GEOLOGICA BELGICA (2004) 7/3-4: 259-265

GEOLOGICAL SETTING AND QUALITY OF THE LIGNITE SEAMS IN THE SEYITOMER BASIN, KUTAHYA, TURKEY

Yakup CELIK[1] & Ali Ihsan KARAYIGIT[2]

1. Istanbul University, Department of Geological Engineering, 34850 Avcilar-Istanbul, Turkey, E-mail: yacelik@istanbul.edu.tr
2. Hacettepe University, Department of Geological Engineering, 06532 Beytepe-Ankara, Turkey, E-mail: aik@hacettepe.edu.tr

(5 figures, 1 table)

ABSTRACT. The Seyitomer basin, which is one of the most productive coal basins of western Anatolia-Turkey, contains two lignite seams, lower and upper, in the Lower-Middle Miocene lacustrine Seyitomer Formation. The lower seam in this basin is extensively exploited by open-cast methods and produced lignites are generally consumed in coal-fired power plants. A total of thirty-six lignite samples, of which thirty-one are from the lower seam and five from the upper seam, were collected from the two locations (DK and S30), and have been subjected to proximate and mineralogical analyses. In addition, six samples from claystone and tuffaceous claystone samples within the lower seam have been also evaluated in the present study. This study indicates that the two lignite seams in the Seyitomer Formation contain high moisture, volatile matter, ash and total sulfur and relatively low calorific values. The mineral matter of the selected lignite samples with X-ray powder diffraction shows that the samples are mainly made up of clay minerals, quartz, feldspar and pyrite, minor/trace amounts of siderite, dolomite, calcite, opal-CT and gypsum. Tuffaceous claystones within the lower lignite seam includes smectite, illite, kaolinite, quartz and feldspar and trace amounts of chlorite; but smectite is much higher in the green claystones.

Keywords: Miocene, Seyitomer, Turkey, lignite, quality, mineralogy, fluvial-lacustrine deposits

1. Introduction

The Tertiary coals of Turkey mainly occur in a number of fault-bounded Miocene and Pliocene lacustrine basins in intermontane regions (Karayigit and Whateley, 1997; Karayigit and Celik, 2003). Total coal reserves of Turkey are estimated to be in the order of 8.4 Gt low-rank coals (lignite and subbituminous) and 1.1 Gt bituminous coal, and total annual low-rank coal production reaches about 65 Mt (Altas *et al.*, 2000). The Seyitomer lignite basin (Figure 2 for location), which is one of the most productive lignite basins in western Anatolia-Turkey, includes two lignite seams, lower and upper, in the Lower-Middle Miocene Seyitomer Formation. The former one is minable, and the later has no economic value. The lower seam reaches about 37 m thickness in some boreholes, but it averages 15 m in the basin. The Seyitomer Basin has a lignite reserve of about 200 Mt (Gokmen *et al.,* 1993). The lower seam is currently exploited in open-cast mines with a dragline, excavator and truck system in the Seyitomer field and supply feed coal to a power plant with 600 MW capacity, which has four boiler units (I-IV) each with 150 MW. The power plant consumes approximately 6.6 Mt per year in lignites.

This study is part of an ongoing research program on coal quality of Turkish coals. Preliminary results on mineralogy and trace element contents of a feed coal to the Seyitomer coal-fired power plant were previously presented by Karayigit *et al.* (2000), who noted that the feed coal includes clay minerals (smectite, illite, kaolinite/chlorite), quartz, and minor amounts of calcite, siderite, pyrite and gypsum, and enrichments in Cr (242 ppm) and especially Ni (678 ppm) on a whole-coal basis. This study is improved from the project study of the first author, and mainly focuses on geological setting, proximate analysis and mineralogy of the two lignite seams in the Seyitomer Formation, which were affected by volcanic ashes.

2. Geological setting

Geological investigation of the Seyitomer lignite basin has been undertaken by some authors such as Lebkuchner (1959), Bas (1986), Gokmen *et al.* (1993), Senguler & Sonel (1999) and Yavuz (2001). A simplified geological setting of the Seyitomer Basin is summarised being information provided by Bas (1986) and the first author's field observations. A generalized stratigraphic sequence of the Seyitomer Basin and a simplified geologic map showing also coal sample locations are presented in Figures 1 and 2, respectively. The metamorphic and ophiolitic rocks and granites of Pre-Neogene age form the basement of the basin. The Miocene-Pliocene aged basin fill rests unconformably on the basement rocks (Figure 1).

