Mineral Res. Expl. Bull., 135, 45-62, 2007

A KEY STUDY FOR SEISMIC REFLECTION APPLICATION; GEOLOGICAL INTERPRETATION OF THE COALIFEROUS NEOGENE SEQUENCE IN AFŞİN-ELBİSTAN

Yahya ÇİFTÇİ* and C. Ertan TOKER*

ABSTRACT.- High-resolution shallow seismic reflection profiles were collected along three lines in Afşin-Elbistan basin, lignite-bearing sequence. Two of these lines are east to west oriented whereas the other is north to south. Collected data were processed first in MTA, then in TPAO and the 2D Seismic Lines were obtained. Stratigraphical and sedimentological data were correlated using well-log data located along the seismic lines. Afterwards, the information was tied to the seismic lines and the contents of the seismic reflection packages were interpreted. High amplitude reflection surface between 300 and 400 msec was described as the bottom of the Neogene-aged coal-bearing sequence. Other reflections between this bottom reflection and the surface were identified as different sedimentary units correlating to the well-log data due to their internal structures and different reflection patterns. This experimental study revealed that high resolution seismic reflection studies would provide useful geophysical data to interpret the coal-bearing sequences in Neogene aged coal-bearing basins. It is proved that high-resolution seismic reflection lines are the most useful geophysical data for stratigraphy and geological interpretation in sedimentary basins.

Keywords- Afşin-Elbistan, coal seams, High-resolution seismics.

INTRODUCTION

The study area is located between Afşin and Elbistan districts of K.Maraş (Figure 1). This coal-bearing zone is still run by TKİ and lignites are used at the thermal power plant. At this coal-bearing zone, drilling reserve development studies are conducted again by MTA separately. The geological data used in this study were provided by MTA Energy Department.

The base depth, lateral continuity and perpendicular seismic resolution of the coal-bearing zone were tested along a total of three seismic profiles two parallel pieces of which had lengths of 1,5 kms and 1,75 kms and a separate one with a length of 1 km intersecting these (Figure 2) in accordance with the drilling plan located on the field. The clay and coal levels, the seismic resolution of which decreased due to close values exhibited by the densities of the clastic rocks and coal levels found in the neogene sequence, were investigated at a frequency band of 25 - 250 Hz of the energy resource.

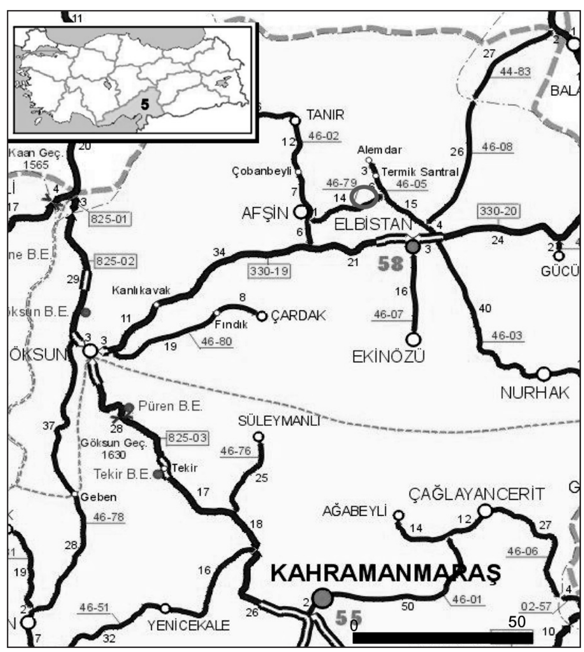

Figure 1- The location map of the Afşin-Elbistan (K.Maraş) coaliferous Neogene Basin.

These lines were processed as high resolution shallow seismic cross-sections in order to be

* Maden Tetkik ve Arama Genel Müdürlüğü, Jeofizik Etütleri Dairesi, Sismik Birimi, Ankara.

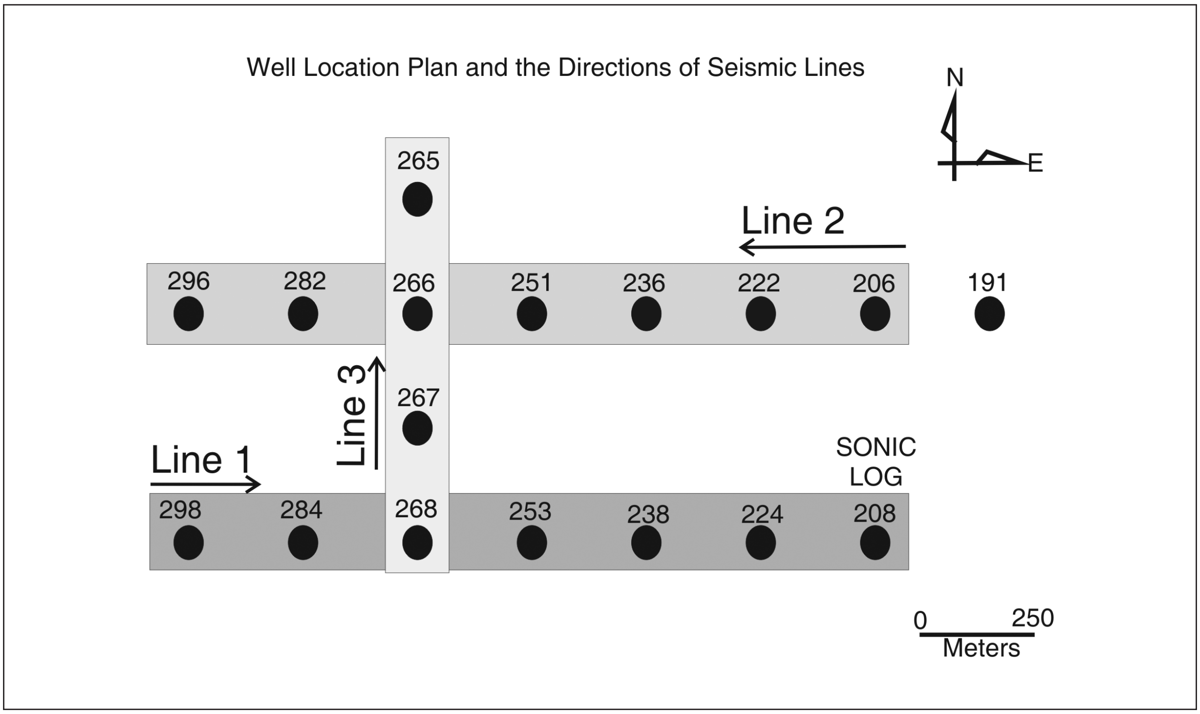

Figure 2- The line geometry of the seismic lines and the location map of the wells.

able to identify geological changes and to establish a correlation along lateral distances; and thus, certain reflection signs that are thought to reflect the inner changes of formations with a strong reflection surface the apex of which reaches up to 200 ms were obtained. The interpretation and lateral correlations of these motifs on each line can be traced on the final cross-sections.

STUDY METHODS

This study was conducted in three stages as seismic data collection on the field, data processing and geological interpretation of seismic cross-sections.

Data Collection

The record parameters used in the study are given in table 1.

During the field study, while shooting priority belonged to the recorder, after the existing canals were laid (66 canals) the profile was completed by advancing on the line sweep the 48 channels that were alive by use of Rollalong. As the advancing method, Off-End (Shooting at the

Table 1 - Shooting geometry practiced in the seismic reflection study and record parameters.

Recorder:	Strawiev 48 channels	Group distance:	5 meters
Geophone:	14 Hz	Shooting distance:	5 meters
Energy Resource:	MiniVib II	Sweep type:	Logarithmic
Sampling Interval:	1 msn	Sweep length:	6 sn
Recording Duration:	1024 msn	Taper:	1 sn symmetrical
Close Offset	15 mt	Pilot Trace	1st Channel

back, geophones in the front, by shifting) method was used in the study (Sakallıoğlu, 1995; Krug, 2004).

