BULLETIN OF THE MINERAL RESEARCH AND EXPLORATION

Foreign Edition 2013 146

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Bulletin of MTA (2013) 146 : 105-116

Bulletin of the
Mineral Research and Exploration

http://bulletin.mta.gov.tr

NEOGENE STRATIGRAPHY OF THE ESKİŞEHİR GRABEN AND THE INVESTIGATION OF COAL DEPOSITION BY SEISMIC REFLECTION METHOD

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Key words:
Eskişehir,
Stratigraphy,
Coal,
Seismic reflection

Abstract

The study area is located within the Eskişehir Graben, north of Ağapınar village in the Sevinç district and east of Eskişehir City. Miocene deposits unconformably overlie the basement of Paleozoic metamorphites and Mesozoic ophiolites. The m1 series constituted by gravel, sandstone and claystone is observed at the base of Miocene deposits. The overlying m^2 series, from bottom to top, represents a sequence of partly conglomerate, green claystone, coal, gray sandstone, dark gray to green siltstone, bituminous marl, claystone, coal, green claystone, sandstone and fine grained conglomerate. The m^3 series of limestone and conglomerate is patchy and Pliocene deposits consisting of loose gravel, claystone overly them. The stratigraphical succession in the region covered by Neogene deposits has been investigated during surveys and reservoir drilling in licence areas belonging to MTA. High resolution shallow seismic reflection data were collected on two lines crossing each other considering field conditions (vegetated areas, irrigation channels, Porsuk River, railway line, etc.) and locations of boreholes made in the basin. These collected data were assessed in the Data Processing Center of the Seismic Research Division of the Geophysical Research Department (MTA),to produce the final sections of the seismic reflection. The data were then correlated with borehole data on or adjacent to the lines. The surface of reflection (yellow colored level) which could be continuously traced through all sections was deduced as the Paleozoic basement corresponded to ophiolites in borehole data. Reflection surfaces which are observed in areas, where the seismic basement deepened by multi-staged discontinuity surfaces of the seismic basement and rely especially on slopes of seismic basement, were determined as coal-claycontactzone. It was also revealed that, data obtained from drilling works continuing in the region correlate with geophysical interpretations made on seismic profiles.

1. Introduction

1.1. The Aim of the Study

The purpose of this study is to investigate the detectability of suitable sites for coal deposition and coal seams in the basin by geophysical methods before running drilling investigations in Neogene basins in our country. The seismic reflection, one of the geophysical methods, has successfully been applied in environments where there are sufficient acoustic impedance contrasts with respect to upper/lower and surrounding units that form as layers. Seismic reflection method was applied in this study as coal seams displayed significant differences regarding the surrounding units in terms of elasticity.

For the last 20 years, seismic reflection methods in 2D and 3D with high resolution have been used by many investigators in order to specify the structural and stratigraphical characteristics of coal in detail (Henson and Sexton 1991; Gochioco 1991*a, b;* Miller et al., 1992; Pietsch and Slusarczyk 1992; Gang and Goulty 1997; Peters 2005; Hendrick 2006). The low resolution in shallow seismic reflection method with high resolution depends on the frequency spectrum

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of the data recorded and the interval velocity of the layer in interest. Resolvable layer thickness is equal to the one fourth of the dominant wavelength of a seismic wavelet (Widess, 1973). The dominant signal frequency and the interval velocity of coal in this study were estimated as 45 Hz. and 1850 m/sec, respectively. Accordingly; the minimum resolvable layer thickness was approximately determined as 10 meters.

Geological discontinuities available along coal seams can be considered as the most important problem that increase the cost encountered at coal production stage. The seismic reflection method has also another importance in determining such problems that might come out during the production planning stage.

The detection of both the upper and lower boundaries of the coal seam has equal importance in seismic investigations where the coal seams are explored. Therefore; it is preferred to have high accuracy during estimation in such basins.

The study area is located at the north of Sevinç district and Ağapınar village, the eastern part of Eskişehir (Figure 1). In other words; it is situated within the Eskişehir Graben, to the north of the Eskişehir Fault zone (Ocakoğlu, 2007). The basement rocks in the study area consist of Paleozoic metamorphites and tectonically associated Mesozoic ophiolites (Figure 2). Basement rocks are unconformably overlain by Miocene deposits. The m1 series consisting of conglomerate, sandstone and claystone is observed at the bottom of Miocene deposits. The overlying m2 series represents, from bottom to top, an alternating sequence of partly conglomerate, green claystone, coal, gray sandstone, dark gray to green siltstone, bituminous marl, siltstone, coal and green claystone, sandstone and fine grained conglomerate. The m3 series consisting of limestone and partly conglomerate, and Pliocene deposits consisting of loose conglomerate and claystone underlain by m2 series. Quaternary alluvial, recent sediments and alluvial fans cover all older units in the area (Figure 3).

2. Methodology

2.1. Data Collection

Seismic lineswere determined as a result of studies for determining the seismic program design and field parameters and their locations were assured by field observations. With these data, parameters were specified performing check shots on related lines for the selection of data collection and record parameters as a result of QC (Quality Control).These parameters were then assessed.

Lengths of crosscutting NW-SE directing ESV0903 and NE-SW directing ESEV0904 profiles are 15.324 and 7.452 meters, respectively; in the study of seismic reflection performed within the scope of project (Figure 4).

