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Petrographic and palynological investigations of Sinanpaşa (Afyon) Miocene coals

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Research Article

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ABSTRACT

In this study, petrographical and palynological analyses of coal samples from two regions (the Kırka region in the south, and the Karacaören region in the north) of the Sinanpaşa (Afyon) Neogene basin were performed. The coal-bearing Neogene sediments indicate the occurrence of five facies: paleosol, matrix-supported conglomerate, coal-bearing mudstone, sandstone-claystone and laminated mudstones. Coal layers are mainly within coal-bearing mudstone facies. In addition, there are various types of coalified materials in matrix-supported conglomerate and sandstone-claystone facies. Based on coal petrography, an interpretation of the coal-forming environment was made. The investigated coals mainly contain a huminite maceral group. From the reflection values (R_{max}), these coals can be classified as sub-bituminous in rank, and as being deposited in swamp zones associated with limnic environments. The palynological data indicates that all studied coal-bearing units are of Mid-Miocene age. On the other hand, based on MAT, CMT, WMT and MAP parameters, it can be stated that at that time climatic conditions changed seasonally in the study area. Humid climatic conditions prevailed during the period when the peat was formed, then later transformed into the coal layers examined in this manuscript.

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1. Introduction

Many basins, which are bounded by normal faults, were formed in western Anatolia during the Cenozoic (Şengör and Yılmaz, 1981; Robertson and Dixon, 1984; Koçyiğit, 1984; Şengör et al., 1985; Zanchi et al., 1993; Ersoy et al., 2011) and the basins with NW-SE extensions were affected by pre-Neogene fault growth; however, the basins with E-W extensions were formed during the N-S-trending extensional tectonic movement (Kaya, 1979, 1981; Gürsoy et al., 2003; Koçyiğit and Özacar, 2003; Koçyiğit and Deveci, 2007). These basins are filled with thick sedimentary and volcanic deposits. In the case of the sedimentary deposits, they form mainly the alluvial fan, fluvial and lacustrine rock units (Helvacı and Yağmurlu, 1995; Öcal and Göktaş, 2011).

The Sinanpaşa (Afyon) Neogene basin is one of several volcano-sedimentary basins in western Anatolia. The basin has suffered two different periods of volcanic activity, which spread over vast areas during the Cenozoic time interval, and so exhibits differences in terms of volcanism dynamic and age (Aydar, 1998; Francalanci et al., 2000). They are represented by the Seydiler ignimbrites and the Afyon volcanism, respectively (Aydar, 1998). In the case of the Seydiler ignimbrites, they were deposited in the Early Miocene (Yalçın, 1988; Anderson, 1997); while the Afyon volcanism, which developed synchronously with the lacustrine deposition, took place in the Mid-Late Miocene (Besang et al., 1977).

The alluvial fan, the fluvial and lacustrine deposits in the study area were formed in the Mid-Miocene. The coal fields outcropping to the south and north of the research area, the Kırka and Karacaören coal fields, were investigated in this study. Geological investigations in the region were carried out in detail by Karamenderesi (1972), Metin et al. (1987), Kartalkanat et al. (1990) and Koçyiğit and Deveci (2007). In addition; the detailed field surveys of coal

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seams that form the stages when the lake had first opened, were conducted by Becker-Platen (1967) and Konyalı (1968). There is no data for any petrographical or palynological studies on the coal units until today.

The purpose of this study is to gain information on the climatic conditions of the period, and age of the coal units in the Sinanpaşa Basin with the help of petrographical and palynological investigations. In part of the Western Anatolian Neogene basins similar studies have already been carried out (Akgün and Akyol, 1999; Akgün et al., 2007), and this study will make up for the shortcomings in research in the Sinanpaşa Basin.

2. Regional Geology

The Sinanpaşa Neogene basin is surrounded by Mesozoic dolomite, dolomitic limestone and limestones in the north, Paleozoic Afyon metamorphics formed by metaclastic metavolcanic and recrystallized limestone in the east (Metin et al., 1987) and Mesozoic (Özgül et al., 1991) dolomite, dolomitic limestone and crystallized limestone in the south (Figure 1). The outcropping rocks in the Sinanpaşa basin are formed from Paleozoic and Mesozoic basement rocks, the Neogene basin fill deposits are mostly represented by Miocene and Quaternary units (Karamenderesi, 1972; Çevikbaş et al., 1988) (Figure 2).

Mid-Miocene deposition begins with alluvial fan deposits formed by dark yellow to orange conglomerate, pebbly sandstone and sandstone located in the Kırka region. The thickness of this alluvial fan deposit varies between 50-300 m. This deposit, which forms the basement of Mid-Miocene deposits, overlies the basement with an angular unconformity at the bottom, and is overlain by the Mid-Miocene lacustrine deposits in lateral and vertical transitions (Metin et al., 1987). The lacustrine deposits of the Mid-Miocene time are represented by the carbonate facies to the north and south of the basin. In stages, when the lake was first opened, the coal-bearing sediments were deposited.

Coal-bearing deposits are wide spread in around the Kırka region in S-SW, and in the Karacaören region in N-NW parts of the basin. The thickness of the coal-bearing layers, which have many lateral continuities, is a few meters, and located within a 150-200 m thick deposit. This deposit was studied from bottom to top in 5 facies; a) paleosol, b) matrix supported conglomerate, c) coal-bearing mudstone, d) sandstone-claystone and e) dirty white laminated mudstone (Figure 3).

a) Paleosol: The red paleosol layers, which forms the lowest section, can be observed in the form of 40-70 cm thick interlayers among yellow-red mudstone, siltstone and sandstone and, occasionally conglomerates can be observed. In them, pebble grains with limestone-marble components are located, mostly of metamorphic origin. The cross bedded sandstones with very fine to fine sand can also be observed at the bottom of the paleosol zones.