Data processing

The processing of the seismic data collected was performed in accordance with the conventional data-process scheme used by TPAO and shown in figure 3 (Yılmaz, 1987; Us, 1993). To this end, SUN work station within the body of MTA Marine Researches Coordination Unit was used. Once the general and routine processes using FOCUS data-process software were performed at that work station, for more detailed (high resolution) processes, TPAO data-process possibilities were made use of. Within this scope, the related profiles were re-processed using Promax data process software. This seismic cross-sections obtained as a result of this second process were of quality that could represent the geological milieu of the field in a high resolution manner.

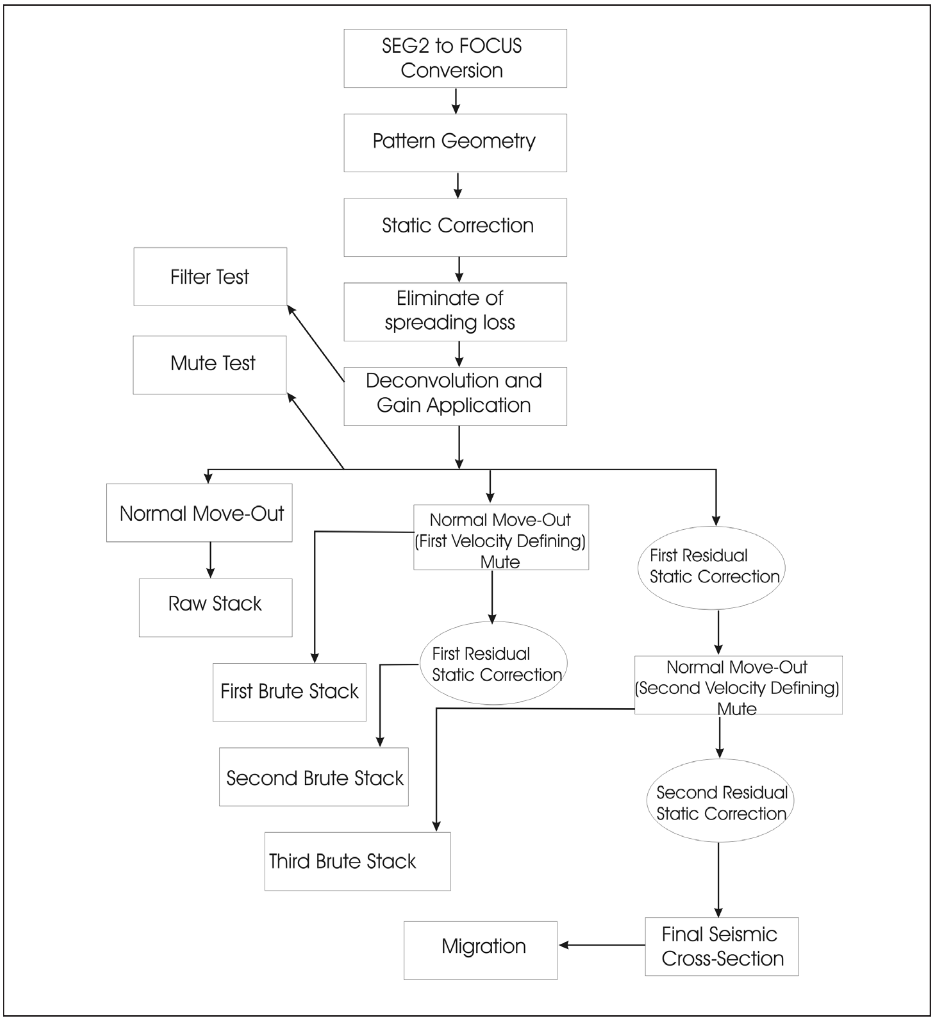

Figure 3- The process flow-chard of Afşin-Elbistan seismic data.

Geological interpretation

On the seismic cross-sections obtained as a result of the processing of the seismic data obtained, geological interpretation studies were conducted in order to both determine the depth and the geometry of the base rock and make lateral correlations relating to the inner structure of Neogene sequence. The geological interpretations on the seismic cross-sections were made using real well information provided by General Directorate of Mineral Research and Exploration (MTA) Energy Department. For this purpose, first, lateral correlations of the wells that remained on the seismic lines were made; and then, in order to be able to understand the evolution of the base morphology of the deposition basin for the Quaternary base, the wells were hung at certain DATUM levels before, during and after the deposition of coaliferous series and general geomorphologic and tectonic characteristics belonging to the deposition areas of the coaliferous level at the related period were tried to be understood. At the final stage, well information was carried onto the seismic lines and their correlations with seismic traces were made. Since the actual coordinate values of the well locations did not overlap with the coordinates of the seismic lines, their locations on the seismic lines were accepted as approximate.

At the second stage, interval speed values for each of the geological formations were calculated based on sonic log speed information. The seismic speed for alluvium and underlying silty clay layers from top to bottom was found to be 1600 m/sec; the seismic speed value for green clay layers (top clay) was found to be 1800 m/sec; the seismic speed value for coal horizon was found to be 2000 m/sec; and the seismic speed value for mudstone - marl layers at the bottom of the coal horizon was found to be 2300 m/sec. The seismic speed value of the formations at the bottom of the Pliocene series was taken as 3750 m/sec. From these values and by the help of Dix (1955) formula, RMS speeds and thus, stack speeds were found and seismic reflection cross-sections were obtained.

The base level of the coal horizon corresponds to 100 to 120 ms TTT (Total Travel Time) time values. When these values are converted to TWT (Two Way Travel Time) on the seismic reflection cross-section, approximately twice as much values of time are obtained. The depth equivalent of this time value is about 200 meters. In the same way, when the geological correlations of the lines are considered, it is seen that the base level of the coal horizon usually remains between 180 and 220 meters. The time values below are given in TWT.

GEOLOGY

Comprehensive geological researches covering basin as well are found in literature (Staesche, 1972; Tarhan, 1984, 1986; Perinçek and Kozlu, 1983). Besides, specifically MTA and TKİ reports are the most significant sources for the evaluation of the geology of this basin and coal formations (Koçak et al., 2002; MTA Collection Reports: Atay, 1981; Aydoğan, 1978; Barkurt et al., 1991; Baydar, 1975; Bilgin, 1982; Karlı, 1983; Mengeloğlu, 1999; Özcan, 1981; Uysal, 1985).

In the first extensive studies conducted on the basin, it is stated that the basin-fill rocks are formed of limnic and fluviatill facies rocks (Staesche, 1972; Gökmen et al., 1993). The generalized stratigraphic column cross-section of the basin is given in figure 4.

Perinçek and Kozlu (1983) state that Senozoic sequence in the Afşin - Elbistan region began with the Miocene aged Kuzgun formation, and upon this, Pliocene and Quaternary series began to subside (Figure 5). The same researchers considered the young terrestrial sediments in the region in two sets as Pliocene and Plio-Quaternary - Quaternary. It is stated that the Pliocene sediments, which constitute the main subject matter of this study, began with conglo-

