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AGE, TECTONIC SETTING AND QUALITY DISTRIBUTION OF THE NEOGENE LIGNITE DEPOSITS OF WESTERN ANATOLIA

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(5 figures and 1 table)

ABSTRACT. The lignite-bearing continental Neogene basins of Western Anatolia are divided into three groups according to their time of formation, tectonic setting, and sedimentary facies. These are, in ascending time/tectonic order, the NE, the NW and the E-W-trending basins. While the NE and the NW-trending Neogene basins of Western Anatolia are filled with respectively Middle to Upper Miocene sedimentary sequences, the E-W-trending basins are filled with Pliocene-Quaternary sediments only. The latter basins have parallel trends from west to east. Generally, the boundaries of the basins are controlled by growth faults which have influenced the thickness and spreading of the sedimentary sequence and lignite seams. These sedimentary sequences of the continental basins consists mainly of fan, fluvial, lacustrine, and volcanoclastic sediments. Most of the economic lignite deposits in the Neogene continental basins occur in the uppermost part of the fluvial sequences which are concordantly overlain by lacustrine sequences. The NE-trending Neogene lignite basins of western Anatolia, have a relatively high calorific value compared to those of the NW-trending lignite basins. The E-W-trending Pliocene-Quaternary basins do generally not contain economic lignite deposits. The total lignite reserve of western Anatolia amount to approximatively 3 billion tonnes.

Keywords: Western Anatolia, lignite, tectonics, economic assessment.

1. INTRODUCTION

Approximately 33 % of Turkey's lignite reserves occur in the western Anatolia lignite basins (Inaner & Nakoman, 1993). Neogene basins are widespread in western Anatolia and contain important lignite deposits. Only the Oligocene lignites were formed in a paralic environment, whereas the rest of the Turkish lignite deposits were deposited in limnic (fluvio lacustrine) environments (Inaner & Nakoman, 1997). In western Anatolia, the lignite–bearing sedimentary sequences fill the depressions which are trending in NE, NW, and E–W directions. These lignite basins are bound by growth faults and contain sedimentary and volcanic rock assemblages which are locally more than 1000 meter thick. In the following chapters the tectonic setting and the stratigraphic features of the Neogene basins of western Anatolia are described (Fig. 1). The NE-trending basins are Beypazarı, Çameli, Çan, Çıtak (Gördes), Gediz, Koyunağılı, Soma, Tefenni, Tunçbilek, Uşak and Demirci. The latter basin does not contain lignites but it contains bituminous shales which at present are considered non-economic. The NW-trending basins are Beyşehir, Ilgın, Kale, Keles, Milas, Seyitömer, Yalvaç and Yatağan. The E-W trending basins are Gediz, K.Menderes and B.Menderes Grabens in western Anatolia. A comparison of the characteristics of the different basins is given in Table 1.

2. TECTONIC EVOLUTION OF THE NEOGENE BASINS OF WESTERN ANATOLIA

The present-day tectonic setting of the Aegean extensional regime province and related graben systems is shown on Fig. 1. The tectonic map of the lignite bearing and other Neogene basins of western Anatolia is shown on Fig. 2. Kaya (1979,1981) suggested that the NW- and NE- trending basins in western Anatolia were controlled by pre-Neogene growth faults and that the E-W-trending basins developed under a N-S extensional tectonic regime. Brinkmann (1976) determined that the NE- and NW-trending depression basins of western Anatolia developed sequentially, from west to east, during the Middle Miocene. According to Luttig & Steffens (1976), the uplift of western Anatolia and adjacent areas caused the development of intermontane basins of various dimensions, which contain nonmarine clastic and some calcareous sediments. According to Zanchi et al. (1990), western Anatolia was influenced by the E-W and ENE-WSW directionally extensional tectonic forces which existed during the Middle-Late Miocene and resulted in the NE- and NW-trending depression fields and basins. During the Pliocene and Early Pleistocene the