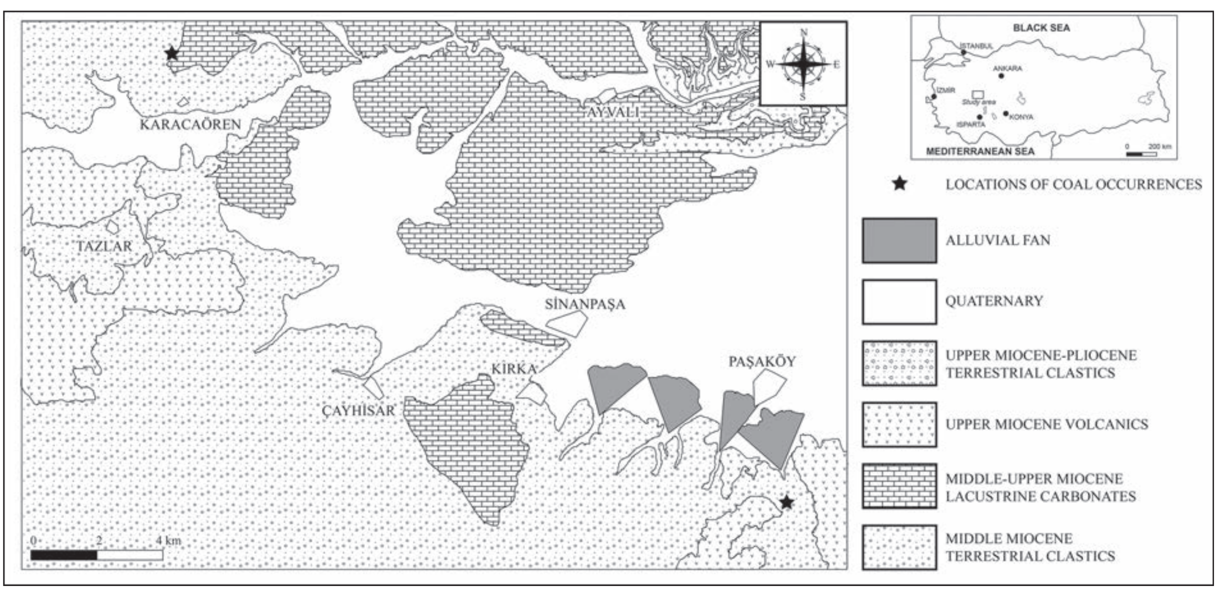

Figure 1- Geological map of Sinanpaşa (Afyon) basin (modified from Metin et al., 1987).

b) Matrix supported conglomerate: It overlies the paleosol layer and has a thickness of 15-20 m. The bottom of this unit, which can be observed as having white-gray tones, is erosional. When its macroscopic features are examined, it can be seen that the pebbles are bonded by the matrix, which is formed from the carbonate sand and carbonate mud. The layers become markedly thinner in a lateral direction within a few 100 meters. In the upper parts of these conglomerate layers the mudstone dramatically increases, as well as the low graded coal layers.

c) Coal-bearing mudstone: This facies is made-up of 5-15 cm thick coal-bearing layers which alternate with gray mudstone. There are 5 coal seams in it. The total thickness of the coal with clayey interlayers is around 5 m. Coal-bearing layers thin-out and disappear into the mixture of micro breccia and mudstone lithology, at the endpoints of a few hundred meter lateral dispersion in a NE-SW direction (Figure 3). These are dark brown-black in color, with intercalations of laminated mud, and contain many plant roots. Thinning out coal-bearing layers reflect the feature of a typical peat with characteristics of

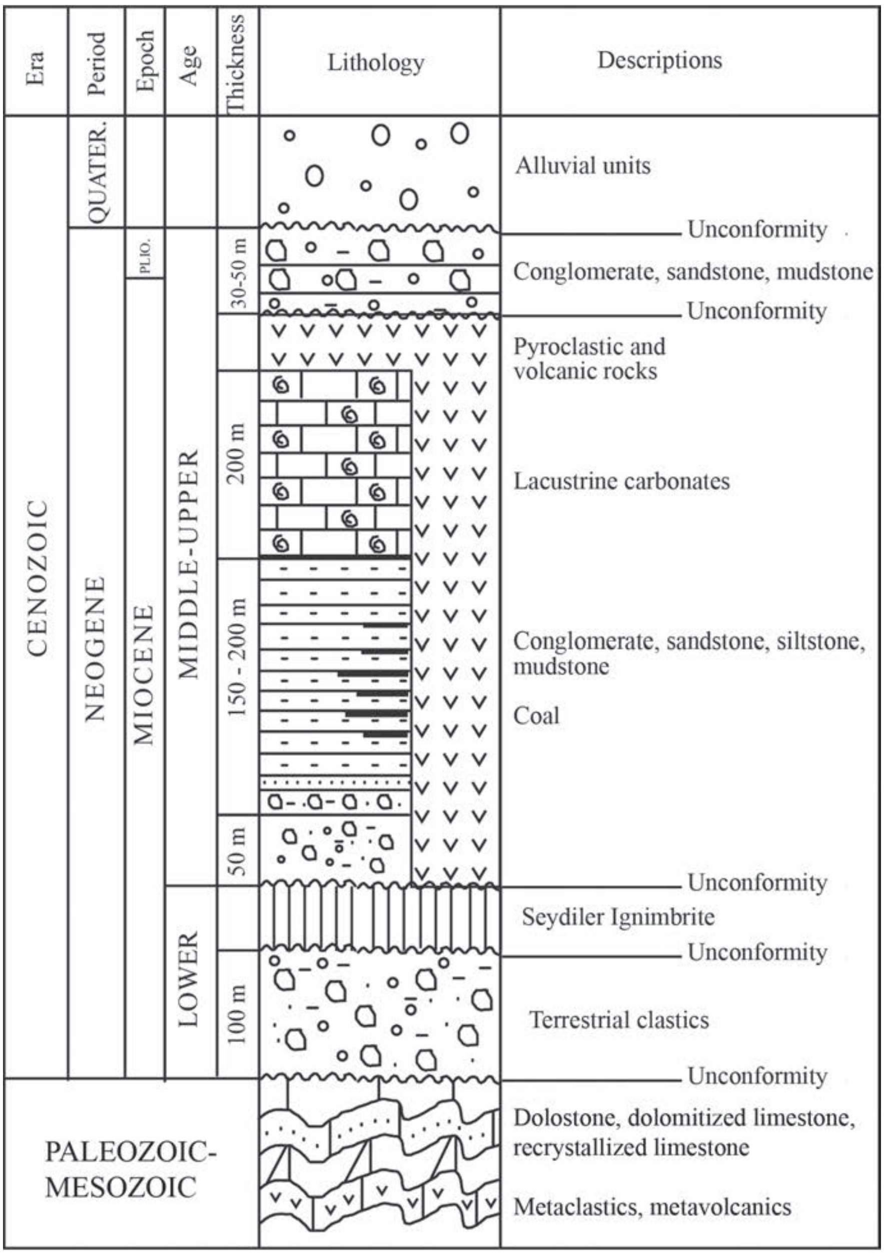

Figure 2- Columnar section of Sinanpaşa (Afyon) basin (modified from Metin et al., 1987).