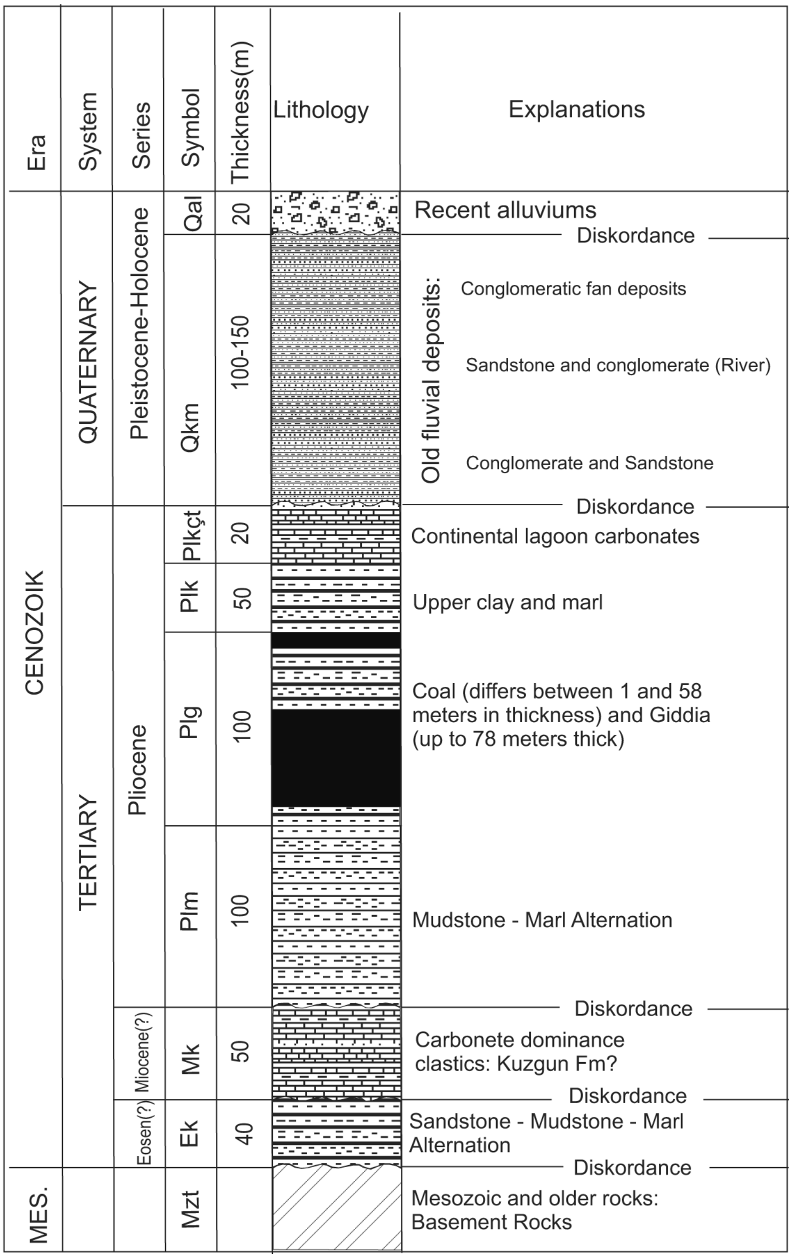

Figure 4- Generalized stratigraphic column-section of the Afşin-Elbistan basin (No Scale).

merate or gravely limestone on the base, and continued with claystone and mudstone upwards. As for Tarhan (1984), he names the Pliocene aged sequence including sandstone, claystone, marl, lagoonal limestone, conglomerate, tuffite, mudstone and coal levels (Afşin lignite) as Nadir formation. This formation is represented by black-red polygenic conglomerates in the SW of Afşin - Elbistan basin around Göksun (Yümün and Kılıç, 2002).

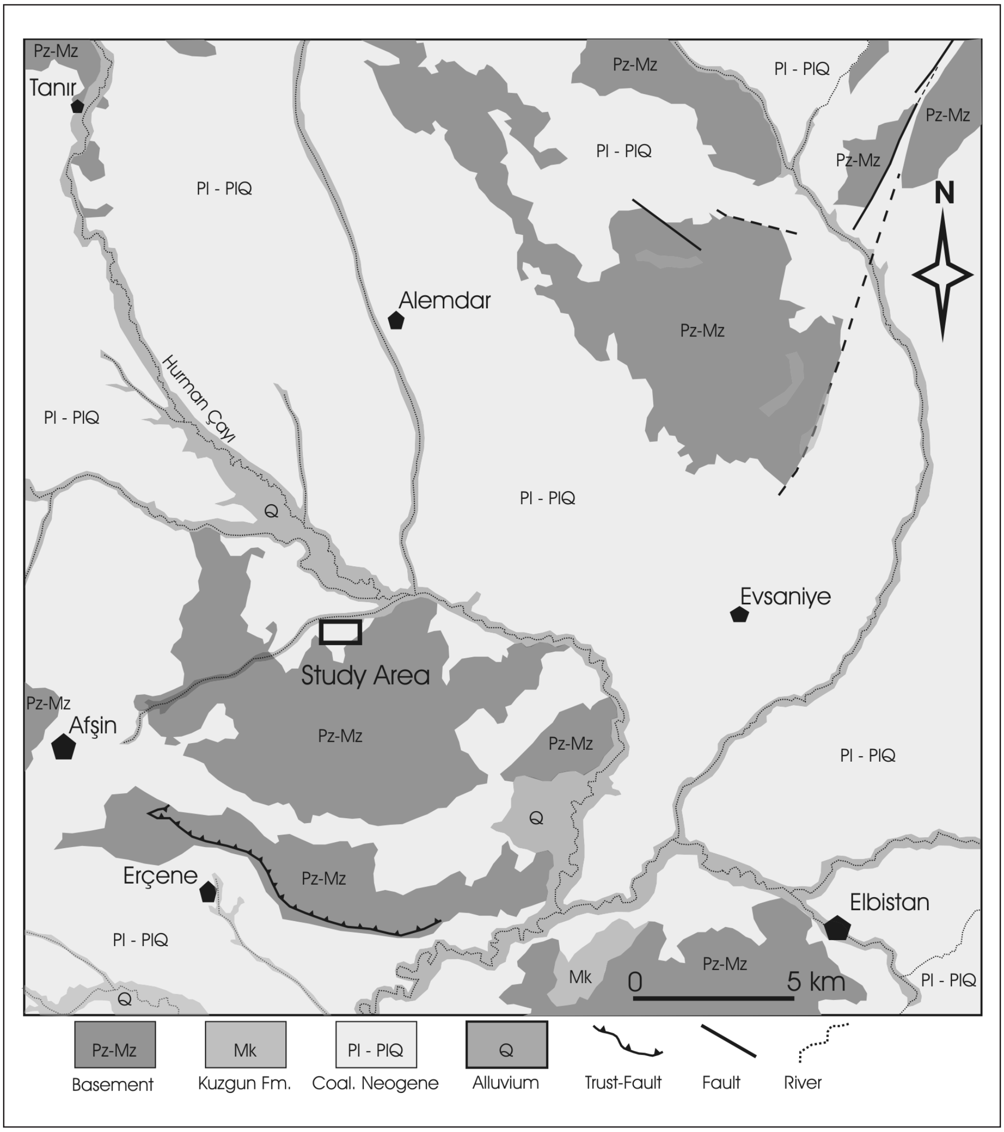

Figure 5- Geological map of Afşin - Elbistan Basin (Simplified from Perinçek and Kozlu, 1983).

In this study, the local stratigraphic sequence in the area which is covered by seismic reflection profiles bears importance in terms of geological correlation. According to the drilling information obtained at the basin, the base of the research field is formed of Mesozoic and more aged limestone - marble - schist etc. rocks (Pz-Mz). On the base, a series formed of sandstone - mudstone - marl alternation which is probably Eocene aged, clastic and with an average thickness of 40 meters comes discordantly (Ek). The carbonate-rich clastic series which comes over this clastic series is probably Miocene aged and has an average thickness of 50 meters (Mk). This series was first named by Çağlayık (1970) and was accepted as Kuzgun Formation by Perinçek and

Kozlu (1983) (Figure 5). The Plio-Pleistocene aged coaliferous series comes over this base series from the discordantly and begins with gravely to sandy levels on the base and contains clay, coal, marl and limestone levels upwards.

This coaliferous series is formed of mainly four separate levels.

Tertiary

Base Level Clay and Marls (Eocene (?) - Miocene (?) - Lower Pliocene) (Plm)

In the study field, the base of Plio-Pleistocene is in the form of clay marl alternation as dominant lithology. It is formed of sandy clay and gravely clay levels towards the base. It is bluish green in color. These formations that are not appear at the outcrop are identified in the wells. According to the location of the coal, this base level begins from various depths in the basin. This level found on the base of the coal can easily be identified thanks to its typical color and the carbonate lumps it contains and its thickness can go up to 200 meters. This sequence comes over the other base rocks that are more aged with direct discordance.

Coaliferous giddia (Pliocene) (Plg)

A level formed of giddias is found on the base clay and marl level and it contains lignite veins. Although the thickness of the giddia level is 10-15 meters below the coal vein, it can go up to 30-40 meters over the coal vein. These limnic formations that do not appear at the outcrop can only be identified from the cores of the wells in the basin. The total thickness of the coaliferous levels and giddias can reach up to 100 meters in places and the giddia levels contain an ample amount of decomposed gastropod shell fragments especially on the upper sections of the sequence.