The first sedimentary system in the basin begins with fluvial regime of the Egrioz Formation (Figure 1),

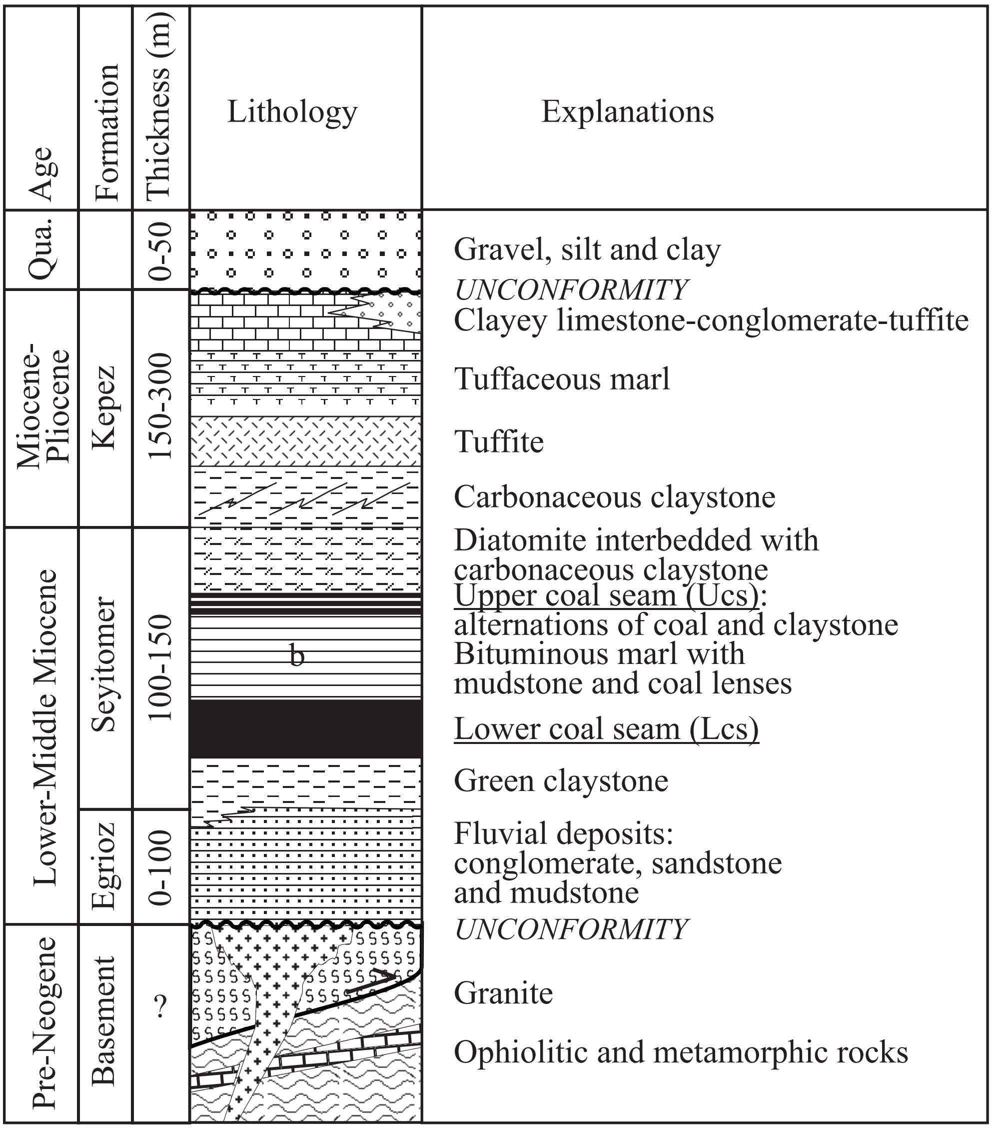

Figure 1. Generalised stratigraphic column section of the Seyitomer Basin.

which consists of conglomerate, trough cross-bedded conglomerate, sandstone, mudstone and thin coal seam. The conglomerates are much more abundant near the basin margin. The conglomerate, trough cross-bedded conglomerate and pebbly sandstone units are channel deposits, which incised into a floodplain and horizontally bedded siltstone and mudstone, which are interpreted as overbank deposits.