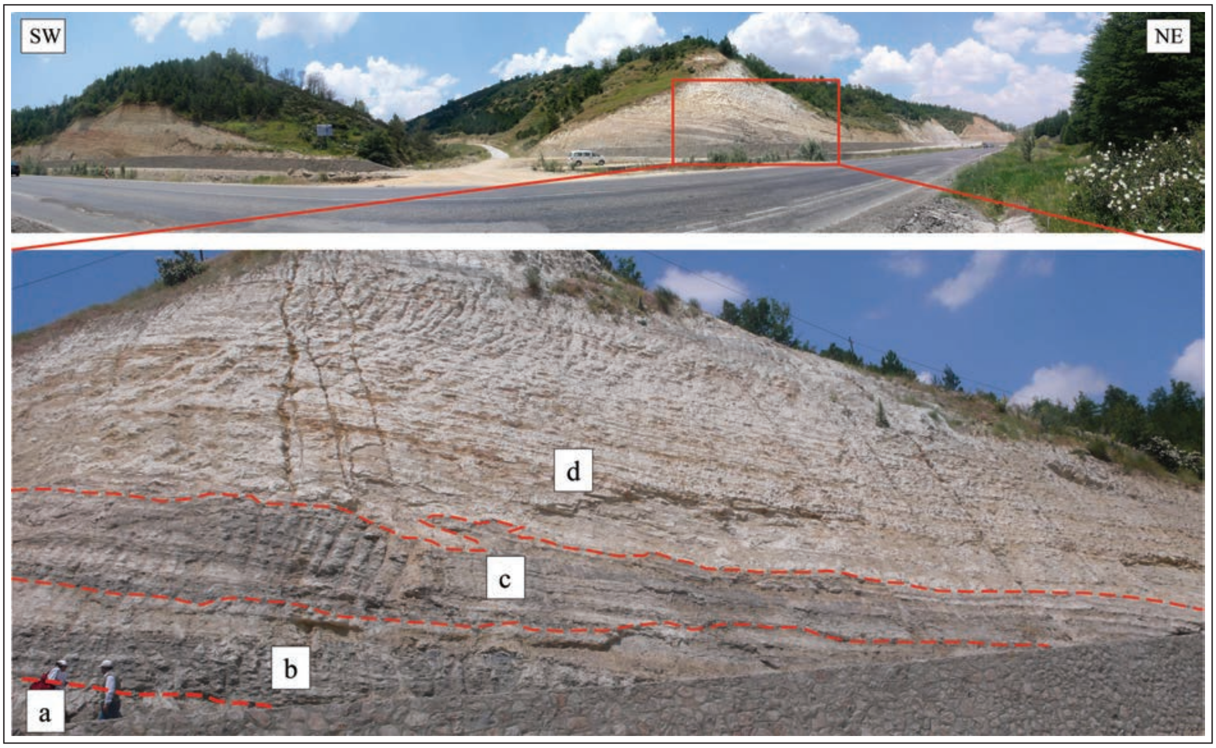

Figure 3- General and detail view of coal levels in the area (a: paleosol, b: matrix supported conglomerate, c: coal bearing mudstone, d: sandstone-claystone facies).

limited dispersion, silt size material and rhythmic alternation (Günen, 2011).

d) Sandstone-claystone facies: This facies alternates with coal-bearing sandstones and is formed by approximately 10 m thick gray sandstones and claystone. In them, the coal seams have completely disappeared, but they consist of coalified, blocky coal-bearing fragments in different size (between 30-50 cm).

e) Laminated mudstone: It alternates with sandstone-claystone facies and is overlain by the lacustrine carbonates. It has a thickness varying between 20-50 m. These are yellow to gray in color, parallel laminated, weak to medium compacted, and consist of fossilized plant root and mold, which are considered descriptive features.

3. Material and Method

The systematical sampling from coal-bearing layers from bottom to top was made within narrow intervals (mostly 10-50 cm), perpendicular to veins, depending on the change of macroscopic features (brightness and dullness) of the coal veins. However, a number of coal samples were taken from the underground mining quarry, as well as the lower and upper layers (The Karacaören Coal Enterprise). Besides; the units of the same layers on the ground were sampled by means of point sampling in different areas.

Petrographical investigations of the coal-bearing units were carried out in the Division of Mineralogy and Petrography Laboratories of the Mineral Analyses and Technology Department in the General Directorate of Mineral and Exploration (MTA). The following materials were utilized for analyses; the Leitz MPV-SP brand photomultiplier microscope, oil immersion lens with a magnification of 32x, polishing oil with an incidence angle of 1,518%, sapphire standard with a reflection value (R) of 0.548% for reflection measurements, and the software GEOR. In the determination of microscopic components in the samples, nearly 400 points for each sample were studied and detected by the point counting method. After the microscopic components of samples had been determined in detail they were subjected to sensitive polishing and prepared for the reflection measurements. The maximum reflection values (R_{max}) were detected during the reflection measurements. Coal petrography studies and descriptions were done according to Stach et al. (1982), Ward (1984), ICCP (1994) and ICCP (2001).