The coal vein found in this unit is more monotonous in the west of the basin and is in the form of a single vein the thickness of which can go up to 40-45 meters. The coal veins in the east portions of the basin form a zone of 70-80 meters with the clay inter-layers. The total thickness of all these coal veins goes up to 50-60 meters.

Ceiling level clay and marl (Plio-Pleistocene) (Plk)

In this level that is found over the coaliferous giddia level, the dominant lithology is clay and silty-sandy-clay alternation. The unit which contains silt and sand bands in places is little fossiliferous. The thickness of the unit is around 20-30 meters.

Fresh Water Limestone (Plio-Pleistocene) (Plkçt):

These formations that are seen on the surface of the basin fill are the final horizontal layered limmnic sediments. They are rich in terms of gastropod fossils. They are white in general and rarely grey and brown. These formations can be defined as shore front shallow lake carbonate shelf (Scholle e al., 1983) and their thickness does not exceed 20 meters.

Quaternary

Quaternary aged sediments are found in two series in the basin: the old stream sediments found on the base are identified in the drills and they do not appear. The actual alluvial sediments cover the whole series with an angled discordance (Figure 4).

Gravel-conglomerate (Qkm)

The old stream sediments are represented by conglomerate-sandstone on the base, stream sediments in the mid sections and conglomeratic fan sediments on the top (Figure 4). Gravel series are seen in many sections of the basin. Gravel dimensions become smaller from the shore of the basin towards the centre of the basin. The sizes of the gravels vary between 2 - 20 centimeters in the rim sections of the streams flowing into the basin and in the centre of the basin, tiny grain sand is dominant. This clastic material is formed of the limestone, quarsit and radiolarite gravels on the sides of the basin, and they are cemented with some carbonated cement. With the drillings performed, it has been determined that the thicknesses of these sediments go up to 150 meters in places.

Recent Alluviums (Qal)

Actual alluviums are seen only along Hurman Creek. This main drainage canal that covers the study field in the NW-SE direction has left actual alluvium on a wide area. The thicknesses of these actual sediments are around 20 meters.

Thes geological units described above were interpreted as five units in the seismic cross-sections and geological correlations were made. These units are as follows: 1) Marbles at the basement of the basin, 2) overlying basin fill sediments, 3) clayey-coal horizon, 4) clay-marl alternated cover series, and 5) Recent alluvial deposits.

GEOLOGICAL CORRELATIONS OF THE WELLS

The study was conducted on a total of three seismic reflection lines (Figure 2). Two of these lines (LINE 1 and LINE 2) are E-W directional and parallel to each other and their lengths are 1500 meters and 1750 meters, respectively. The horizontal gap between the lines is about 500 meters. The third line (LINE 3) is selected as perpendicular to these two lines in the N-S direction and its length is approximately 1000 meters. There are wells on each of the three seismic reflection lines. The geological correlation of these wells that are drilled with intervals of 250 meters is made and in the geological correlation, the stratigraphic sequence given in Figure 4 is complied with. The locations of some guide levels shown on the lithological stamps of the wells are arranged according to the core information.

Establishing a correlation between the stratigraphic sequence and the seismic cross-sections constitutes the main objective of this study. Besides, the known main stratigraphic and structural elements are defined and matched on the seismic reflection cross-sections produced.

One of the most important parameters during seismic data processing is to collect seismic speed information from formations directly and to ensure real depth conversion by applying these speeds to related levels during data processing. For this purpose, well geophysics was applied to well no. S-222 found on Line 2 and sonic log was obtained. When this sonic log is examined, it is observed that the seismic speed values of Pliocene series vary between 1600 and 2300 m/sec. In addition, seismic refraction studies reveal that the seismic wave speed of the uppermost layer is about 650 m/sec. During seismic data processing, the average seismic speed for the entire seismic recording was selected as 1500 m/sec considering the low seismic wave speed zone at the shallow surface. After this selection, the stratigraphic log data and the major reflection surfaces of seismic cross-section was tied at around 270 meters. According to this seismic speed information, the average depth of the reflection surface of the base of the basin and that occurred on the seismic reflection cross-sections were calculated as 250 to 300 meters. On the other hand, wells drilled in the basin so far do not generally go deeper than 180-220 meters except for the few number of pilot wells, and they do not reach the bottom of the basin. In this case, for the deeper units, the wells and the seismic cross-sections do not overlap one to one and this causes difficulties in the geological correlation of the more aged units.

When the generalized stratigraphic column cross-section of the basin is considered, it is seen that below the coaliferous horizon, there is a series with an approximate thickness of 100 meters forming the base of the Neogene sequence and that consists of mudstone - marl alternation (Figure 4). Since the reserve development wells drilled in the basin are programmed mainly for the determination of the change in the thickness of the coaliferous horizon, lithologies that are accepted as basic rock in well lithology stamps and the basin base rocks that are identified at seismic-cross sections as 'Seismic Basement' most probably do not overlap. Since the wells in the basin are usually ended when they enter the mudstone-marl sequence (Plm) found on the base of the coaliferous horizon, the lithologies below this zone are not reflected on the well correlation cross-sections. Yet, when the seismic cross-sections are considered, it is observed that high resolution seismic reflection data are obtained up to approximately 400 milliseconds (TWT: Two Way Travel Time). When an average seismic speed of 1500 m/sec is applied to these seismic cross-sections, 200 milliseconds (OWT) time depth corresponds to an approximate depth of 300 meters. Thus, since the coal horizon goes down to an average depth of 200 meters, the sequence found below this horizon can be distinguished on the seismic reflection cross-sections but it can not be correlated geologically.

According to figure 4, on the base of the mudstone - marl (Plm) sequence, there are probably Miocene aged clastic rocks with an approximate thickness of 50 meters and that are very rich in terms of carbonate (Mk; Kuzgun Formation), and on the base of this sequence, there are probably Eocene aged sandstones (Ek) with an approximate thickness of 40 meters but these geological units are not represented in seismic cross-sections. All thes units have deposited on Paleozoic-Mesozoic aged basement rocks with an angular unconformity (Figure 4, Figure 5). The newly constructed borehole numbered as S-222 reaches to the seismic basement rocks at the 271-meter depth. This borehole also revealed that the Pliocene-aged coaliferous sediments have been deposited directly on the seismic basement rocks (marbles) onconformably.

Since the mudstone - marl and sandstone type litologies found on the base of coaliferous horizon do not have a great speed contrast with the coaliferous horizon; these series do not display strong reflections. But physically, a speed jump in transitions from this mudstone - marl - sandstone sequence to metamorphic rocks, specifically to marbles would be expected. In the same way, according to the sonic log of S-222 borehole the seismic wave speed dropped from 3750 m/sec to 2300 m/sec. So, the reflections observed on the base along the seismic cross-sections (300 - 350 milliseconds TWT) and forming the dome-like structure belonging to the basement rocks (limestone - marble) point to the presence of a paleo-basic high in this location.