The coal-bearing Seyitomer Formation of Lower-Middle Miocene age in the basin was conformably underlain by fluvial deposits of the Egrioz Formation and conformably overlain by the Kepez Formation of Miocene-Pliocene age. The coal-bearing Seyitomer Formation in lateral-vertical direction was developed in lacustrine facies, and is represented, from the base to the upwards, by green claystone, lower coal seam, bituminous marl with mudstone and sapropelic coal lenses, upper coal seam, diatomite interbedded with carbonaceous claystone and fossiliferous marl. However, field studies show that fluvial inputs with trough cross-bedded sandstone and tuffaceous sandstone are increasing to the southwest of the Seyitomer Basin, around Arslanli and Kepez villages (Figure 2).

The Kepez Formation that accumulated in lacustrine-partly fluvial environment, from the bottom to the top, consists mainly of carbonaceous claystone, tuffite, tuffaceous marl, clayey limestone and conglomera-tuffite. The facies units of the Kepez Formation are interpreted as freshwater carbonates, volcanic fall deposits, and river deposits.

A thick and lateral extensive coal seam, lower seam, is located to the bottom level of the Seyitomer Formation (Figure 2) and field studies implied that this seam in the DK location includes only thin dirt bands, but they are increasing towards S30 location (Figures 1 and 3). The dirt bands indicate the introduction of fine clastics during peat formation in a fresh-water lacustrine environment with a relatively high water table. The fresh samples of