The samples selected for palynological studies were crushed and then washed with different acids, such as; HCl, HF, HNO_3 and KOH, in order to remove them from calcium, silica and organic materials based on palynologic sample preparation techniques. For each sample 1-4 slides were prepared then sample count and selections were made. For paleoclimatic interpretations the method of "Coexistence Approach" was used (Mosbrugger and Utescher, 1997). The purpose of this method is to determine the interval of different paleoclimatic parameters of a given fossil. At the end of this method, the "coexistence" interval was obtained. This is considered the best descriptor for explaining which plant types live at what temperature for each climatic parameter. The application of the "Coexistence Approach" method was done using around 2000 Paleoflora Databases (for more information: www.paleoflora.de) for plants which lived in Tertiary conditions, by means of ClimStat software. The palinoflora obtained in this study was interpreted using 4 climatic parameters. These are the values of "Mean annual temperature" (MAT), "Mean temperature of the coldest month" (CMT), "Mean temperature of the warmest Month" (WMT) and "Mean annual precipitation" (MAP).

4. Coal Petrography

Coal-bearing layers in the Sinanpaşa basin exhibit wide spreads to the east of the Kırka region located in the S-SE of the basin, and around the Karacaören region located in the N-NW of the basin. The petrographical investigations of the coal samples taken in both regions were completed and the results of the coal petrography analysis were used for environmental interpretations.

4.1. Kırka Region

When looking at microscopic components of the eight coal samples collected from this region, the macerals ranging from most to least in abundance are ordered as; the huminite, liptinite and inertinite macerals. The relatively high inertinite ratio is due to oxidation (Hacquebard et al., 1967; Toprak, 1984).

In several studies it was observed that corpohuminite tissues (Figure 4a), with their homogenous rounded sights, began to disappear among huminite macerals. Also; ulminite macerals (ICCP, 1994), with their typical views in which lineaments that had formed by the accretion of tissues on each other are dominant, can be widely observed. Besides; gelinite macerals were also observed (Figure 4b) with their homogenous and nonwoven views with wide surfaces.

Among liptinite macerals; the sporinites, which formed due to the flattened spore and pollens parallel to the bedding, and cutinites (Figure 4c) which had formed because of the leaf cuticles, were determined as the most dominant macerals. In addition; the resinite macerals, which had been formed by resins released from the plants, were also observed. Resinites are generally observed in the form of amorphous void infillings or in rounded, oval shapes (Stopes, 1935; Toprak, 1996).

Funginites are the most common inertinite maceral in these coals. They are rounded to oval in shape (ICCP, 2001). However, the macrinite maceral is typical with non-textured views covering wide surfaces. It has been emphasized that the macrinites with these views and formations are the most important component of the lignite and sub bituminous coals of Turkey (Toprak, 2009).

The percentage of maceral groups and inorganic materials in these coal samples and R_{max} reflection values are given in table 1. According to this Table, the percentage of clay and other silicate minerals were observed, varying from 5-11%. Pyrite varies from 7-10%, wherein framboidal pyrite is 4%, granular (idiomorph) pyrite is 2% and fracture filling is 1-2%. The framboidal pyrite (Figure 4d) indicates a stagnant swamp environment and the growth is due to in-situ bacteria (Stach et al., 1982).

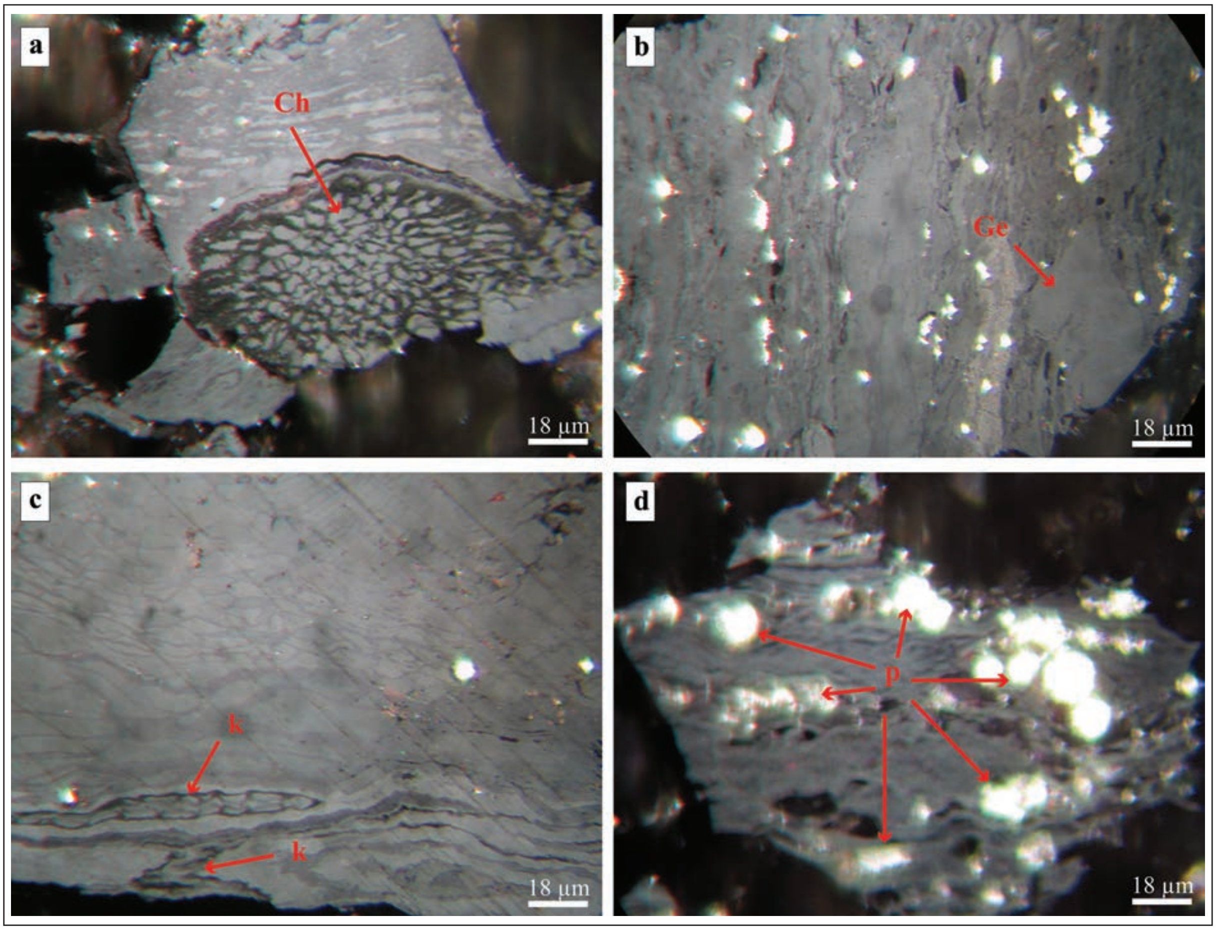

Figure 4- a) Corpohuminite maceral (Ch) with rounded appearance, b) Non-textured gelinite maceral (Ge) with homogenous and wide surfaces, c) Cutinite macerals (k) occurring from leaf fossils, d) fromboidal pyrites (p) formed in coal.

