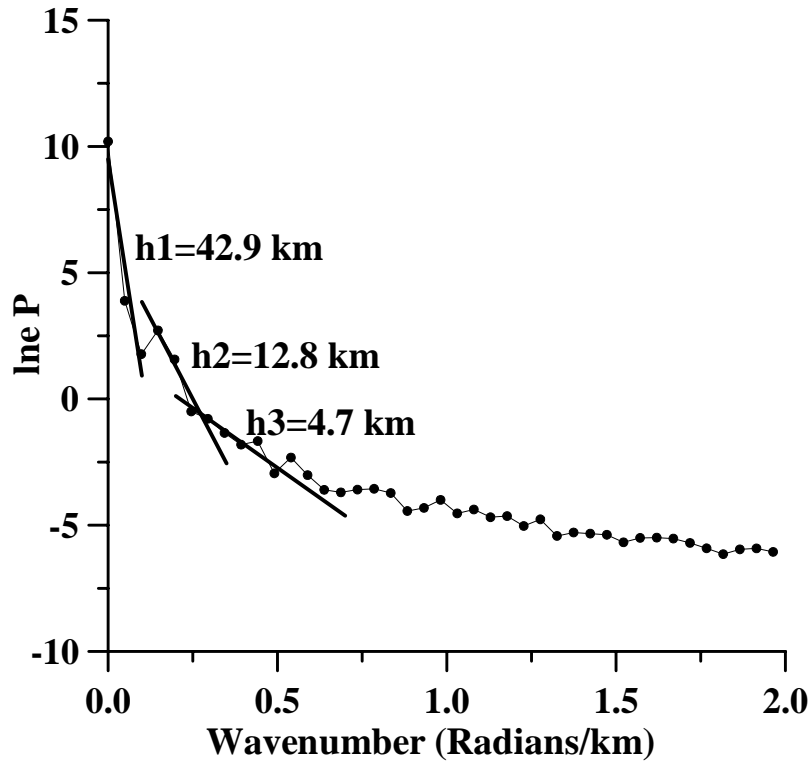——— Geologically known faults   — — — Geophysically inferred faults

FIG. 4. Power spectrum of the Bouguer gravity data. It is a plot of the logarithm of the energy versus wavenumber of the gravity data collected in Pasinler-Horasan basin and its surroundings. The estimate h1 represents the Moho depth; h2 and h3 represent the depth estimates for the main physical interfaces within the crust.
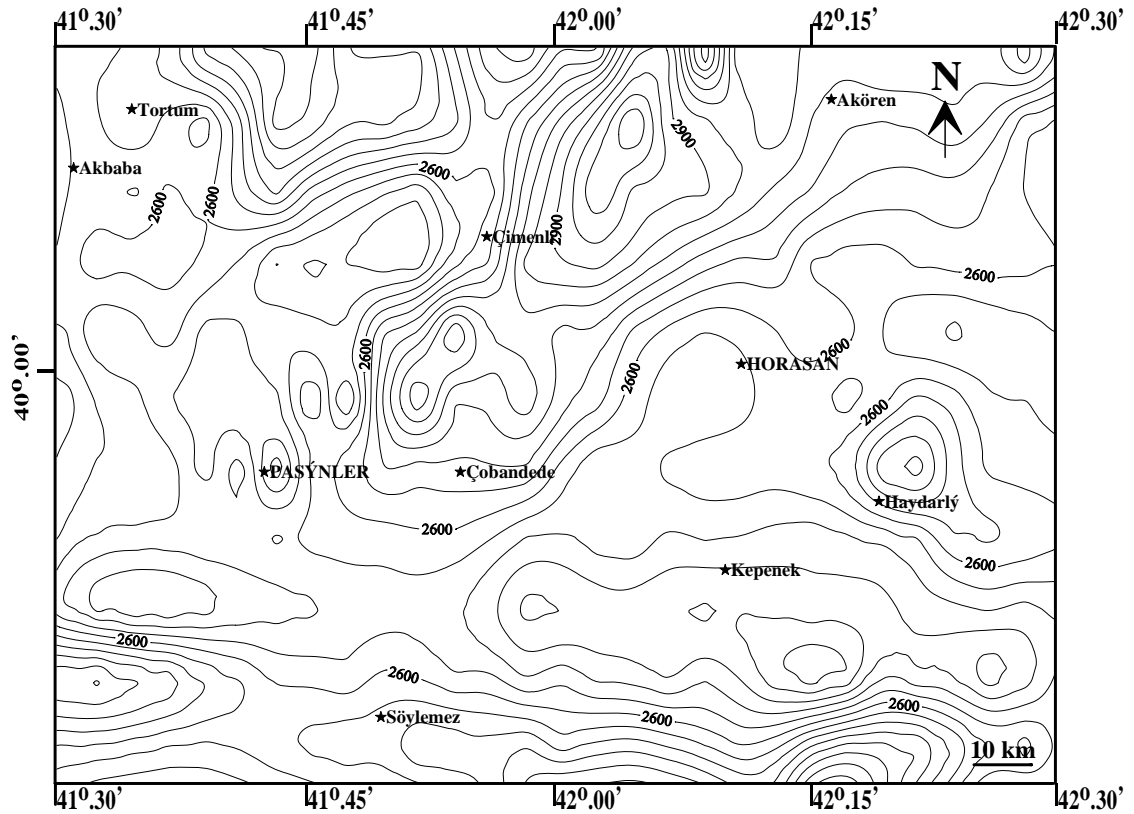