While there is no sufficient geological data available about the beginning and development process of this paleo - basic high; a general approach about the tectonic development of the basin can be provided with the palinspastic analysis of the stratigraphic levels of the geological cross-sections obtained with the correlation of the wells. Within this scope, the sequence was hung up in the coaliferous horizon from a selected characteristic surface and the base geometry of the basin during coal deposition was determined palinspastically (Figure 6). When this figure is examined, it is understood that at the period when coal deposition occurred, possible block faulting could have developed in the basin and in the depression areas that were formed, coaliferous series deposited. The same process was made for Lower-Middle Pliocene, Upper Pliocene and Quaternary base and the base morphological evolution of the basin was tried to be interpreted from Pliocene to our day (Figure 7). In Figure 7, from the shape of the (B) curve, it can be understood that at the period when the coaliferous horizon almost completed its formation, (Middle) Pliocene paleo-topography was in a location that was in harmony with the dome-like morphological structure that occurred in the actual seismic cross-sections and the base of the basin was rather undulated. What attracts atten-

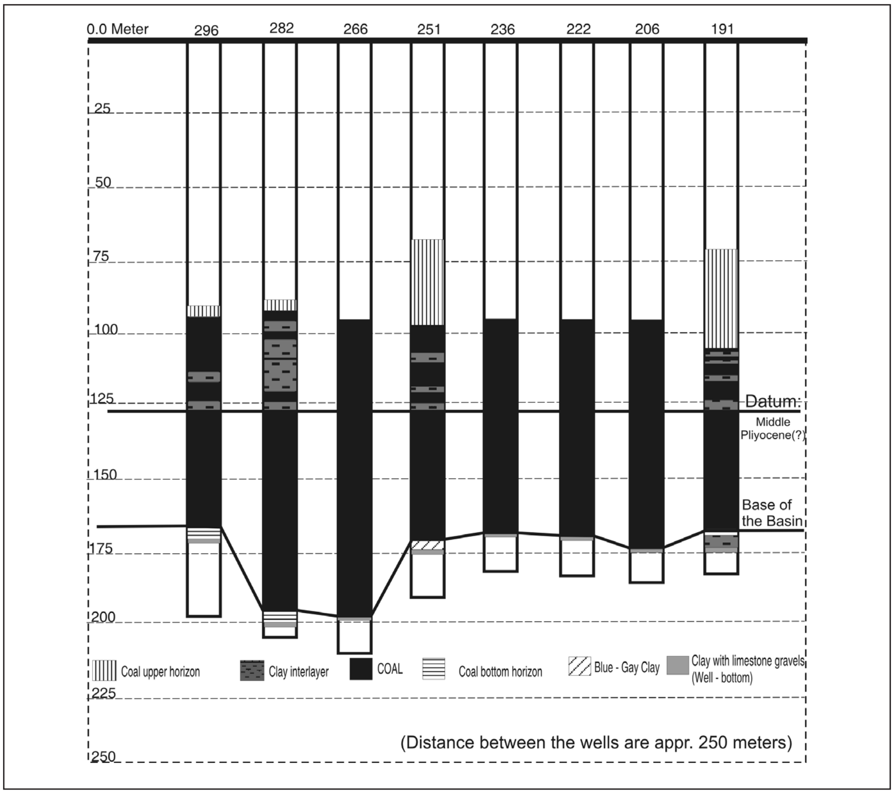

Figure 6- The basin morphology and stratigraphic correlation of the Early-Middle Pliocene deposits according to the Datum that selected from middle section of the coal section in Line Two.

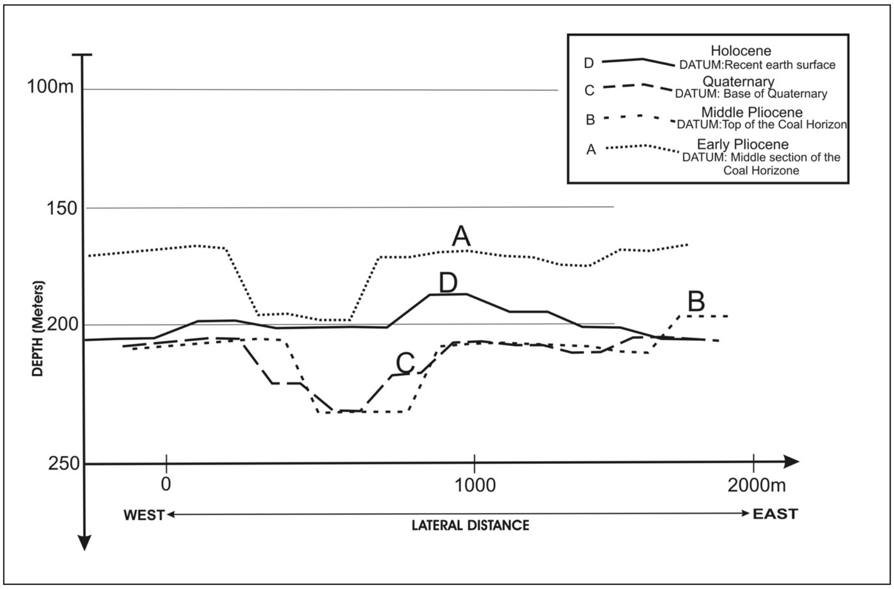

Figure 7- The tectonic evolution of the Afşin-Elbistan Coaliferous Basin from Early Pliocene to the Recent.

tion in the (C) curve in the same figure is that in lateral distances, the depth of the basin exhibits much sharper changes. In the same way, when geological correlations are considered, it is observed that while carbonated sediments are formed at regions that are very close to each other, in other sections, silty clay type litologies are formed. When this section is compared to today's geological location (Figure 8, 9 and 10) it is understood that only along Quaternary do the vertical replacements exceed 25 meters in places in the basin. The sections where these alluvium fills are formed can also be interpreted as incised valleys. When interpreted such, it is found that a rapid elevation or a rapid water discharge has developed in the basin.

When the coaliferous horizon is hung up from a typical interface on Line 2, the geomorphologic structure of the period when the basin was formed can approximately be understood (Figure 6). In the cross-section prepared accordingly, it can be observed that the west region of the basin is relatively deeper in the deposition period, and after some time, (after the hung-up surface deposits) the basin is tilted towards the east (Figure 7, A Curve). When the same process is applied from the base of the upper coal horizon, the geometry and the geomorphologic structure of the basin in the period when the cover series began to deposit can be better understood (Figure 7, B Curve). Accordingly, it again comes to light that the basin does not have a homogenous depth distribution and there is a certain undulation. This case is more clearly observed on the Quaternary base (Figure 7, C Curve).

When Figure 7 is examined, it can also be seen that after Early Pliocene, a depression of approximately 50 meters has occurred in the basin, and from Middle Pliocene on, the basin has started to elevate as a block.

According to geological data, the correlations on the seismic lines are listed below:

LINE 1; Geological Correlation of the E-W Directional Seismic Line

The lateral correlation of the well lithological stamps belonging to the wells on Line 1 (Figure 2) is given in figure 8. There are seven wells cutting coal on this line. Geophysical log (sonic log) was recorded in well no. 208 located on the very east of the line. According to this sonic log, the average seismic speed of the formation is 1850 m/sec. When this sonic log is examined, it can be seen that a great speed contrast is not formed in the transitions of the formations. That the seismic speeds are so close to each other has been related to the closeness of the lithological characteristics of the formations to each other. Because of the physical parameters were not found as reliable values, a new borehole was constructed near the nr. 222 borehole located on the Line 2. This borehole (S-222) represents the whole Pliocene sequence and the phisical parameters were accepted as reliable for the seismic cross-sections.

The coaliferous series in the wells found on Line 2 seismic reflection line was hung up from the base of the upper horizon (DATUM) and thus, the basin geometry for the depression period of this series was set forth (Figure 6). The same process was applied for the Quaternary base, and by arranging the developments in the basin morphology during geological periods, the lines were compared. For interpretations on this issue, Line 2 was used.

LINE 2; Geological Correlation of the E-W Directional Seismic Line

The total length of the line is 1750 meters (Figure 2). Total nine boreholes located onto this line includet the newly constructed S-222 borehole. The gap between the wells is around 250 meters but the S-222 borehole is located between the 222 and 206 numbered boreholes. The thickness of the coal horizon varies between 50 - 100 meters. The highest thickness is 100