4.2. Karacaören Region

When looking at the microscopic components of 5 coal samples collected from this region, macerals ranging from most to least in abundance are ordered as; the huminite, liptinite and inertinite macerals. High organic material content of the coals most likely indicates the sulfate inputs, and that the organic material sedimentation is in excess.

In previous studies, the most dominant type among the huminite macerals were the gelinites, and there were also humotelinites and humodetrinites (clastic huminites) in significant amounts. Gelinites are typical with their homogenous and nonwoven views and their wide surfaces (Sỳkorovå et al., 2005) (Figure 5a). In addition, ulminite macerals (Figure 5b) with views in which tissues begin to disappear, and atrinite and densinite macerals with views that consist of thin huminite clastics were found.

Among liptinite macerals; the sporinites, which had been formed by flattened spore and pollens parallel to the bedding, and thin cutinites (Figure 5c), which had been formed by the leaf cuticles, were found to be the most dominant macerals. In addition; the macrinites, known as most dominant inertinite maceral in coals of the basin, were typically observed in their nonwoven state (Figure 5d).

The percentage of maceral groups and inorganic materials obtained from coal samples and R_{max} reflection values are given in table 2. According to the figures, pyrite presence was detected at 7% in total volume, with 5% for framboidal pyrites and 2% for granular (idiomorph) pyrites. Besides; the percentage of clay and other organic materials was determined as 24%. High clay ratio shows that average clastic material input into the environment has increased. Micro-lamination structures of which coal-clay alternation formed can be typically observed in the study area.

Table 1- Maceral and mineral components of coal occurrences in Kırka area.

Samp-le No	Rmax (%)	HUMINITE				Tot. Hum.	LIPTINITE			Tot. Lipt.	INERTINITE				Tot. Inet.	PYRITE			Tot. Pyrite	CLAY etc.
		Humotelinite		Humodetrinite	Gelohuminite															
		Text	Ulm	(Densinite)	Gelinite		Spor	Resinite	Cutinite		Fus.	Macr.	Fu	I.det.		Pseu	Grn.	Cf		
EG-5	0,436	1	8	7	62	78	3	1	1	5	-	3	1	1	5	4	2	1	7	5
EG-16	0,440	2	9	6	49	66	4	2	1	7	-	2	1	-	3	4	4	2	10	11
EG-17	0,473	1	8	5	61	75	3	1	1	5	-	3	1	1	5	4	2	1	7	5
EG-18	0,440	2	8	8	63	81	4	1	1	6	-	3	1	1	5	3	1	1	5	3
EG-19	0,435	1	8	7	62	78	3	1	1	5	-	3	1	1	5	4	2	1	7	5
EG-20	0,442	2	7	7	60	76	4	3	1	8	-	2	1	-	3	3	2	2	7	6
EG-24	0,412	1	8	6	60	75	3	1	1	5	-	2	1	1	4	4	3	2	9	7
EG-26	0,436	1	7	5	62	75	3	1	1	5	-	3	1	-	4	4	4	2	10	6
EG-27	0,465	2	7	7	62	78	4	2	1	7	-	3	1	1	5	2	2	1	5	5

(Tot: Total, Hum: Huminite, Lipt: Liptinite, Inet: Inertinite, I.det: Inertodetrinite, Text: Textinite, Ulm: Ulminite, Spor: Sporinite, Fus: Fusinite, Macr: Macrinite, Fu: Funginite, Pseu: Framboidal, Grn: idiomorph crystalline, Cf: Crack fill, Clay etc: Clay and carbonate minerals).