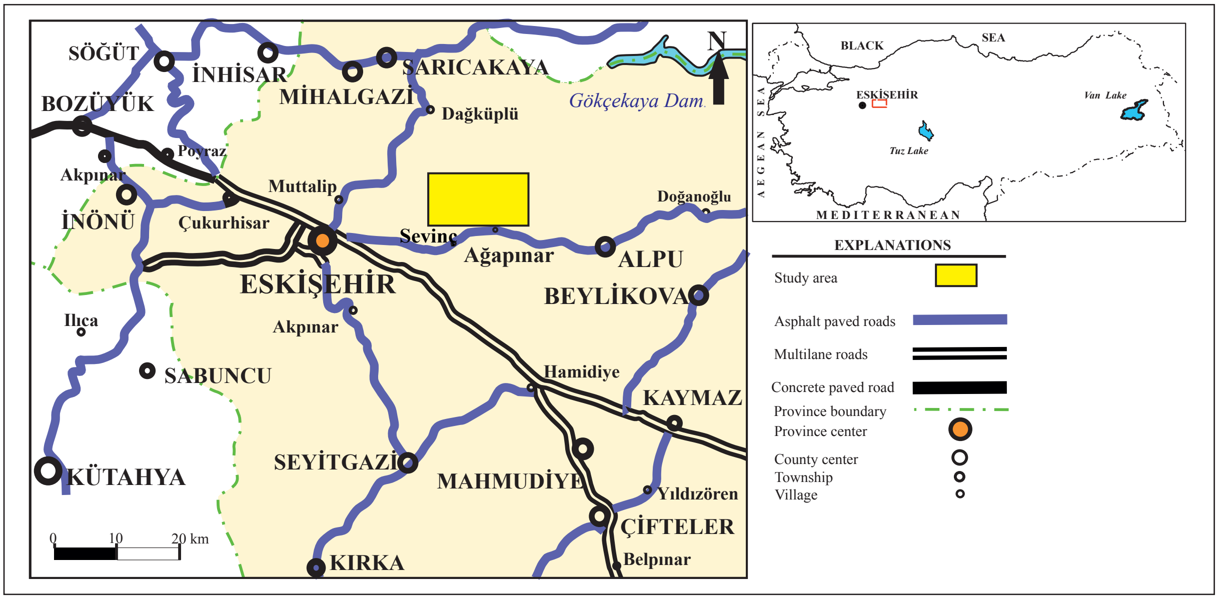

Figure 1- Location map of Sevinç - Ağapınar (Eskişehir) Coal Site.

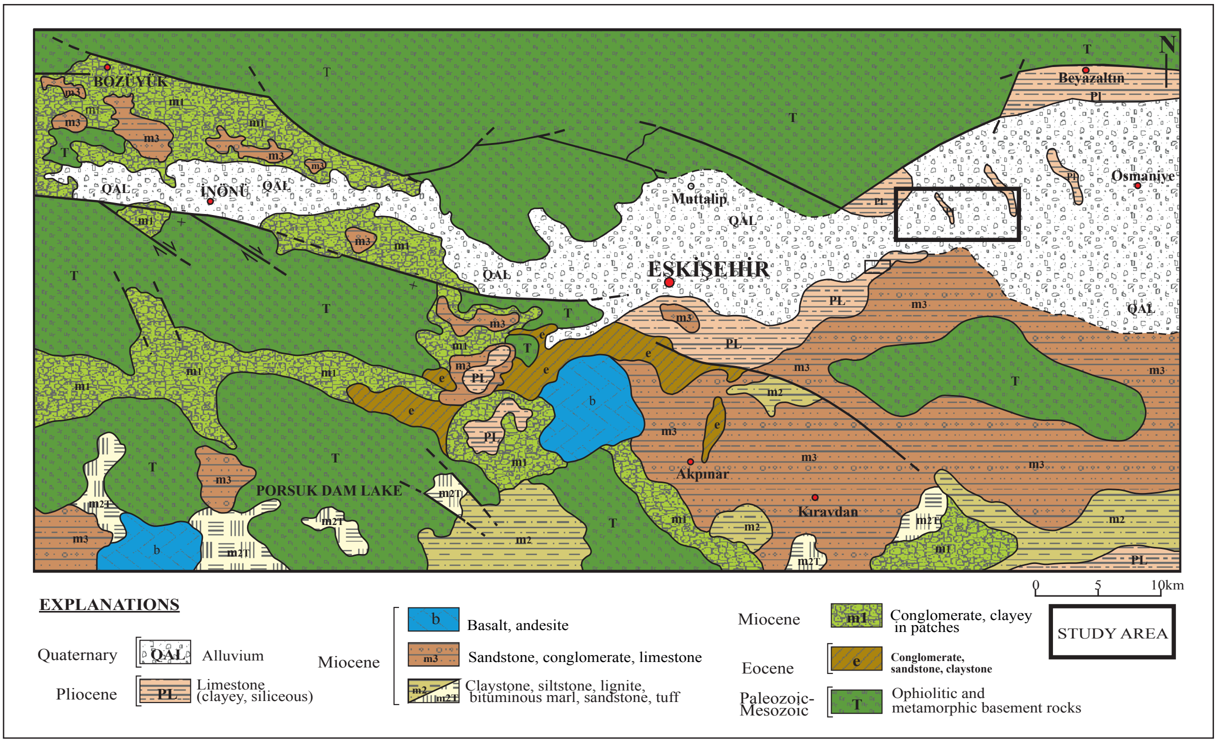

Figure 2 – Generalized geological map of the Eskişehir Basin (Şengüler 2011)

For check shots; 240 channel spread was made and the offset amount was considered to be increased beginning from 30 meters.The optimum distance was determined considering the shallowest level in the study and that the closest traces could get affected from seismic noises originating from shots.

Sercel 428 XL data acquisition equipment was used in the study. The system is composed of both the ground and recording equipment. The seismic energy in the study was formed by using 2 (Mini Vib II) vibro seismic energy sources.

Parameters given below were selected regarding the depth at which the information to be acquired, the purpose of the study, vertical and horizontal separations and to increase the data quality. In doing so; the spread geometry was selected as asymmetric spread (Table 1).

2.2. Seismic Data Processing

The purpose of the seismic data processing is to make data collected more meaningful and interpretable. To do that, first the data collected is refined from noises by means of various data processing techniques related to the purpose and target of the study.

The best seismic profile was obtained by data processing on data conducted within the scope of project and data collected on field. During data processing, total of 1647 (valid shootings) shooting points were madeon ESV0903 and ESV0904 seismic lines as 1127 and 520 points, respectively (Izladı et al., 2010).

Data collected on field were recorded in SEDG format, and then the quality control of each shooting was performed by being investigated in data analysis mode in Disco Focus software. Data processing flow chart which was used as a basis for the data collected on field and built for the use of Seismic Researches Division was given in figure 5.