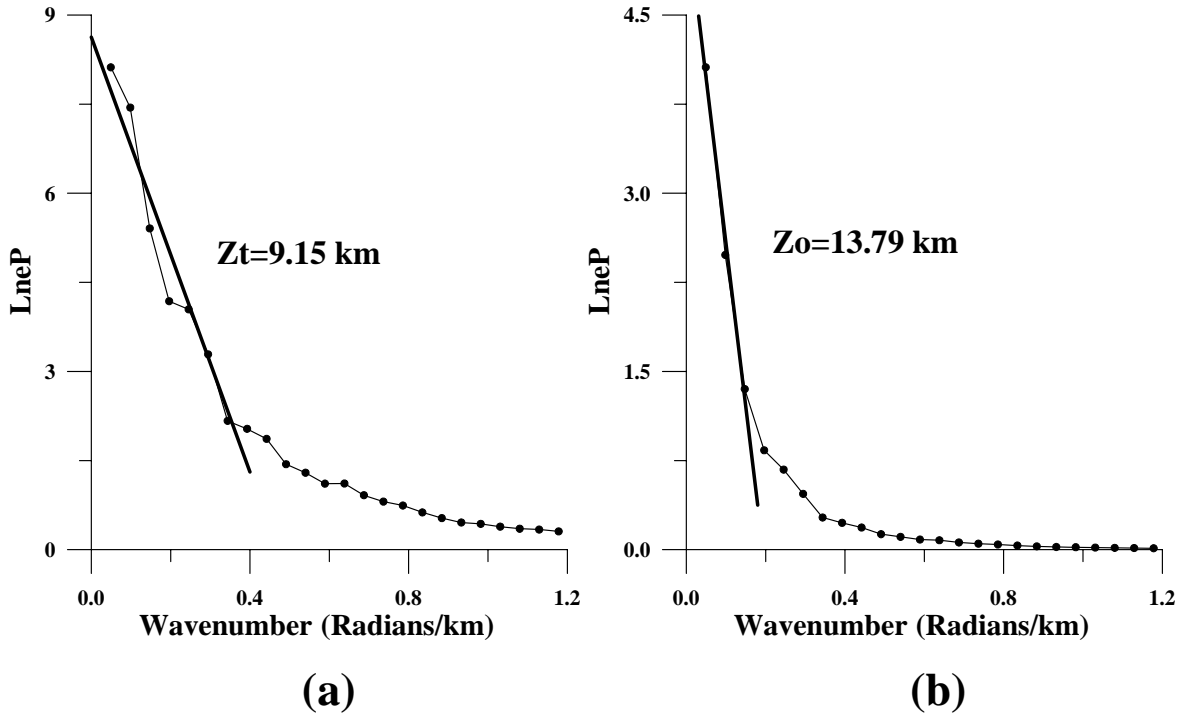**FIG. 5.** Total-field aeromagnetic map of Pasinler-Horasan basin, contour interval is 50 nanoteslas.

FIG. 6. Power spectrum curve of the aeromagnetic data, (a) top boundary of magnetic layer (Z_t), (b) centroid of a magnetic layer (Z_o) derived from the slope of the power spectrum curve.

This power spectrum method was applied to the Pasinler-Horasan basin aeromagnetic data.

The data were transformed to the Fourier domain, in order to calculate the log power spectrum and to estimate the Curie point depth (Fig. 6). The data were reduced to the pole with high pass filtering. The depths to the top boundary and centroid of the magnetic layer in this basin are equal to 9.2 km (Fig. 6a) and 13.8 km respectively (Fig. 6b). The estimated Curie point depth is 18.4 km. Whereas the Curie point depth ranges from 7.9 km to 22.6 km in central Anatolia (Ateş *et al*., 2005) and from 8.2 to 19.9 km in Western Anatolia (Dolmaz *et al*., 2005).

(maximum values of the horizontal derivative) are evident and continuous in the north and have fragmental structure to the south. Thus, the full horizontal derivative map gives compatible information regarding the tectonic structure. According to the gravity data, the Moho depth is 42.9 km, upper crust thickness is 12.8 km and average thickness of the sedimentary basin is 4.7 km. The Curie point depth is equal to 18.4 km, indicating that a magnetic body or a layer is located within the LC.

CONCLUSION

Gravity, magnetic and full horizontal derivative gravity maps of the region were employed in order to study the Pasinler-Horasan basin. The full horizontal gradient map in the study area revealed the extension directions of the basin and fault locations. Due to the rotation caused by volcanic compression, NE direction faults dominate the northern part of the region, while E-W faults are present in the southern part. The faults determined from the main tectonic lineaments

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