LIGNITE-BEARING BASINS	AGE OF MAJOR LIGNITE SEAMS	TECTONIC TREND OF BASIN	DEPOSITIONAL ENVIRONMENT OF MAJOR LIGNITE SEAMS	CHEMOPHYSICAL CHARACTERISTICS OF LIGNITES				KNOWN OR GAUGED RESERVES OF BASINS (tonnes)
				ASH	MOISTURE	SULPHUR	CALORIFIC VALUE	
				(%)	(%)	(%)	(kJ/kg)	
BEYPAZARI	Middle Miocene	NE	Fluvial-Lacustrine	25,36-48,70	14,83-26,44	2,79-4,04	8328-11886	390.317.500
ÇAMELİ	Late Miocene/ Pliocene	NE	Fluvial-Lacustrine	16,55-22,71	24,49-41,20	3,24-3,92	7570-14017	5.000.000
ÇAN	Middle Miocene	NE	Fluvial-Lacustrine	27,90	18,21	4,20	12535	86.887.000
(GÖRDES) ÇITAK	Middle Miocene	NE	Fluvial-Lacustrine	17,43	30,9	5,8	15072	27.000.000
GEDİZ	Middle Miocene	NE	Fluvial-Lacustrine	25,54	4,41	6,51	21771	23.945.000
KOYUNAĞILI	Middle Miocene	NE	Fluvial-Lacustrine	30,90	25,73	2,51	10630	57.430.282
SOMA	Lower-Middle-Late Miocene	NE	Fluvial-Lacustrine	30,00-46,54	12,24-30,28	0,93-3,52	6858-14352	678.592.202
TEFENNİ	Pliocene	NE	Fluvial-Lacustrine	10,73	53,00	2,50	7344	15.000.000
TUNÇBİLEK	Middle Miocene	NE	Fluvial-Lacustrine	41,00	14,82	1,60	10718	335.378.000
UŞAK	Late Miocene	NE	Fluvial-Lacustrine	13,46	35,33	3,20	11551	5,000,000
BEYŞEHİR	Pliocene	NW	Fluvial-Lacustrine	16,55-27,00	45,35-53,42	1,01-1,10	4534-5987	308.866.000
ILGIN	Middle-Late Miocene	NW	Fluvial-Lacustrine	11,38	50,31	2,2	9374	13.032.575
KALE	Late Miocene	NW	Fluvial-Lacustrine	31,6	25,57	2,59	9546	8.184.000
KELES	Pliocene	NW	Fluvial-Lacustrine	26,42	33,7	1,51	7955	34.000.000
MİLAS	Late Miocene	NW	Fluvial-Lacustrine	22,97-34,83	28,21-39,19	3,09-4,25	6004-9563	363.073.000
SEYİTÖMER	Middle-Late Miocene	NW	Fluvial-Lacustrine	31,18	32,98	1,21	7955	198.666.000
YALVAÇ	Late-Miocene	NW	Fluvial-Lacustrine	22,61	25,00	2,41	11723	8.100.000
YATAĞAN	Late Miocene	NW	Fluvial-Lacustrine	18,54-27,16	25,58-37,75	2,35-3,15	8838-11183	392.994.000
						TOTAL RESERVE		2.946.465.559

Table 1. General properties of western Turkey lignite deposits.