3. Geology of the Study Area

The study area is located within the Eskişehir Graben at the north of Eskişehir Fault Zone, the eastern part of Eskişehir (Figure 1).

3.1. The Basement Rocks

Paleozoic metamorphites and Mesozoic ophiolites form the basement rocks in the area. Metamorphic rocks are tectonically in contact with ophiolitic rocks at north of the basin (Figure 2) with an imbricated structure directed from north to south (Gözler et al.,

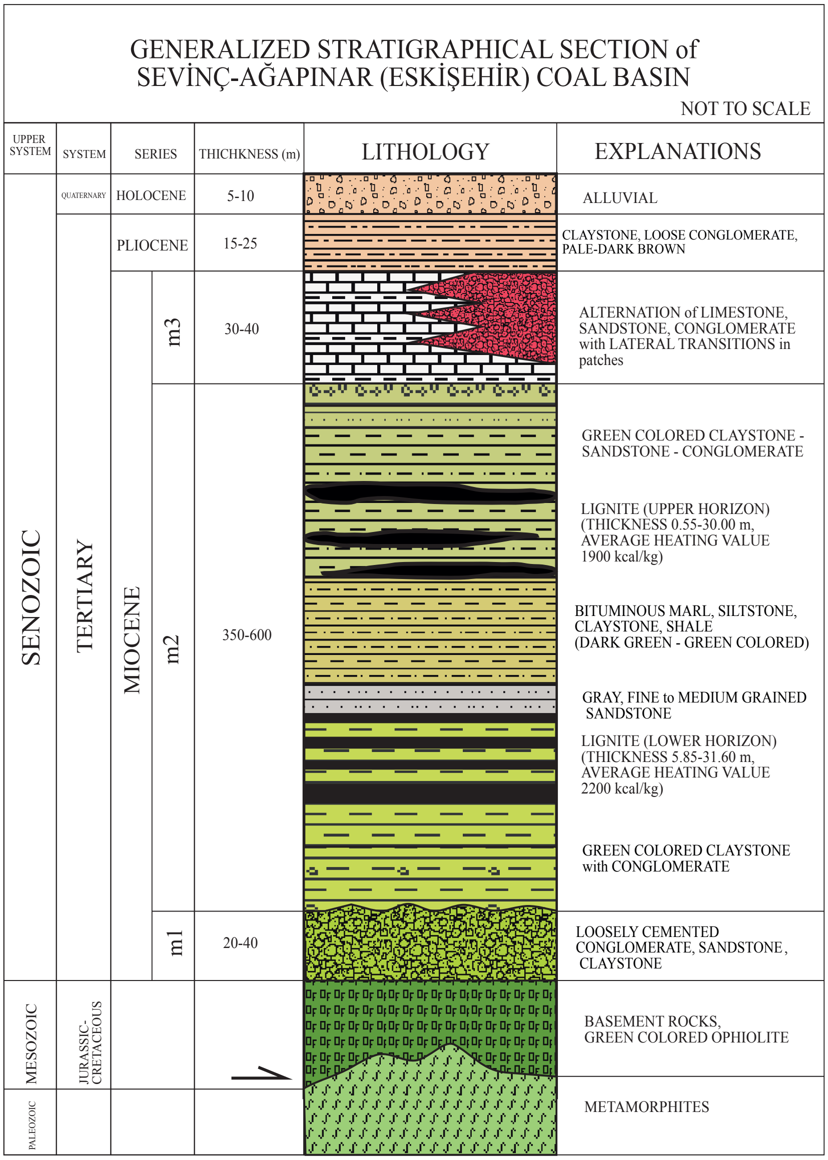

Figure 3 – Generalized stratigraphical section of Sevinç - Ağapınar (Eskişehir) Coal Basin (Şengüler 2010).

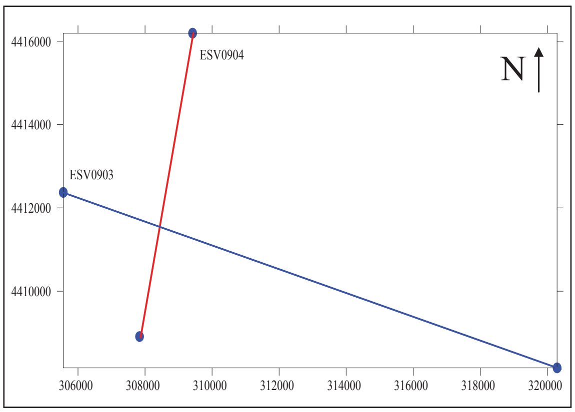

Figure 4 – Plot of ESV0903 and ESV0904 lines.

1996). It is hard to make a guess for the thickness of these rocks which display folded, faulted and fractured structures. However; it was observed that, schists and marbles in the area had thicknesses of 1000 and 200 meters, respectively.

The ophiolitic mélange, which does not have a regular sequence, is represented by; radiolarites, radiolarian limestones, mudstones, serpentinites, diabase, limestone, schist blocks, partly serpentinized peridotite and partly metamorphosed diabase and gabbro. The unit is generally dark green, brown and red colored, and highly folded and fractured structures are observed in radiolarite and mudstones.

Table 1- Shooting geometry applied in Seismic Reflection and recording parameters.

Sweep type	Linear
Sweep frequency rate	20-200 Hz
Sweep amount	8
Sweep time	8 sec
Sweep Taper	300 msec
Recording time	2 sec
Sampling rate	1 msec
Spread type	asymmetric
Shooting distance	12m
Group distance	6 m
Fold	60
Receiver type in-line	50cm (6 pack 2 string)
Offset	48 m

Serpentinization is widely observed in parts where peridotitic nappes are very near the contacts; however, the rate of serpentinization decreases within the massif. Peridotite and gabbro have formed high relief areas at the very north of the study area and at the south of the basin.

Melange, peridotite and gabbroic rocks, and metamorphites and metadetrites are tectonically associated among each other. This relation is determined by rather thick limonitized, carbonated and silicified listwaenite zones which run several kilometers at some places (Gözler et al., 1996).