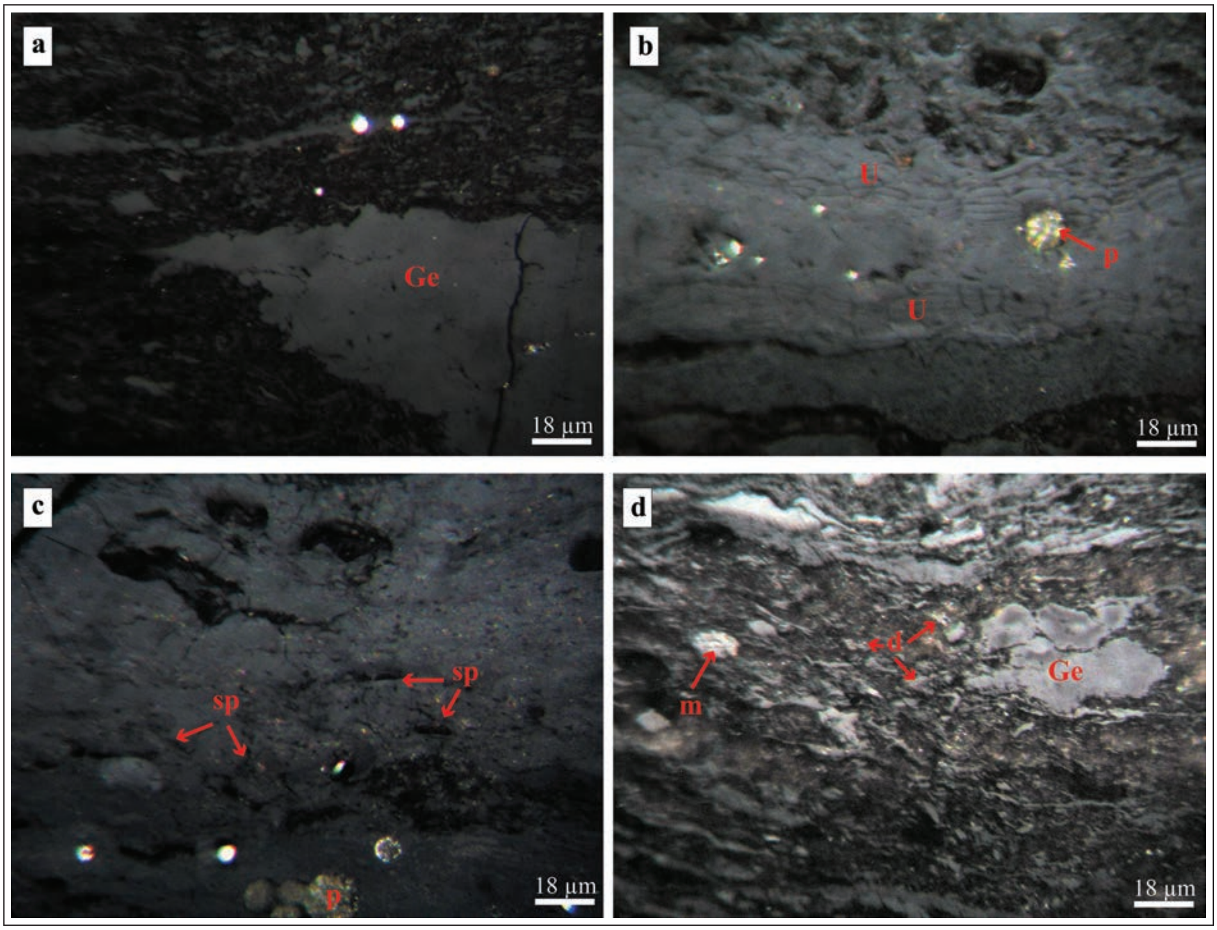

Figure 5- a) Non-textured gelinite maceral (Ge)with wide surfaces, b) Ulminite macerals (U) with disappearing textures and framboidal pyrites (p), c) Non-textured macrinite (m), homogenous gelinite (Ge) and densinite maceral (d) including fine huminite fragments, d) Sporinite macerals (sp) formed by spors and polens with framboidal pyrites (p).

5. Discussion

5.1. Palynology

A total of 13 samples, of which 8 samples were from road cuts along the Afyon-Sandıklı autoroad and 5 samples from Çalışlar-Karacaören, were passed through palynological sample preparation stages and made ready for microscopic studies. However, it was noticed that samples were poor in terms of sporomorph content and their forms were not well preserved. In sporomorph communities obtained as a result of studies carried out on samples, the spore diversity was very low and only *Laevigatosporites* genus was abundant (Table 3). Among the gymnosperm pollens; the pollens of *Picea* and *Pinus* genus conifers, swamp plants and pollens of Taxodioideae and Cupressaceae appear. Among angiosperms, the species of Chenopodiaceae and Graminae families, which show wide flat areas, were observed in small amounts. Chenopodiaceae, Graminae and Umbelliferae in the Miocene of Turkey have been recorded only in the deposits from Mid-Miocene in small amounts, though it has been detected that the percentages of these forms had increased in the Late Miocene or younger deposits (Benda, 1971; Benda and Meunlenkamp, 1990; Akgün and Akyol, 1999; Akgün et al., 2000; Akgün et al., 2007). Therefore; the samples obtained from the study area should be even older than Upper Miocene. The spore forms inherited from Oligocene (Leiotriletes maxoides ssp. maxoides and maximus, Verrucatosporites, Lycopodiumsporites, Polypodiaceoisporites) were not encountered in samples, even at low ratios, during the early Miocene. Besides; the angiosperm forms, of which their vertical distributions concern the whole Cenozoic, accompany other forms, though in low diversity. So, looking at all the aforementioned reasons the age of samples is said to be in Mid-Miocene.

Table 2- Maceral and mineral components of coal occurerences in Karacaören area.

Sample No	**Rmax (%)**	**HUMINITE**						**Tot. Hum.**	**LIPTINITE**			**Tot. Lipt.**	**INERTINITE**		**Tot. Inet.**	**PYRITE**			**Tot. Pyrite**	**CLAY etc.**
		Humotelinite		Detrohuminite		Gelohuminite														
		Text	Ulm	Attr.	Dens.	Gelinite	Co.hum.		Spor	Alginite	Cutinite		Fus.	Macr.		Pseu	Grn	Cf		
K-1	0,524	3	12	4	11	28	1	59	3	2	1	6	1	3	4	5	2	-	7	24
K-2	0,520	2	10	4	10	22	1	49	4	2	1	7	-	2	2	4	4	-	8	21
K-3	0,530	3	11	5	11	25	1	52	3	2	1	6	-	3	3	5	2	-	7	21
K-4	0,526	3	11	4	11	26	1	56	4	1	1	6	1	3	4	5	2	-	7	25
K-5	0,524	3	12	4	12	26	1	58	3	2	1	6	-	4	4	4	3	-	7	24

(Tot: Total, Hum: Huminite, Lipt: Liptinite, Inet: İnertinite, Text: Textinite, Ulm: Ulminite, Dens: Densinite, Spor: Sporinite, Fus: Fusinite, Co.hum: Corpohuminite, Macr: Macrinite, Pseu: Framboidal, Grn: idiomorph crystalline, Cf: Crack fill, Clay etc: Clay and carbonate minerals).

Table 3- Sporomorphs and botanical affinities of the samples.