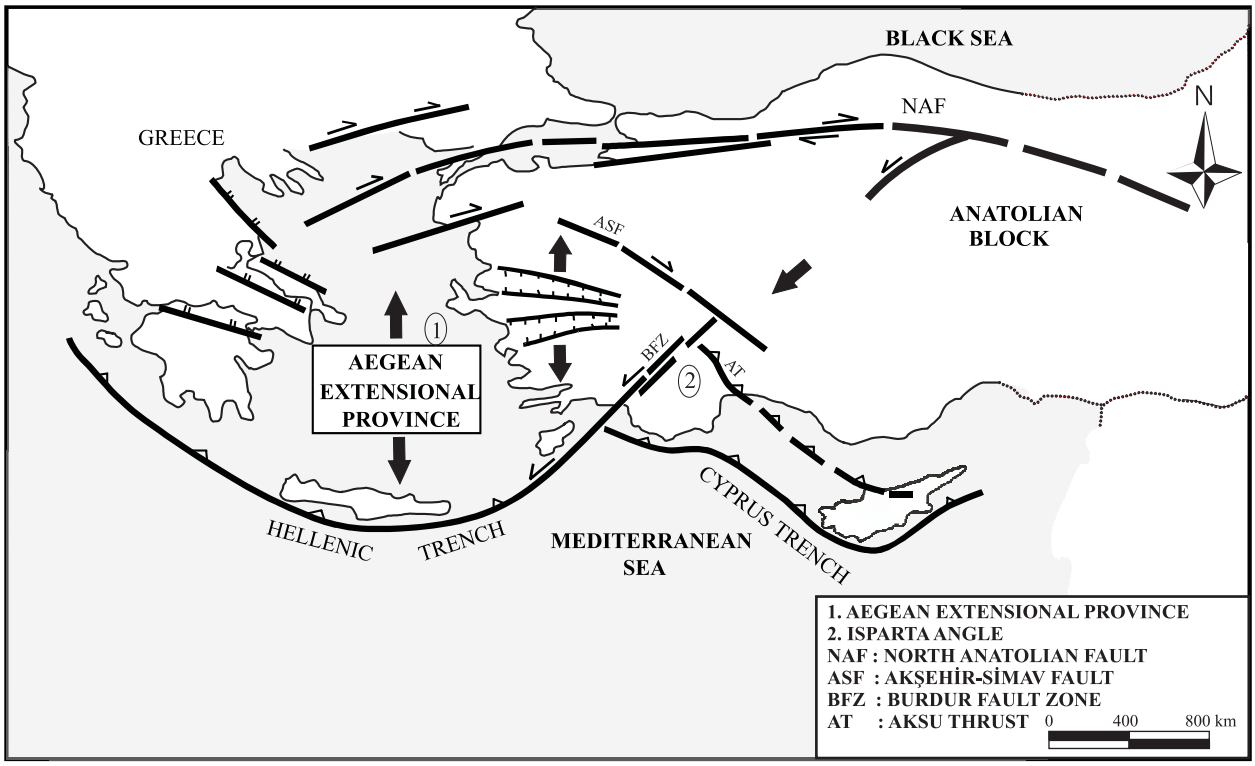

Figure 1. Present-day tectonic setting of the Aegean extensional province and related graben systems (Yağmurlu, 2000)

N-S directionally extensional forces influenced western Anatolia and formed the mainly E-W-trending Aegean graben systems. Owing to the southwestward motion of the west Anatolian region, the NE-SW directionally extensional regime has influenced western Anatolia since the Middle Pleistocene to the present. These last tectonic movements within western Anatolia reactivated the NW-trending fault systems.

The western part of the Anatolian plate is characterized by three main intracontinental extensional neotectonic structures, which are formed by NW-SE, N-S and NE-SW directed extensions respectively. These extensional tectonic regimes resulted in lignite bearing NE and NW-trending basins and no lignite-bearing E-W-trending basins in the western Turkey. According to currently available seismotectonic data of western Turkey, the E-W and the NW-trending basins and faults are younger and of a more active seismic character than the NE-trending basins. The E-W-trending grabens which possess normal fault systems, in accordance to the structure of the Aegean region, have developed by N–S extension due to subduction of the African plate under the Aegean zone along the Hellenic trench. Additionally, the NW-trending asymetric grabens developed under the influence of the NE-SW extension which is probably related to the SW-motion of the Aegean plate from the Late Miocene to the present day.

3. GENERAL CHARACTERISTICS OF THE LIGNITE–BEARING BASINS

The lignite bearing basins within western Anatolia are divided into three groups according to the periods of their formation, their tectonic setting and their sedimentary

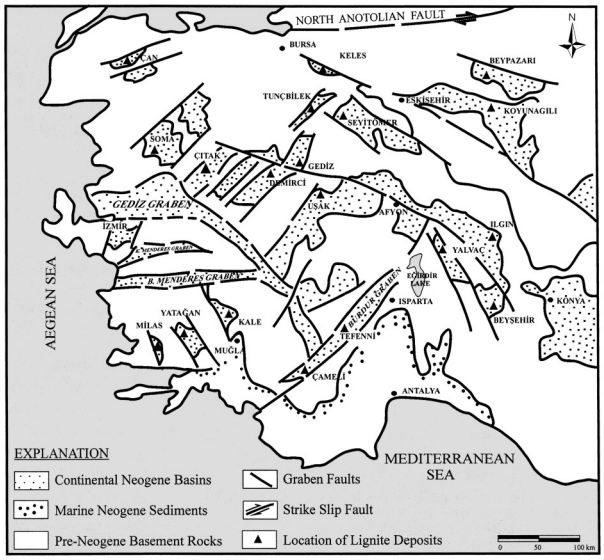

Figure 2. Geological setting of the Neogene basins of western Anatolia and location of the main lignite deposits (modified from Helvacı & Yağmurlu, 1995).