3.2. Miocene Deposits

Miocene deposits unconformably overly Paleozoic and Mesozoic rocks forming the basement of the basin. At the bottom of Miocene deposits, m1 series takes place consisting of pebble, sandstone and siltstone. These deposits, on the other hand, are overlain by m2 and m3 series (Figure 3).

3.2.1. m1 Series

The m1 series at the base of the Miocene rocks is distinctive with its thick to very thick layer and red, yellowish gray, gray to pale gray and mostly with its red, brown-red colors. This unit starts with conglomerate and gravel ranging from pebble size to block size consisting of schist, marble, radiolarite, chert, gabbro, diabase, serpentinite, granodiorite and limestones from the underlying older units (Siyako et al., 1991). The conglomerates are typically cemented by dolomite in areas close to ultramafic rocks but are cemented by chalcedony and limonite where listwaenitization is dense, however the cement is calcite near metamorphic and carbonate rocks (Gözler et al., 1996).

3.2.2. m2 Series

The m2 series which overlies the m1 series, from bottom to top, represents a deposition formed by a sequence of partly pebbly green claystone, coal, gray sandstone, dark gray to green siltstone, bituminous marl, claystone, coal and green claystone, sandstone and fine grained conglomerate. The deposit is mainly green to yellow in color and partly speckled. The lower levels of claystone and marls which are observed as in very thin layers are red to purplish red in color and pass into green color.

Yellow colored parts of the m2 series take place generally in the upper levels of claystone and marls. There are observed partly sandy limestone bands within marls, and quartzite, marble, ophiolite, radiolarite and granodiorite pebbles in yellow to yellowish gray sandy limestones. Thinlayers of sandstone transitional with conglomerate are observed within layers of marl-claystone. Gray colored, fine to medium grained sandstone layer presenting thicknesses that vary between 2-5 meters which is located over the lower coal seam is distinguishable (Şengüler, 2011). The thickness of m2 series varies between 350-600 meters in deeper parts of the basin, but this thickness is about 400 meters in the study area (Figure 3).

Tuff and tuffite is encountered within m2 series at the southern part of the basin. These units consist of white, speckled, pinkish and brick red colored, fine grained pyroclastic materials. There is observed welded tuff around the basin, and tuffite intercalating with marl and clay within the basin. Marls and clays are generally in green, yellow, gray in color and partly speckled, and are observed at the deepest part of the basin. It is possible to see very thinly banded limestones in patches among marl and clay layers.

Coal formations are observed at places where lower parts of marl and claystones overlie conglomerate and sandstones. The formation of coal and bituminous marl at the north of Sevinç - Ağapınar takes place at depths varying between 250 – 450 meters (Şengüler, 2010). The coalification in the study area is in the form of two horizons. The heating value of coals

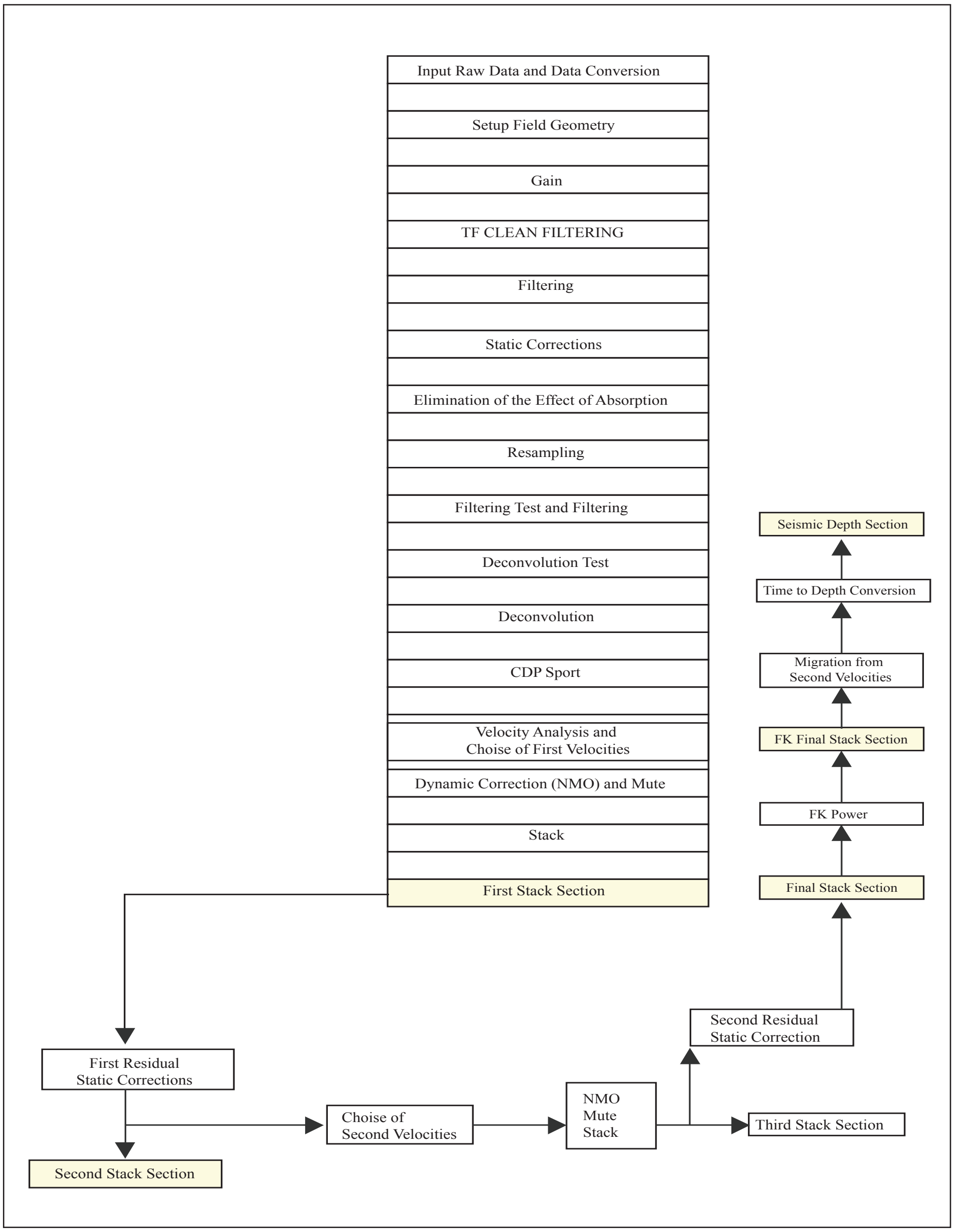

Figure 5 – The generalized flow chart of data processing of MTA Seismic Division.

varies between 1500 -3000 kcal/kg, and the average heat value is 2050 kcal/kg. It was again estimated that, the moisture as 34 %, ash as 32 %, volatile material as 21 %, fixed carbon as 13 % and sulfur as 1.5 %. The average coal thicknesses between the lower and upper coal horizons are different, and the average coal thicknesses for both zones are around 13 -14 meters.