SPOROMORPH	BOTANICAL AFFINITIES
Laevigatosporites haardti (Potonié and Venitz) Thomson and Pflug ssp. *haardti* Krutzsch	Polypodiaceae
Graminidites sp.	*Graminae*
Inaperturopollenites dubius (Potonié and Venkatachala) Thomson and Pflug	Taxodioideae
Cupressacidites cuspidateaformis (Zaklinskaja) Krutzsch	Cupressaceae
Pityosporites microalatus (Potonié) Thomson and Pflug	Pinaceae; *Pinus* haploxyon tip
Piceapollis planoides Krutzsch	*Picea*
Pityosporites pristinipollinius (Traverse) Krutzsch	*Pinus*
Pinuspollenites macroinsignis (Krutzsch) Planderova	*Pinus*
Piceaepollenites alatus R.Potonie	Pinaceae
Piceapollis praemarianus Krutzsch	*Picea*
Pityosporites sp.	Pinaceae
Caryapollenites simplex (Potonié) Thomson and Pflug	*Carya cordiformis*
Alnipollenites verus R.Potonié	Betulaceae; *Alnus*
Tricolpopollenites microhenrici (Potonié) Thomson and Pflug	Fagaceae; ? *Quercus*
Tricolpopollenites henrici (Potonié) Thomson and Pflug	Fagaceae; ? *Quercus*
Tricolpopollenites densus Pflug *in* Thomson and Pflug	*Quercus*
Oleoidearumpollenites microreticulatus (Flug *in* Thomson and Pflug) Zimbinska-Tworzydlo	Oleaceae
Tricolporopollenites cingulum (Potonié) Thomson and Pflug ssp. o*viformis* (Potonié) Thomson and Pflug	Castanea-Castanopsis
Tricolporopollenites krucshi (Potonié) Thomson and Pflug	*Nyssa*
Araliaceoipollenites euphorii	Araliaceae
Rhoipites cf. pseudocingulum	Anacardiaceae, *Rhus*
Periporopollenites multiporatus Pflug and Thomson *in* Thomson and Pflug	Chenopodiaceae
Tetracolporopollenites sp.	Sapotaceae

The forms of the Nyssacea family, which are observed all the time and known as the swamp forms in the Mid-Miocene of Turkey, and Alnus, Quercus, Castanea-Castanopsis, Anacardiaceae and Araliaceae, which are observed during the Mid-Miocene representing the mixed forest community, take place in the obtained community. Consequently; the age of the samples obtained from the measured section supports the Mid-Miocene.

5.2. Environmental Interpretation

When the maceral distributions of coals located in Kırka and Karacaören regions in the Sinanpaşa basin were plotted on the ternary diagram, it was clear that these coals were formed by the huminite (mostly galenite) rich macerals and consisted of liptinite (mostly sporinite) and inertinite (mostly macrinite) groups of macerals, though in small amounts (Figure 6).

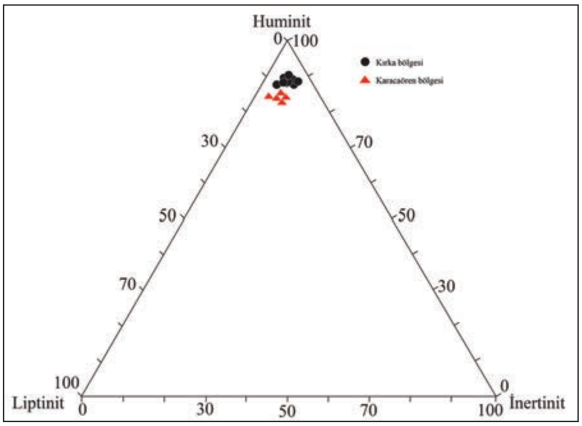

Figure 6- Ternary diagram of maceral groups in Kırka and Karacaören coal occurrences.

The analyses performed on the coals are important in terms of detecting the old depositional environments and their conditions. Many researchers have carried out investigations into this subject and aimed at finding parameters that could solve the old depositional environments of samples (Spackman, 1958; Diessel, 1986; Kalkreuth and Leckie, 1989; Lamberson et al., 1991). In this study, the values of GI (gelification index) and TPI (tissue preservation index) were determined using a graphic which had been developed by Diessel (1986), and improved by Kalkreuth and Leckie (1989) and Lamberson et al. (1991) for the environmental interpretation of the coals. The results are shown in figure 7. Accordingly;

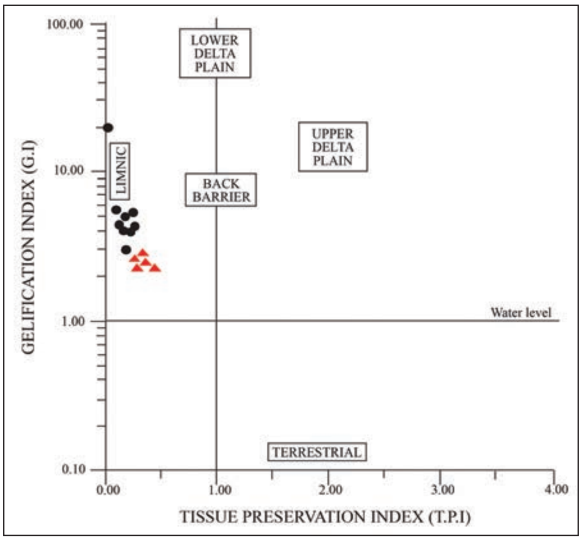

Figure 7- Coal facies diagram with depositional environments (Diessel, 1986; Kalkreuth and Leckie, 1989; Lamberson et al. 1991) (see figure 6 for the explanations of the symbols).

the maceral contents, tissues and gelifications of both regions show similarities. It was observed that coal samples collected from both regions had occurred in the lacustrine environment 1.00 line above the Y axis (above water level) in figure 7. When this data was taken into consideration as sedimantological and palynological data, it was noticed that the coals in the basin had been deposited in swamp zones associated with lakes. Besides; the high gelinite maceral component indicates that coals were developed in swamp environments which increased the gelification (Diessel, 1986; Toprak, 1996).

The R_{max} (%) values of the coals in the Kırka region being lower than 0.47 shows that the maximum paleotemperature value of the environment is below 100°C and corresponds to sub bituminous as coal rank (Stach et al., 1982; Ward, 1984). In addition; the R_{max} values of the coals in the Karacaören region are higher than 0.47. R_{max} values of these coals, the increased levels are partly attributed to the increase in the oxidation in similar geological environments (Toprak, 2009).

5.3. Paleoclimate

The plants to which polens and spores belong in the palynological community are assessed in order to understand the climatic conditions. Numerical climatic assessments were made using the “Coexistence Approach” method, developed by Mosbrugger and Utescher (1997).