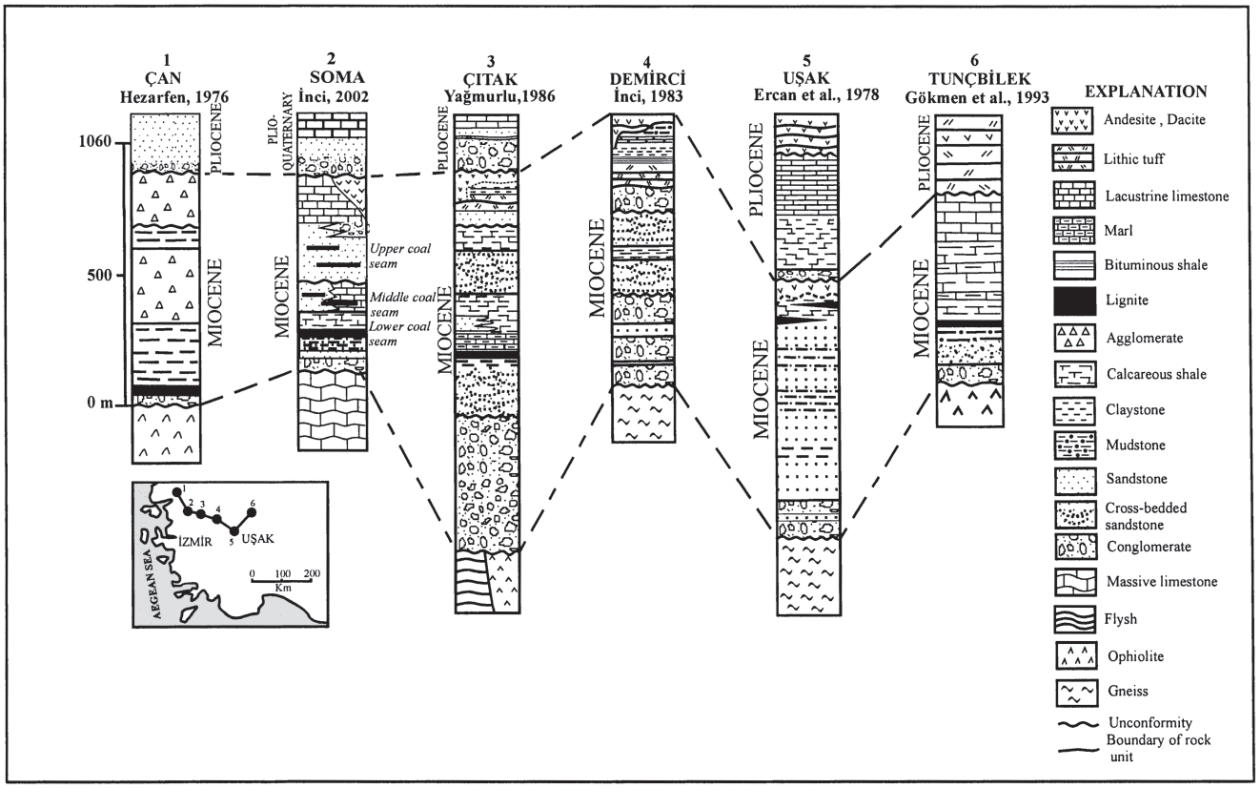

Figure 3. Generalized stratigraphic correlation of lignite bearing NE-trending Neogene basins in western Anatolia.