Tuffite and marl intercalations are common at south of the basin. These are both laterally and horizontally transitional with the underlying unit and generally inter tongue with conglomerate and sandstone (1 meter). Places where there is intercalating vertical transition with tuffites above was observed at southern parts of the basin. Limestone intercalations were observed within conglomeratic sandstones and tuffites. Besides; lensodial and wedging tuffite and conglomerates were encountered within limestones as well.

3.2.3. m3 Series

This series consists of partly encountered limestone and pebble in upper layers. The limestone is in creamy white and gray colored and generally is observed as lenses. It is observed in the form of silicified and partly siliceous inter banded limestones at west, and as porous clayey and tuffaceous limestones at east. The sandstone was also encountered as alternating. Limestones and conglomerates display lateral transitions at north of the basin of the study area. Thickness of the unit in the study area is between 30 -40 meters (Figure 3).

3.3. Pliocene Deposits

Pliocene deposits in the study area are represented by creamy to pale brown claystone and by loosely cemented conglomerate. Conglomerate layers underlain by m3 series contain pebbles of all units older than it. Pebble sizes range between 1-10 cm and the thickness of the unit varies between 15 – 25 meters.

3.4. Quaternary Deposits

Quaternary alluvial, recent sediments and alluvial fans unconformably cover all older units (Figure 3).

4. Drilling Investigations

Drilling investigations related to reservoir determination which started in 2002 within the scope of “Project of Eskişehir Basin Coal Explorations” still continue in license areas of MTA. Some of the exploration studies and reservoir drillings conducted within the scope of project (which were assessed in the study) were located on and near the seismic lines and shown as blue points in figure 4.

5. Geological and Geophysical Interpretation of Seismic Reflection Sections

In 2009, a seismic section over two lines were generated during seismic reflection studies conducted on license areas of MTA at north of Sevinç District and Ağapınar Village in Eskişehir. After data processing of these sections were completed in Data Processing Center of the Geophysical Researches Department, the main structural characteristics of the geological environments were studied and interpreted.

The product generated after the process of seismic data is the section of a seismic time in this method. In seismic time section,the horizontal axis indicates the CDP numbers in terms of meter as distance on the seismic line measured on field. However, the vertical axis displays the travel time in terms of seconds.

Average velocities obtained during seismic data processing stage were used in the assessment made by correlating the aforementioned two seismic time sections with borehole lithologies drilled near lines. These velocities do not represent velocities ofthe actual formation layer, but only make an approach. If the vertical seismic profile (VSP), check shots, and/ or geophysical well log (density, sonic) data were not obtained in drilling wells in the study area then the depths estimated using average velocities which had been obtained only from data processing would make a predictive approach to actual depths.

The reflection surface (yellow colored level) which can continuously be traced along all sections was detected as the seismic basement entrancewhen seismic sections were assessed in general. On interpreted sections, the reflection of surfaces observed in areas especially where the seismic basement were deepened by the effect of both sided, cascaded fault lines (green colored levels) were specified as the coal-clay bypass zone.

It is considered that, discontinuities observed on surfaces of reflection that could be traced on interpreted seismic time sections correspondwith fault lines. Most probably, the basin deepens by the effect of fault lines corresponding with the CDP points numbered as 14063 -15280 in ESV0903 line and with CDP points numbered as 22120 – 23640 in ESV0904 line, and displays a multi staged and fractured structure in it. The seismic basement as well shows an elevation in north - south and in east - west directions beginning from these CDP points. Besides; there is observed a multi staged and highly fractured structure cutting through the seismic basement and cover layers as well in the basin.

5.1 ESV0903 Line

The probable deepestplace was determined as 650 meters,considering the average velocity between CDP points of 14560-14600 as 2030 m/sec, as a result of the average velocity obtained by velocity analysis for the level designated as the seismic basement based on interpreted time section.

Wells of ES-JF, ES-44, ES-45 and ES-9 along the line were plotted onto the scaled section at corresponding CDP points (Figure 6). The level determined as coal-clay zone in the study corresponds one to one with the carboniferous level cut in the well. Considering the average velocities at CDP points that correspond to ES-JF well, the coal velocity was

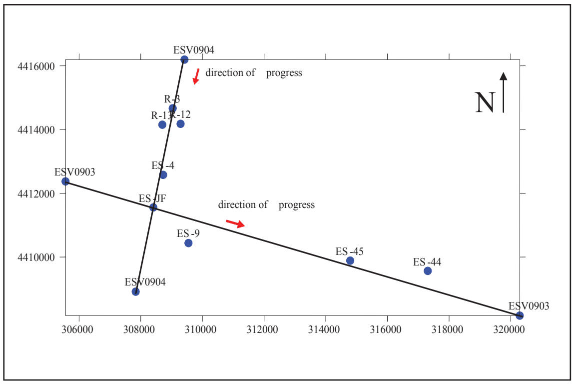

Figure 6 – Location of drillings on and near the lines.

approximatelyestimated as 1871 m/sec. By using this velocity,it was estimated that the probable deposition of the coal begins at a depth of 355 meters. This value almost corresponds approximately with the value of 356.15 meters which was determined in borehole data.