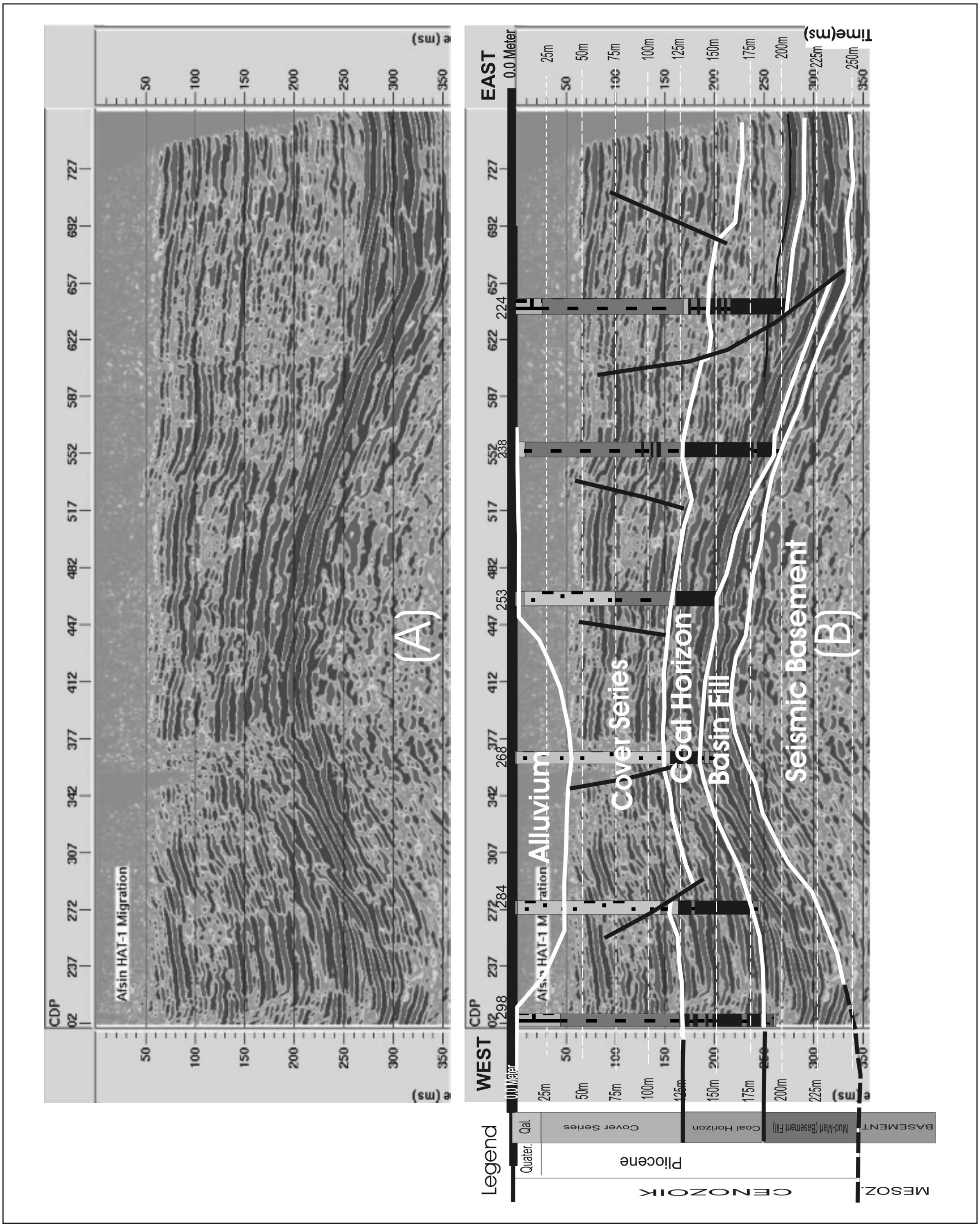

Figure 8- The raw (A) and interpreted (B) seismic cross-sections of Line-One: correlation of the coal section (the lateral distance between the wells are 250 meters).

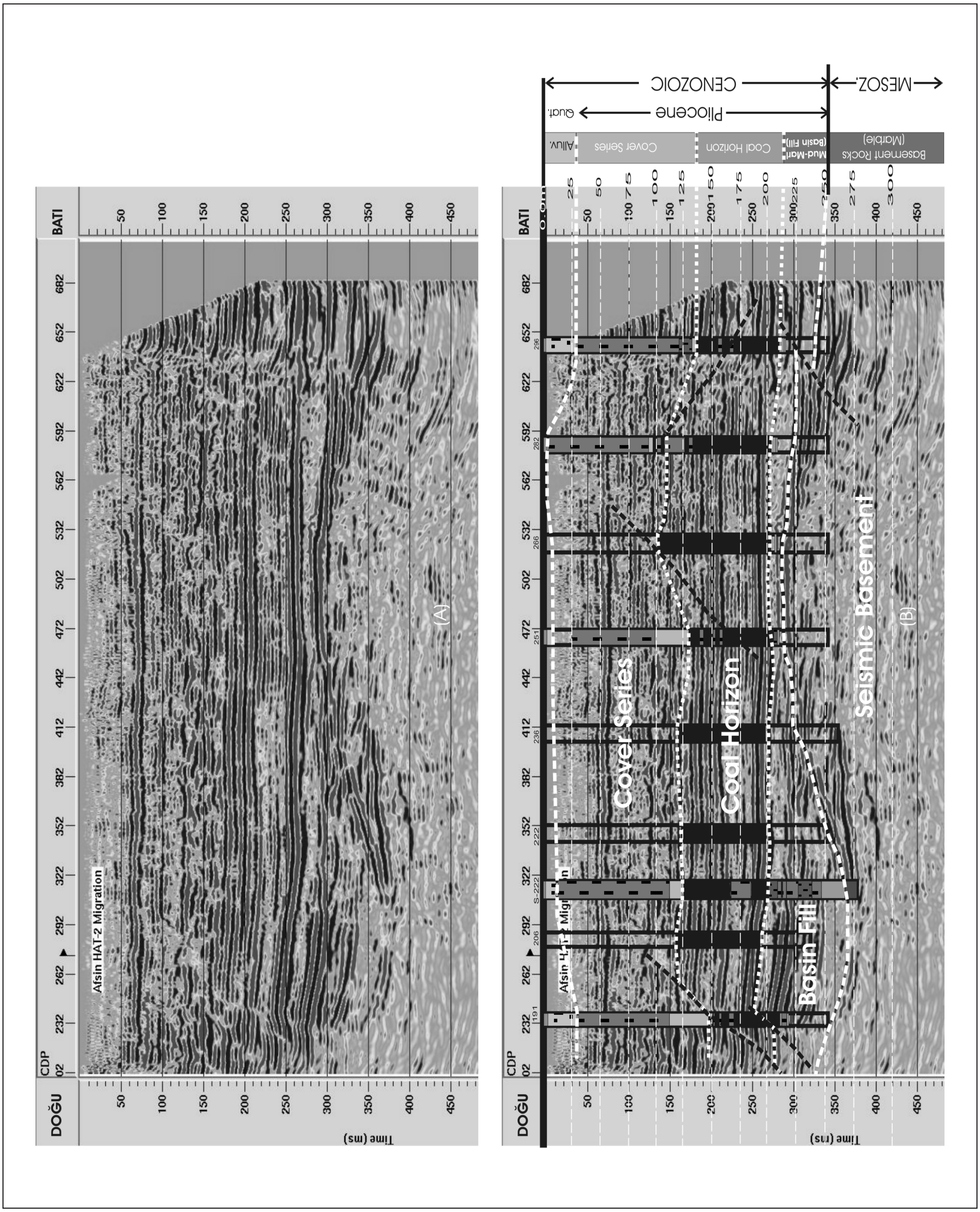

Figure 9- The raw (A) and interpreted (B) seismic cross-sections of Line-Two: correlation of the coal section (the lateral distance between the wells are 250 meters).