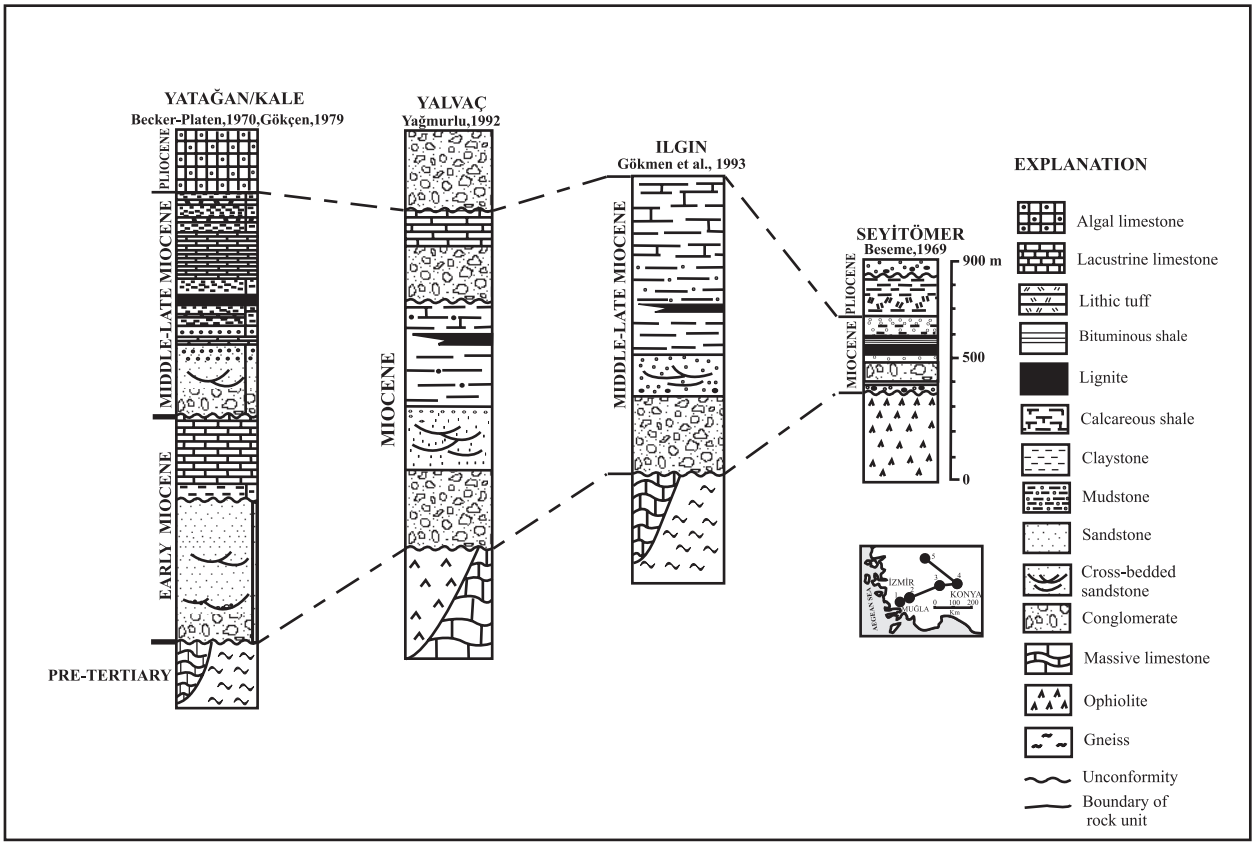

Figure 4. Generalized stratigraphic correlation of the lignite-bearing NW-trending Neogene basins in western Anatolia.

facies. These are in ascending time/tectonic order, the NE , the NW, and the E–W-trending basins (Fig. 2).

(a) Stratigraphic features:

Whereas, the NE and the NW-trending Neogene basins of western Anatolia are filled with Lower/Middle to Upper Miocene sedimentary sequences, the E–W-trending basins are generally filled with Pliocene to Quaternary sediments only (Figs. 3 & 4).

(b) Tectonic trend

The orientation of the basins has varied in the course of the regional tectonic history. The Plio-Pleistocene basins have parallel trends from west to east and are generally controlled by synsedimentary growth faults.

(c) Sedimentologic features

The sedimentary sequences of the continental basins consist mainly of alluvial-clastic sediments, directly overlying the basement. The Pre-Neogene basements of western Anatolia comprises both metamorphic and nonmetamorphic basement rocks. The main metamorphic basement rocks in western Anatolia are formed by the Menderes, Sandıklı and Sakarya massifs (Helvacı &Yağmurlu, 1995). Nonmetamorphic basement rocks include mainly ophiolite, flysch, and platform-type limestones.

The continental lithostratigraphic divisions of the Neogene fluvio-lacustrine sediments in western Anatolia have been assessed by Becker-Platen (1970,1971) and characterised with the sporomorph associations (Benda, 1971a, 1971b).