Considering the average velocities on CDP points corresponding to ES-9 well, the coal velocity was approximately estimated as 1867 m/sec. By using this velocity,it was estimated that the probable deposition of the coal begins at a depth of 399 meters. This value almost corresponds approximately with the value of 376.15 meters which was determined in borehole data. No traces of coal were encounteredin wells of ES-44 and ES-45 located near the line.

5.2. ESV0904 Line

The probable deepestplace was determined as 741 meters,considering the average velocity between CDP points of 22840 - 22880 as around 2100 m/sec as a result of the average velocity which was obtained by velocity analysis for the level designated as the seismic basement based on interpreted time section.

Wells of R-3, R-12, R-13, ES-4 and ES-JF along the line were plotted onto the scaled section at corresponding CDP points. The level determined as coal-clay zone in the study shows one to one correspondence with the carboniferous level cut in the well (Figure 7). Taking the average velocities at CDP points corresponding to ES-JF well into consideration, it was determined that the coal velocity detected for coal was estimated as 1810 m/sec approximately. Using this velocity, the coal-clay zone probably begins at a depth of 348 meters. This value almost corresponds approximately with the value of 356.15 meters that was determined in borehole data.

Considering the average velocities at CDP points corresponding to ES-4 well on the line, the coal velocity was determined approximately as 1808 m/sec. By using this velocity,the probable depth ofthe coal-clay zone begins at a depth of 316 meters. This value almost matches with the depth value detected by borehole data obtained which is 316.7 meters.

Considering the average velocities at CDP points corresponding to R-3 well on the line, the coal velocity was determined approximately as 1814 m /sec. By using this velocity,the probable estimated depth for coal-clay zone is 290 meters. This value almost matches with the depth value detected by borehole data obtained which is 304.85 meters.

Considering the average velocities at CDP points corresponding to R-12 well on the line, the coal velocity was determined approximately as 1819 m / sec. By using this velocity,it was estimated that the coal-clay zone probably begins at a depth of 364 meters. This value almost matches with the depth value detected by borehole data obtained which is 358.8 meters.

Considering the average velocities at CDP points corresponding to R-13 well on the line, the coal velocity was determined approximately as 1818 m / sec. By using this velocity,it was estimated that, the depth for coal-clay zone probably begins at a depth of 250 meters. This value almost matches with the depth value detected by borehole data obtained which is 243.3 meters. In order the depth to be relatively seen in the study, all well logs on seismic sections were plotted over lines as scaled.

The borehole data which was opened after the seismic reflection had been completed on the field as well indicate that the seismic reflection method could be used in coal sites. In drilling investigations performed in 2010 on the field, wells corresponding with seismic lines were studied. So, these wells and the compatibility of coalified zone detected on the stack section interpreted in 2009 indicate that, disciplined studies would contribute a lot to the country in terms of both the economy and time.

As a result of the seismic process performed in Data Processing Center, the average velocity for the drill R230 coinciding with ESV0903 Line was used as 1817 m/sec. (Figure 8). In depth conversion made by using this velocity, the depth at which the coalified zone begins at CDP point number 15610 was found as 410 meters. The coal was tested at 399 meters at the

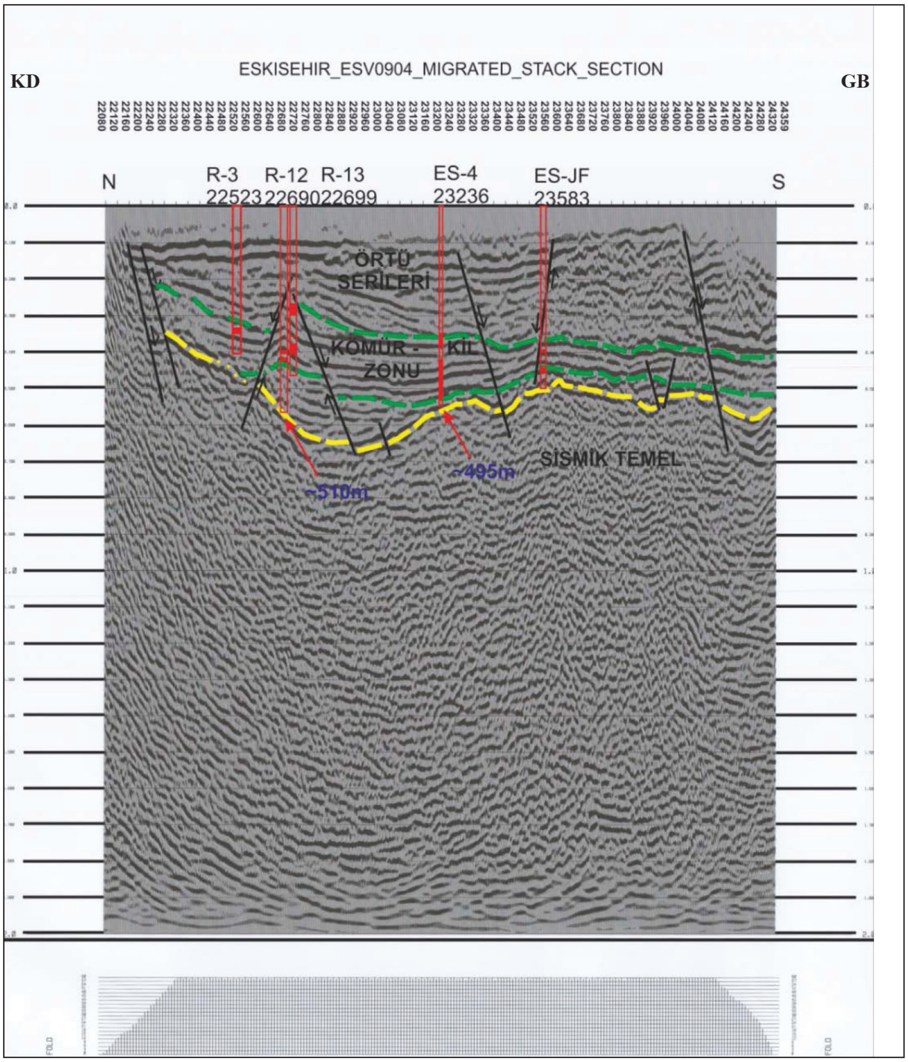

Figure 7 – Interpreted, migrated stack section of ESV0904 line.

drilling run at the same point. The average velocity for the drill R34 coinciding with ESV0904 Line was used as 1810 m/sec. In the depth conversion made by using this velocity, the entry depth into the coalified zone at CDP point number 23909 was found as 348 meters. The coal was tested at 306 meters at the drilling run at the same point. Sections of average velocity anomaly for the lines were given in figures 9 and 10.