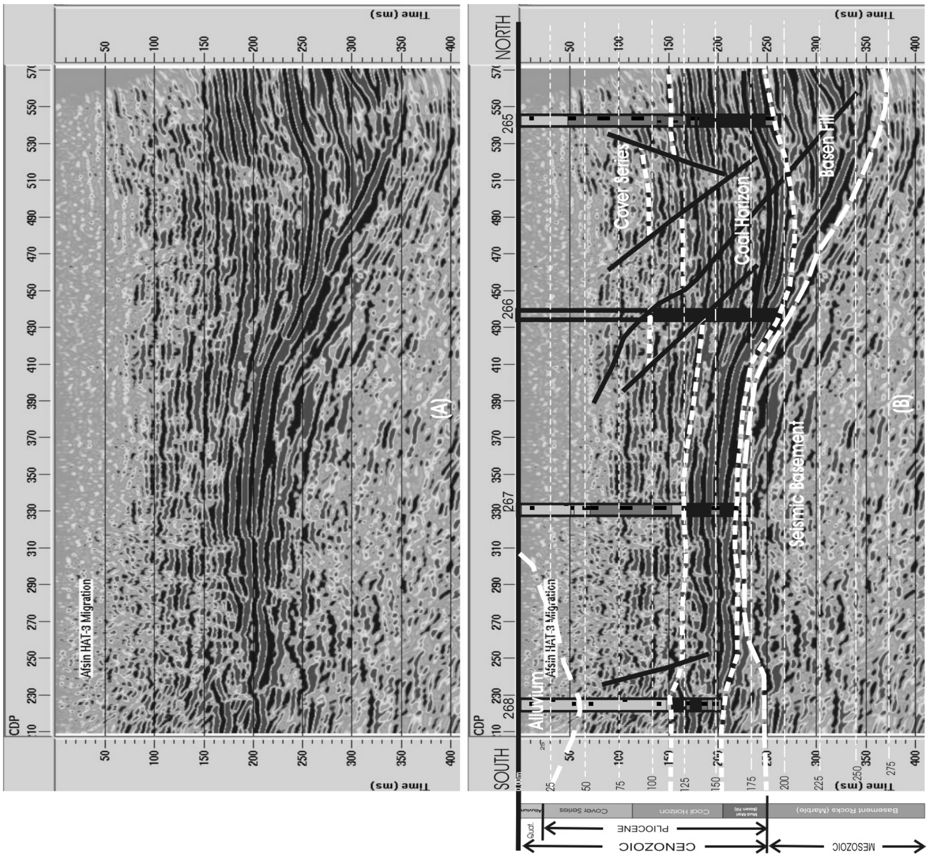

Figure 10- The raw (A) and interpreted (B) seismic cross-sections of Line-Three: correlation of the coal section (the lateral distance between the wells are 250 meters).

meters and it pertains to well no. 266, and the lowest thickness is 50 meters and it pertains to well no. 191. When the correlation curve on the line is examined, it is observed that the thickness value decreases towards the east (Figure 9). Besides, as mentioned in the text above, the coal horizon both becomes thinner and bifurcates with thin coal-layers when headed towards the east. Despite this, on the western portion of the basin, the coal horizon is relatively thicker and demonstrates an integrated structure. When the correlation curve is examined, another factor that draws attention is the undulation on the top and bottom boundaries of the coal horizon. While the upper limit begins at a depth of about 100 meters on the west of the basin, the depth of this zone increases when headed towards the east and becomes 150 meters in well no. 191. When it is considered that coal formation is depressed into a state close to horizontal in a shallow, stable and still basin, it is known that Neogene sediments are deformed, bent and broken in the period following the coal formation (Atay, 1981; Gökmen et al., 1993; Staesche, 1972). In the same way, on the seismic reflection cross-sections, fault systems that have caused significant shifts can be identified in places. A seismic reflection line that exhibits this deformation can be much more clearly observed on the base of Figure 10. After using the sonic log values of the

S-222 borehole located onto this line, the speed /depth conversions were made and the boreholes were tied onto the seismic profiles. The calculated seismic speed walues are given in previous section.

The dome-like reflection surface that offers clear reflection at an approximate level of 300 ms (TWT) on the seismic cross-section is the high of the paleo-basic on the base of the basin and identified as the base level.

LINE 3; Geological Correlation of the N-S Directional Seismic Line

Both on Line 1 and Line 2 seismic lines, the changes in the coal horizon were identified in E-W direction. There are not enough wells on Line 3 to make a detailed evaluation. Making an evaluation about the North-South directional changes of the basin using a total of four wells can yield misleading results. But still, by taking the truth above into consideration, it might be appropriate to make a limited assessment.

Line 3 is laid perpendicular to Line 1 and Line 2 in the direction of North - South (Figure 2). There are four coal cutting wells on the line. From among these, well no. 266 is at the same time on Line 2 seismic line, and well no. 268 is at the same time on Line 1 seismic line. The horizontal distance between Line 1 and line 2 seismic lines is 500 meters. Well no. 267 inspects this distance. The well which is on the very north of Line 3 is well no. 265. Therefore, the coal horizon changes between Line 1 and Line 2 seismic lines can be traced up to maximum 250 meters towards north and the portion between the lines can be inspected from exactly the mid section of the lines.

The geological correlation cross-section belonging to this line was hung up from two stratigraphic levels (DATUM) and the paleo-geographical milieu of the related periods was examined. The first characteristic surface in the coal horizon was selected as the base plane of the coal upper horizon. According to this cross-section, the coal horizon in the basin becomes thinner towards the south at a significant rate. The north portion of the cross-section is probably a depression zone controlled by again an E-W directional perpendicular fault system in regions where Line 1 pass. In the same manner, the coal horizon has significantly become thicker in this section. This depression zone which is understood to be of the same age with the sedimentation of the coal horizon has deposited in contrast to other sections of the basin that are gradually elevating and the swamp environment conditions required for coalification were preserved. In the period when deposition of coal horizon was completed and the covering layers began to deposit, the depression in this region stopped and the entire basin began to shallow. In the same way, the milieu first became stream-delta-lake and then entirely transited to terrestrial environment; and the sediments that are the products of stream sediments filled the basin.

The same seismic line was examined after being hung up once again from the Quaternary base above (DATUM) and here again, it was understood that the basin went through a quite active tectonic period during the Quaternary period and perpendicular movements of about 25-30 meters were developed (Figure 7).

THE GEOLOGICAL INTERPRETATION OF SEISMIC REFLECTION CROSS-SECTIONS

The reflection cross-sections that were produced reflect the general structural and stratigraphical state of the basin to levels of 350 - 400 ms (TWT) quite well. In the seismic reflection cross-sections, fairly high resolution seismic reflection values from about 50 ms were obtained. There is a regular reflection package that continues between 50 and 100 ms; and this regular structure disappears after 100 ms. It is seen that this weak reflective chaotic zone that appears at 100 and 150 ms levels represent the clay-marl alternation of the cover series. These strong reflection values that occur again between 150 ms and 250 ms are resulted from the clayey coal horizon. The weak reflections below these levels represent the basin-fill sediments, consisting of clay-marl alternation. Finally, strong reflections starting from 350 ms represent the seismic basement rocks.

The basin fill sediments are deposited directly onto the Mesozoic-aged marbles unconformably thus big thickness changes have been ocurred. This reveals that the deposition of the Pliocene series were tectonically controlled. The coal horizon, however, was deposited under relatively stable tectonic conditions but after their deposition regional tectonic processes were reactivated. Number of non-described faults in seismic lines the most important evidence of this idea.

CONCLUSION

Researching of coal beds using high resolution shallow seismic reflection method started to become widespread in the 80ies (Greanhalgh et al., 1986; Gochioco and Cotten, 1989). These studies became more widespread in the 90ies (Gochioco, 1991; Henson and Sexton, 1991; Kragh et al., 1991), and even a patent was received from USA Patent Service (US Patent No: 4298967). Today, the developments both in the measuring and data processing and interpretation fields made the applicability of this method possible not only in coal areas but also in mine beds with all kinds of layers. The methodologies of this method were set forth especially in coal searching (Kamkar-Rouhani, 2007). While there are numerous coaliferous Neogene zones in our country, coal searching using seismic reflection method has not been conducted yet. This paper is the first study which shows that this method can be applied to coal beds in our country.

Since the formation in Neogene lagoonal basins deposited in depositional environments which do not have sudden depth differences in general and fed by streams, they consist of series that are laterally and perpendicularly transitive with each other, clastic and sometimes carbonated. Except for the thick carbonated surfaces, the geophysical characteristics of these clastic sediments are similar to each other. Since the physical changes of the formations are not sharp, it is generally difficult to produce detailed seismic reflection cross-sections the perpendicular resolution of which is high in such basins. But again, at the end of this study it is understood that when the shot pattern and frequency interval on the field are selected properly, it is possible to obtain high resolution. In this study, the sediment packages suited to the general stratigraphic sequence of the basin were allocated on seismic reflection cross-sections and their lateral correlations were made. Specifically, when the detailed speed and age data of the formations constituting the aged base are provided, the sequencing in the basin and stratigraphic and seismic stratigraphic studies can be examined more easily.

Using softwares designed to make geological interpretations on the seismic reflection cross-sections, these 2D seismic reflection data can be made usable for real coal study purpose; top, mid and bottom levels of the coal can be mapped separately and the structural analysis can be reflected onto these maps.