The first paleogeographic atlas of Turkey was prepared by Luttig & Steffens (1976) for the Oligocene to the Pleistocene. A second paleogeographic atlas was made by the Turkish Scientific and Technical Research Council (TÜBITAK), Istanbul Technical University (ITÜ) and the General Directorate of Mineral Research and Exploration (MTA). In accordance with these investigations 19 maps were published, entitled "Triassic-Miocene Paleogeographic Atlas of Turkey" by Görür et al. (1998). Unfortunately, the chronostratigraphic ages of the coal deposits cannot be accurately assessed at present. Luttig & Steffens (1976) were of the opinion that most important Turkish coals were of Middle Miocene age, whilst Görür et al. (1995) believed that the most important coal deposits were formed during the Late Miocene in both west and east Anatolia. According to the mammalian faunas an early Miocene age had been suggested for the main coal deposits of Turkey (Bruijn & Saraç, 1991, 1992; Bruijn et al., 1992, 1993, 1999; Saraç, 2003 & personal communication, 2004).

In this paper (cf. Table 1), the accepted ages of the coal deposits are rough approximations mainly based on palynological studies (Nakoman, 1967, 1978; Akyol, 1982; Benda & Meulenkamp, 1979; Akgün & Akyol, 1987; Gökmen et al., 1993; Karayiğit et al., 1999; Takahashi & Jux, 1991; Hazerfen, 1976; Yağmurlu, 1986; 1992 & Tuncalı et al., 2002), as unfortunately, the stratigraphic allocations given by different authors appear to be partly conflicting.

4. SEDIMENTARY FACIES OF LIGNITE–BEARING NEOGENE SEQUENCES

The lignite bearing Neogene sequences of western Anatolia consist of two main sedimentary facies, the lignite-bearing fluvial facies and the lignite and evaporite bearing lacustrine facies (Helvacı &Yağmurlu, 1995).

The alluvial facies of the Neogene sequences is represented by alluvial-fan and fluvial sediments (Fig. 5). Generally, these coarse-grained alluvial-fan deposits grade into fluvial sediments towards the central parts of the basins. The fluvial sediments are characterized by channel and flood plain deposits.

The lacustrine sediments consist mainly of shale, mudstone, tuff, calcareous shale, and limestones. The lacustrine sediments rest unconformably on the alluvial-fluvial sequences; in some basins, they transgressively overlie the basement rocks.

Miocene, Pliocene and younger coals are formed in limnic and limnic-fluvial environments with some volcanogenic intercalations. The areal extention of coal-bearing Miocene (835,1 km^2) and Pliocene (526,9 km^2) deposits is 1.362 km^2 for the whole of Turkey (Tuncali et al, 2002).

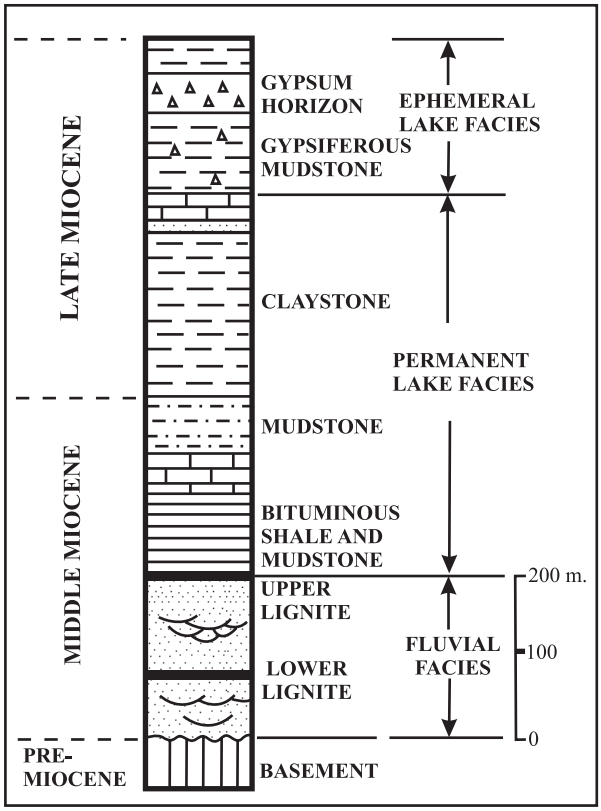

Figure 5. Generalized stratigraphic columnar section of the lignite-bearing Beypazarı Neogene basin and facies types (modified from Inci, 1991, and Helvacı & Yağmurlu, 1995).