6. Results

It can be seen above that, there are small differences between the depths estimated during data processing for the entrance of the coal bearing zone and entrance values of drillings for the coal bearing zone. The reason is that, the estimated and used velocities during data processing are not completely the same with actual velocities of the medium. Since the most ideal velocities representing the medium could be obtained from methods such as; Sonic Log and Check Shot, the depths estimated will make the best approach to actual depths. However; in cases when these methods cannotbe used, then depth conversions can be made by using velocities estimated at data processing stage and an approach to actual depths can be achieved. As a result, all methods make an approach to actual velocity of the medium and differences at depth values given above are within acceptable limits of the depth estimated from velocities selected at data processing stage.

On interpreted ESV0903 and ESV 0904 sections, the reflection of surfaces observed on areas especially where seismic basement were deepened by the effect of both sided, cascaded fault lines (green colored levels) were specified as entrance for coal-clay zone.

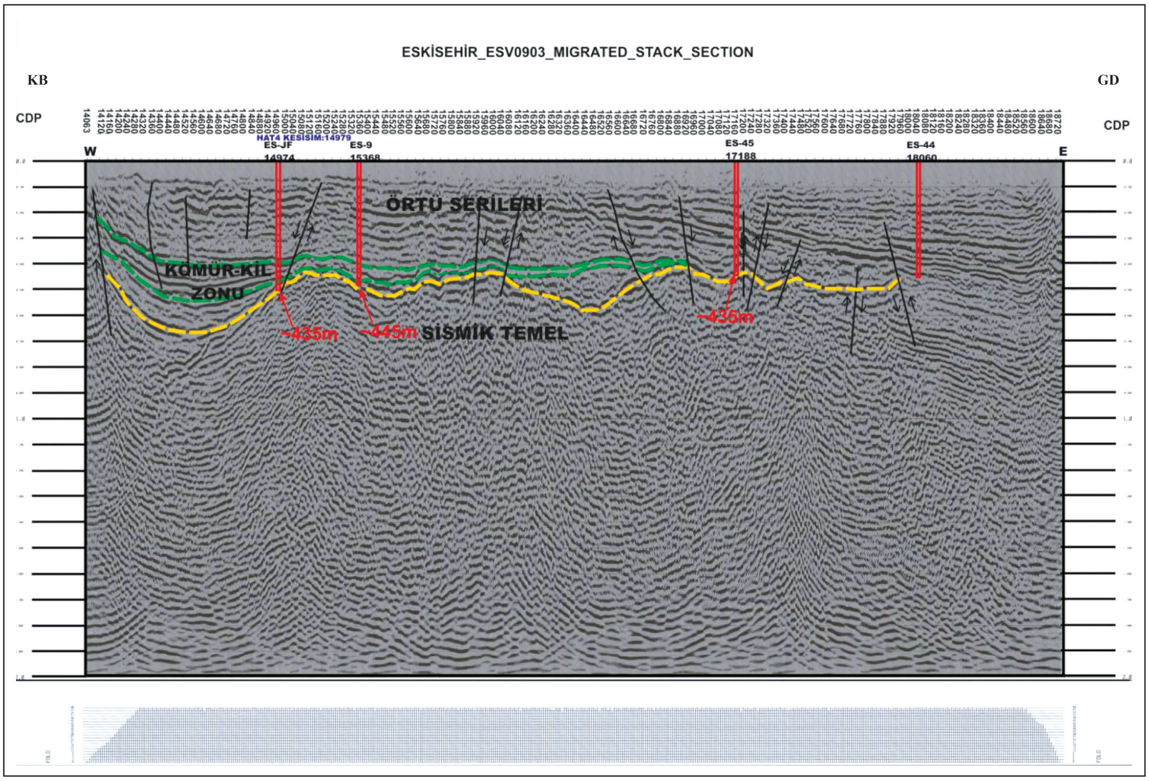

Figure 8 - Interpreted, migrated stack section of ESV0903 line.

It was seen that, these zones were conformable with lithological unit boundaries of these levels determined when compared with borehole data performed on the field.

It was seen that, the seismic basement was deepened especially in the region of ESV0904 section to the west of the study area and the coal thickness became thickened.

It is considered that, discontinuities seen on reflection surfaces that can be observed on interpreted seismic time sections correspond to fracture systems. Most probably; the basin deepens by the effect of mutual fracture systems and displays a multi staged and fractured structure in it. This fact is also compatible with sections obtained by resistivity studies that have been carried out in Eskişehir basin in recent years.

All these studies that have been carried out within scope of project reveal that, geophysical methods supported by geological data could be used for the determination of the basement topography in covered Neogene areas.

Acknowledgment

This study has been made within the framework of “Project of Eskişehir Basin Coal Explorations” conducted by the Department of Energy Raw Material Research of the General Directorate of Mineral and Exploration (MTA).

Korhan Köse and Vasfi Pektaş have made literature surveys forthe positioning of lines by using the seismic program design relevant to the purpose of the study and by aeromagnetic and regional gravity maps studied prior to field investigations.

Data collected in the field have been processed and made ready for the interpretation by Z. Rezzan Özerk and Sinem Aykaç of the Data Processing Center of Seismic Researches Division in Geophysical Researches Department.

During seismic reflection studies, seismic section along two lines have been formed and data processing completed at Seismic Data Processing Center of the Geophysical Researches Department then these data have then been interpreted by A. Tolga Toksoy and Abdullah Gürer.