Consequently, though they are not representatives of the entire basin, when the seismic reflection cross-sections and the well's geological correlations were taken into consideration as a whole, it was set forth with seismic studies as well that the base of this basin started to acquire a shape tectonically before the Neogene sediments determined by use of geological data. The influence of the Paleo-basic high on coalification can be seen clearly. Structural deformation continued its course during Neogene period and the deposition in the basin must have been kept under tectonic control continuously. In the same way, it is understood that the same perpendicular movements continued during Quaternary as well. With the determination of the underground geometry and the distribution characteristics of coal more exactly, it will be possible to study the open operational conditions in sections where stream sediments, the thicknesses of which reach up to 150 meters in places during Quaternary, are found and to consider the slope stability calculations once again. Application of high-resolution shallow seismic methods to coals may ensure more exact determination of the cover thickness of coal horizon, the type of the cover rocks or sediments and the changes in depth and may contribute in the preparation of operational plans in a more carefully considered manner.

It has been determined that seismic reflection method is appropriate as a rapid and reliable research method for such studies, supported by geological data and physical parameters collected from representative boreholes. We are hopefull that this key study would give a different opinion to the researchers for their ongoing or futur geological studies.

ACKNOWLEDGEMENT

The data collection stage of this study was conducted within the scope of MTA Geophysical Studies Department Monitoring Assessment Unit's 'Project for Geophysical Methods Field Practices and Testing of Field Equipment, (2007-31-14.01)'. We wish to thank Mrs. Ayşe ERKOL, the head of the project.

Field, data processing and interpretation studies of this work were conducted by Geophysical Studies Department Seismic Unit staff, and the advanced process stage was performed by Geophysical Engineer Ayhan ÖZKAN (M.Sc.) from Turkish Petroleum Corp. The sonic log used for speed/depth conversion has collected by the Well-Log Team of the Geophysical Department. We would like to extend our thanks to all our colleagues who contributed in this study, which is entirely the product of a teamwork.

We wish to thank especially the Afşin camp staff and Dr. Berk Besbelli, who provided us the facilities of Afşin Drilling Camp shared the geological data used in this study with us.

Manuscript received March 21,2007

REFERENCES

Atay, M., 1981. K. Maraş Afşin - Elbistan Linyit Sahası Kızıldağ ile Kışlaköy Sektörü Arası Jeoloji Etüdü, Derleme Rapor No: 7077, Ankara (unpublished)

Aydoğan, M., 1978. K. Maraş - Elbistan Collolar Kömür Yatağı Fizibilite Araştırması, Derleme Rapor No: 6413, Ankara (unpublished)

Barkurt, M., Bilginer and E, Pehlivan, S., 1991. Elbistan - Nurhak - K. Maraş Dolayının Jeolojisi, Derleme Rapor No: 9423, Ankara (unpublished)

Baydar, O., 1975. GD Anadolu Kenar Kıvrım Kuşağı, Amanos Dağları Kuzeyi ve Doğu Torosların Jeolojisi, Derleme Rapor No: 9944.

Bilgin, Y., 1982. K. Maraş - Elbistan D1 Sektörü Linyit Kömürü Fizibilite Araştırması, Derleme Rapor No: 7216, Ankara (unpublished)

Çağlayık, V., 1970. Ceyhan - Berke Bent Yeri Rezervuarının Jeoloji İncelemesi, EİE raporu (unpublished)

Dix, C. H., 1955. Seismic velocities from surface measurements, Geophysics, V.20, Pp. 68-86.

Gochioco, L. M., 1991. Advances in seismic reflection profiling for US coal exploration, The Leading Edge, V.10, N.12, Pp. 24-29.

______ and Cotten, S. A., 1989. Locating faults in underground coal mines using high-resolution seismic reflection techniques, Geophysics, V.54, Is. 12, Pp. 1521-1527.

Gökmen, V., Memikoğlu, O., Dağlı, M., Dinçay, Ö. and Tuncalı, E., (Editörler), 1993. Türkiye Linyit Envanteri, MTA Yayını.

Greanhalgh, S. A., Suprajitno, M. and King, D. W., 1986. Shallow seismic reflection investigations of coal in the Sydney Basin, Geophysics, V. 51, Is. 7, Pp. 1426-1437.

Henson, H. Jr. and Sexton, J. L., 1991. Premine study of shallow coal seams using high-resolution seismic reflection methods, Geophysics, V.56, N.9, Pp. 1494-1503.

Kamkar-Rouhani, A., 2007. Seismic survey design for exploration of subsurface coal seams in Mazino and Parvadeh areas, Tabas, Iran, Geophysical Research Abstracts, V.9, 01410.

Karlı, R., 1983. K. Maraş Afşin - Elbistan Neojen Havzası Linyit Aramaları Rezistivite Etüdü, MTA Derleme Rapor No: 7310, Ankara (unpublished)

Koçak, Ç., Kürkçü, S. N. and Yılmaz, S., 2002(?). Afşin-Elbistan Linyit Havzasının Değerlendirilmesi ve Linyit Kaynakları Arasındaki Yeri, TKİ Rap. http://www.tki.gov.tr/personelden/afsin_elbistan.doc

Kragh, J. E., Goulty, N. R. and Findlay, M. J., 1991. Hole-to-surface seismic reflection surveys for shallow coal exploration, AGI-GeoRef, First Break, 9 (7), Pp. 335-344.

Krug, J.V.D., 2004. Reflection Seismic-I. Ders Notları, 136 sh., Zürih Üniv.

Mengeloğlu, M. K., 1999. K. Maraş - Elbistan Yöresi Genel Jeokimya Raporu, Derleme Rapor No: 10245, Ankara (unpublished)

Özcan, K., 1981. K. Maraş - Elbistan D1 Sektörü Kömür Yatağı Jeoloji Araştırması, MTA Derleme Rapor No: 7054, Ankara (unpublished)

Perinçek, D. and Kozlu, H., 1983. Stratigraphy and structural relations of the units in the Afşin-Elbistan-Doğanşehir region (Eastern Taurus), Geology of the Taurus Belt, Int. Symp., p. 181-198, Ankara-Turkey.

Sakallıoğlu, Y., 1995. İki Ve Üç Boyutlu Sismik Program Dizaynı ve Saha Kayıt Parametrelerinin Seçimi. TPAO Arama Grubu Yayını, 111 sh.

Staesche, V. U., 1972. Die Geologie des Neogen Beckens von/ Elbistan, Türkei und seiner Umrandung; Geol. Jb., B4, 3-52.

Scholle, P. A., Bebout, D. G. and Moore, C. H., 1983. Carbonate Depositional Environments, Sh. 129, AAPG Memoir 33, ISBN: 0-89181-310-1

Tarhan, N., 1984. Göksun-Afşin-Elbistan Dolayının Jeolojisi. Jeoloji Mühendisliği Dergisi, 19, 3-9.

______, 1986. Doğu Toroslar'da, Neo-Tetis'in kapanımına ilişkin granitoyid magmaların evrimi ve kökeni. MTA Dergisi, 107, 95-111.

US Patent No: 4298967. High resolution downhole-crosshole seismic reflection profiling to resolve detailed coal seam structure, Link: http://www.freepatentsonline.com/4298967.html

Us, E. A., 1993. Sismik Yöntemler ve Yorumlamaya Giriş. Jeofizik Müh. Odası Yayınları, 227 s., Ankara.

Uysal, S., 1985. GD Anadolu Boyunca (Muş-Palu-K.Maraş-Hatay) Bazı Tersiyer Kesitleri, MTA Derleme Rapor No: 7783, Ankara (unpub lished)

Yılmaz, Ö., 1987. Seismic Data Processing. Soc. of Expl. Geophysicists, 526 sh..

Yümün, Z. Ü. and Kılıç, A. M., 2002. Kamandağı İle Camdere Köyü Arasının Stratigrafisi (Göksun-K.Maraş), Cumhuriyet Üniversitesi Mühendislik Fakültesi Dergisi, Seri A-Yerbilimleri C.19, S.2, s. 193-202, Aralık 2002.