5. DEPOSITIONAL CHARACTERISTICS OF THE LIGNITE DEPOSITS

Economic lignites within the Neogene basins of western Anatolia have mainly been deposited in fluvial and/or fluvial-lacustrine environments (Table 1). Fluvial lignites generally formed in well-drained floodplain marshes related to fluvial system. Fluvial-lacustrine lignites have mainly been deposited in mudplain environments extending along the shoreline of a lake system.

Lignite basins of western Anatolia, such as the Yatağan, Soma, Tunçbilek, Seyitömer and Çan basins contain mainly fluvial-lacustrine lignites. However, the Beypazarı and Yalvaç basins contain lacustrine and dominantly fluvial lignites.

The fluvial lignites are characterized by rapid lateral thickening and coal quality changes. In addition, the fluvial lignites grade into levee and flood-plain sediments of fluvial systems in short lateral direction.

However, the thickness and quality of the fluvial-lacustrine lignite deposits within most of the western Anatolian Neogene basins are generally laterally uniform over greater distances.

The lignite and evaporite-bearing (gypsum, trona, thenardite, and borate) sedimentary assemblages in the Beypazarı basin probably were deposited in fluvial, saline mudflat, hypersaline and ephemeral playa-lake environments (Inci, 1991; Helvaci & Yağmurlu, 1995) as represented in Figure 5.

6. LIGNITE CHARACTERISTICS

The NE-trending Neogene lignite basins of western Anatolia, ash, moisture, sulphur and calorific value vary between 10,73%-48,73%, 12,24%-53,00%, 0,93%-5,8 %, 6858 kJ/kg-21771 kJ/kg respectively (Table 1). Total (proven, probable and possible) reserve of these basins are 1.614.549.984 tonnes.

The NW-trending Neogene lignite basins of western Anatolia, ash, moisture, sulphur and calorific value vary between 11,38%-34,83%, 25,00%-53,42%, 1,01%-4,25 %, 4534 kJ/kg-11183 kJ/kg respectively (Table 1). Total (proven, probable and possible) reserve of these basins are 1.326.915.575 tonnes.

Total coal reserves of western Anatolia are 2.946.465.559 tonnes. Only the Keles, Beyşehir and Tefenni deposits are of Pliocene age. The Miocene deposits generally have higher reserves than the Pliocene ones in western Anatolia.

The relationships between chemical properties and calorific values of some lignite deposits in SW Turkey have been evaluated by Inaner & Nakoman, 1995. Some correlations can be observed (cf. Table 1) between moisture and ash, moisture and lower calorific values, ash and lower calorific values, volatile matter and fixed carbon values, volatile matter and lower calorific values and fixed carbon and lower calorific values, but there appears to be no relationship between moisture and total sulphur, and between lower calorific value and total sulphur (Inaner & Nakoman, 1995).

7. CONCLUSIONS

The total lignite reserves of western Anatolia amount to some 3 billion tonnes. The lignite and evaporite-bearing continental Neogene sequences have filled depressions bound by NW-, NE- and E-W-trending growth faults. The tectonic trends of western Anatolia have changed during the geological history, from NE to NW during the Miocene, rotating to W-E during the Plio-Pleistocene.

The economic lignite occurrences have mainly been deposited within the fluvial-lacustrine facies. They are of Middle and Late Miocene age, based on spore and pollen assemblages, which are indicative for subtropical and humid climates.

The quality characteristics of western Anatolian lignites indicate that ranks differ between the NE- and the NW-trending basins. Also, it is possible to observe different combustion quality parameters between different coal seams occurring in the same basin (e.g. Soma basin). Generally the quality of the lignites appears to be high in NE trending basins and low to medium in NW-trending basins in western Anatolia. The seams of Miocene age possess a considerably better quality than those of Pliocene age.

The quality of the lignites also depends on the predominant depositional setting. Lignite seams in fluviatile settings show higher quality in their uppermost part, and generally are of better quality than those of fluvial-lacustrine settings. But the latter have the advantage of more consistent lateral extension.

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