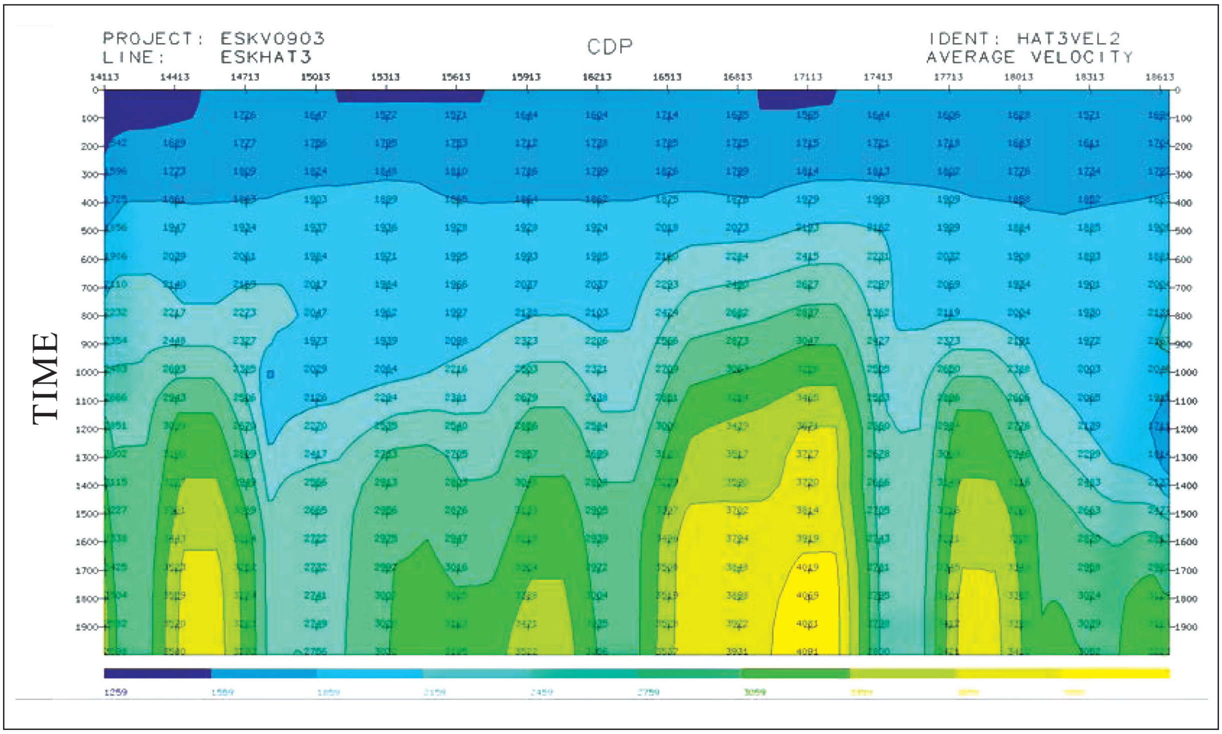

Figure 9 – Average velocity anomaly section of ESV0903 seismic line.

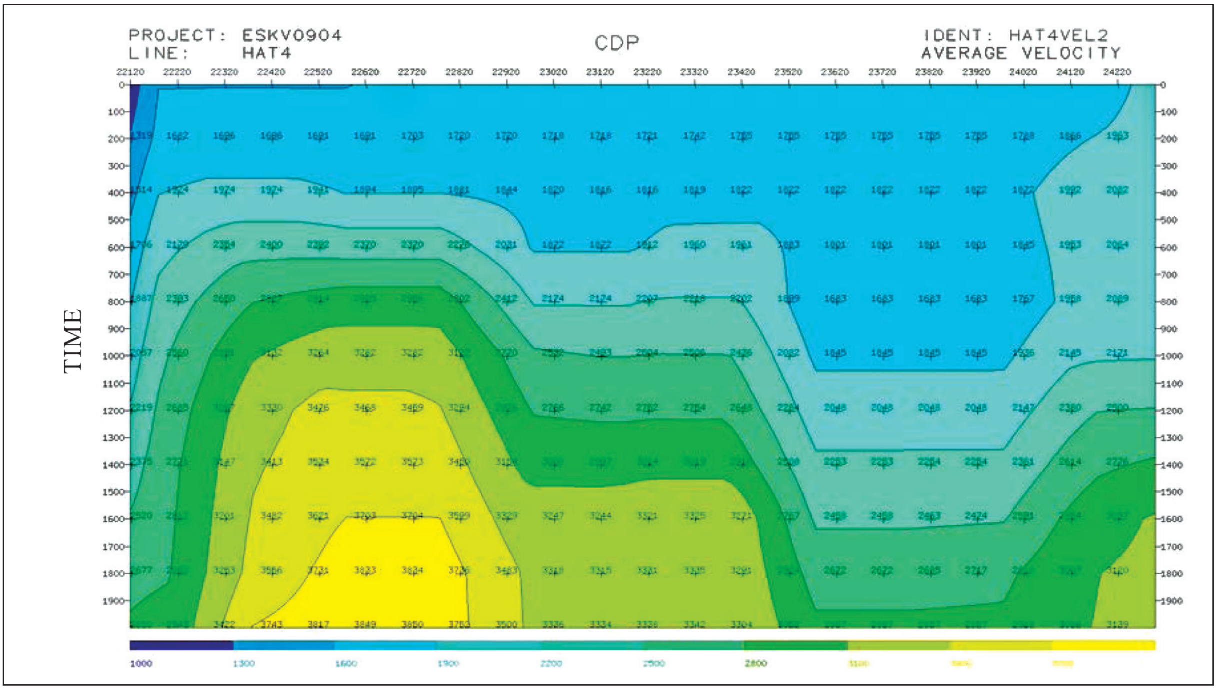

Figure 10 - Average velocity anomaly section of ESV0904 seismic line.

We are thankful to Yılmaz Bulut, Korhan Usta, Mahir Sezgin, Semih Kutlu, İmam Çelik, to all staffs of the Laboratory Division of the Geophysical Researches Department, the Seismic Data Collection Unit and to map technicians who have contributed a lot at different stages of the investigations.

Received : 23.07.2012
Accepted : 20.11.2012
Published : June 2013

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