When the Sinanpaşa Mid-Miocene palynoflora was studied it was seen that pollens, which belonged to plants that could develop in cool climates, had been more dominant (eg. Pinaceae, Carya, Quercus and Alnus). The numerical climatic calculations of this flora were made by the ClimStat software using 21 species. These numerical values support that the deposition of coal-bearing deposits occurred under cool climatic conditions. These paleoclimate conditions are represented by the numerical values MAT: 13,3–18,1°C, CMT: 0,9–8,3°C, WMT: 23,6–27,0°C and MAP: 622-1322 mm (Figure 8).

Akgün et al. (2007) stated that the West Anatolian Mid-Miocene low numerical temperature values of MAT (~12-17°C) and CMT (~2-9°C) were lower than the Early Miocene. It was also seen that numerical findings obtained from this study were compatible with other Mid-Miocene numerical values. The lower boundary of MAP being low and the upper boundary being high makes us consider the presence of seasonal change. Besides; the high MAP value explains the presence of *Alnus* and *Nyssa* plants which can evolve on a stream bank or in a swamp environment with high water levels defined as sporomorph flora in the study area.

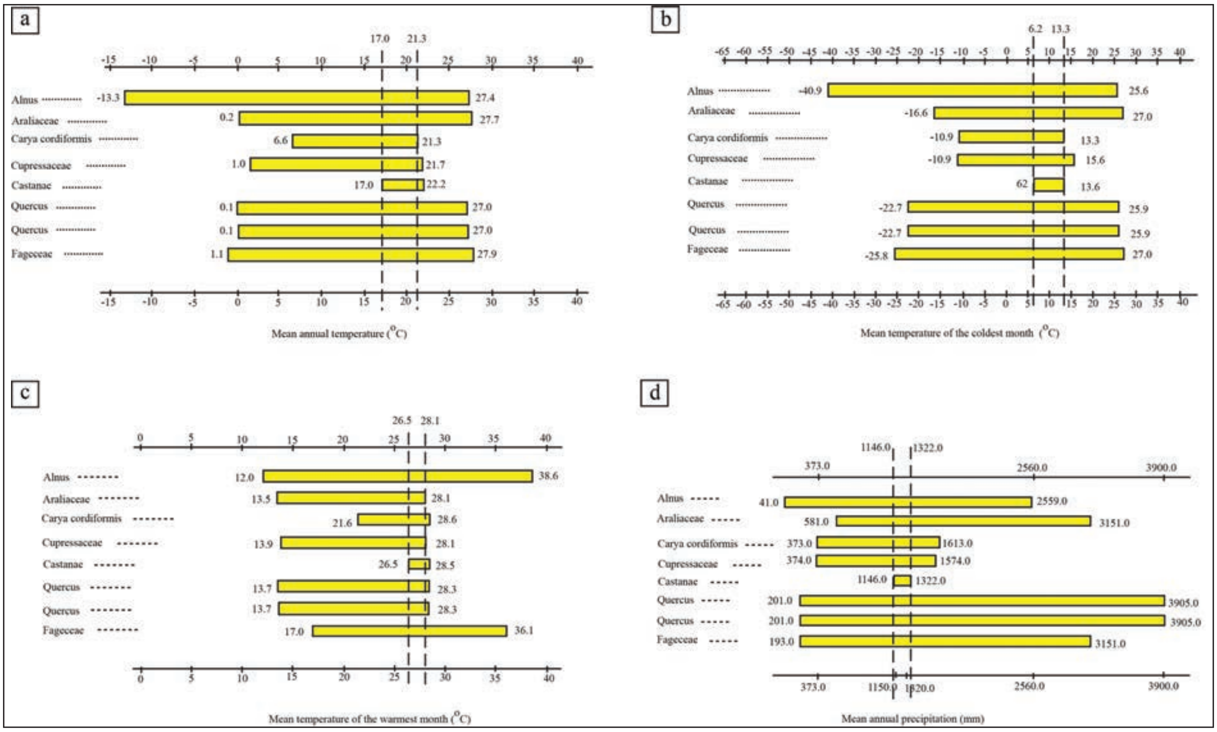

Figure 8- Numerical climatic calculations ; a) Mean annual temperature, b) Mean temperature of the coldest month, c) Mean temperature of the warmest month, d) Mean annual precipitation.

5. Conclusions

The Miocene deposition in the study area begins with the alluvial fan deposits at the bottom and grades into lacustrine deposits in the upper layers. Coal-bearing layers were detected in stages when the lake was first opened. These layers crop out in the Kırka region in the South and in the Karacaören region in the North of the investigated area.

As a result of petrographical investigation of the coal-bearing units taken from both regions, it was observed that these regions presented similar petrographical features. So, it was determined that both regions had huminite rich coals and consisted of liptinite and inertinite in small amounts.

It was found that the R_{max} (%) values of the coals in the Kırka region ranged between 0.44-0.47. According to the studies carried out on the coals these values correspond to sub bituminous coals (Stach et al., 1982; Ward, 1984). In addition, the R_{max} (%) values of the coals from the Karacaören region were found to be high (>0.47%), which makes us consider the presence of increasing oxidation in the environment. Besides; the presence of the Afyon volcanism and tectonic activities in and around the study area might have also been a factor in the increase of the R_{max} values as it had been in similar coal fields in Turkey (Toprak, 2009).

In the study area, mainly the swamp forms of the Nyssaceae family and the forms of the mixed forest community (*Alnus*, *Quercus*, *Castanea-Castanopsis*, Anacardiaceae and Araliaceae) were detected. The age of coal-bearing units in the study area indicates the Mid-Miocene because of the presence of the forms observed in the Mid-Miocene of Turkey.

As a result of paleoclimate studies carried out, it was found that MAT and CMT temperature values were low, however, MAP values were variable. This situation makes us consider whether climatic conditions have changed due to seasonality in the study area. As a result; the presence of cool climate conditions during the time of the coal production based on palynological data in this study should be mentioned. This data is compatible with climate conditions that prevail in Western Anatolia during the Mid-Miocene time.

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