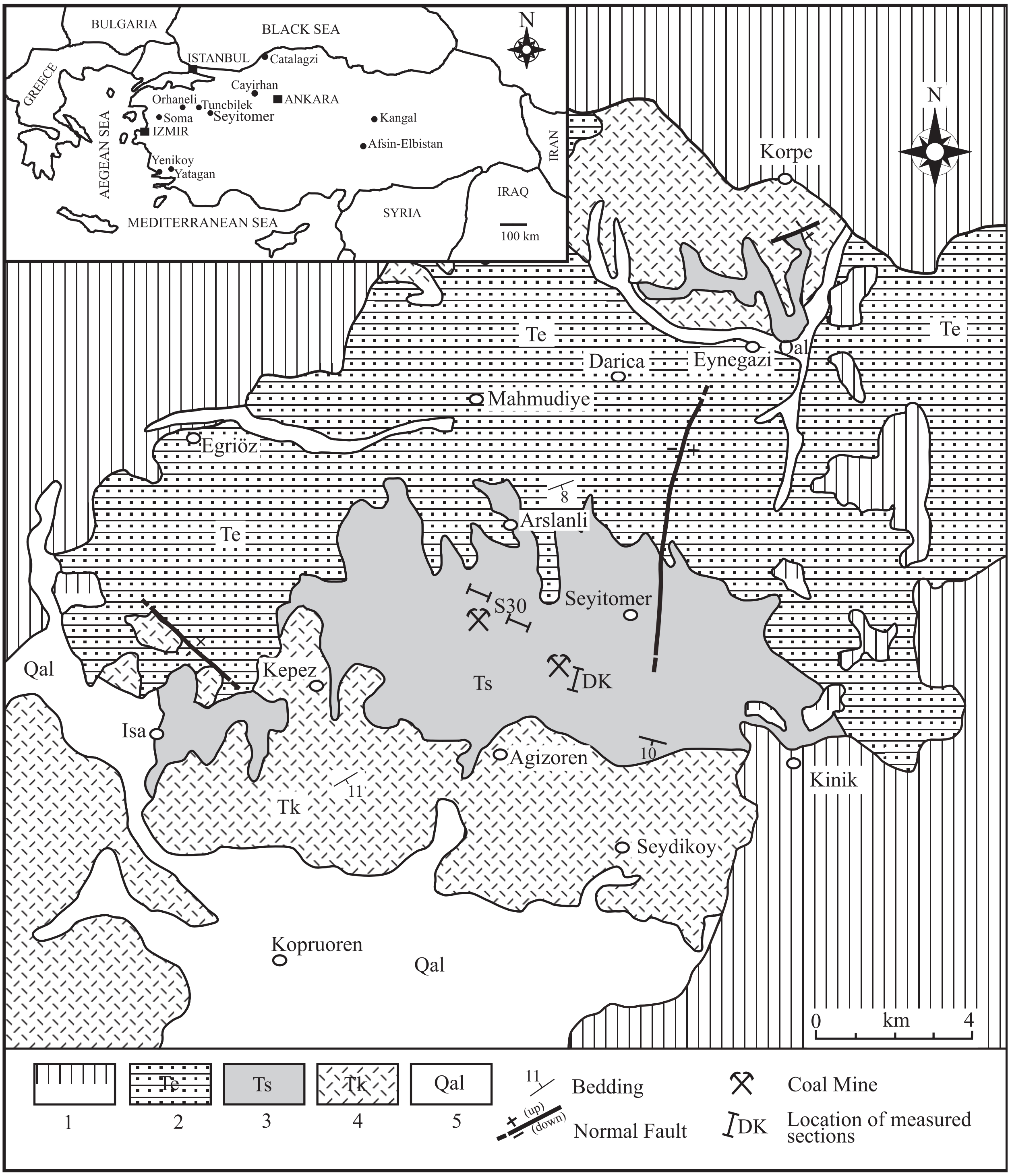

Figure 2. Location map showing some Turkish coal-fired power plants and simplified geological map of the Seyitomer Basin, which is modified from Bas (1986) and Celik (2002). Abbreviations: 1) Pre-Neogene basement rocks, 2) Egrioz F., 3) Coal-bearing Seyitomer F., 4) Kepez F., 5) Alluvium.

lignite are of dark brown color. After air-drying they become blackish brown-brown and develop abundant macroscopic desiccation cracks. The palynological studies suggest a Lower-Middle Miocene age for the coal-bearing Seyitomer Formation, and the coal forming was rich in subtropical forest taxa together with some riparian and hill-side forest elements (Yavuz, 2001). Celik (2002) indicated that maximum reflectance measurements of selected ten samples from the Seyitomer basin are between 0.25 and 0.33 % (0.29 %, avg.), which imply a lignite coal rank according to the ASTM classification given by Stach *et al.* (1982). These reflectance values are clearly lower than those of the Tuncbilek-Domanic coals with 0.42-0.51 % (0.46 %, avg. % R*random*), which indicate that the reflectance values of the Seyitomer lignites are quite different in rank from the Tuncbilek-Domanic coals.

The coal-bearing Seyitomer Formation in the basin has bedding dips between 5° and 15°. An important normal fault is developed within the Seyitomer Formation and Egrioz Formation.

3. Methodology

A total of 36 lignite samples and 6 claystones-tuffaceous claystones in this study were collected from the two locations, S30 and DK (Figure 2 and 3 for sample locations). Raw samples weighing about 1 to 2 kg were sampled. Lignite samples were crushed, blended, and split to obtain about 0.5 kg subsamples for analysis. Coal quality was carried out using proximate analysis, following the American Society for Testing and Material (1991) recommended guidelines. The minerals in the selected samples were identified using an X-ray diffraction (XRD) with CuKα radiation (5-40° 2Θ range). The clay fraction minerals of all the claystones for better identification of clay minerals on the XRD powder diffraction traces were identified using normal, saturated with ethylene glycol preparations and heated to 490 °C.

4. Results and discussion

In this section we describe and discuss the results of proximate analysis and mineralogy of the samples.

4.1. Proximate analysis

Table 1 summarises the results of the proximate analysis of the lower and upper seams on an as-received and air-dried basis at the three locations and means on this table for the lignite seams were calculated using the sample thickness. The samples show that the lower and upper seams at the three locations, on an as-received basis, average high moisture contents (36.3, 37.9 and 34.5 %), and relatively low calorific values (2564, 2895 and 3255 kcal/kg). The upper seam includes a relatively higher calorific value than the lower seams due to its relatively low ash yield. After air-drying in the laboratory, the lignite samples lose surface moisture and the values for the two coal seams decrease respectively to 13.1, 12.3 and 15.0 %, as would be expected. The samples on an air-dried basis average relatively high ash yields (26.4, 18.1 and 13.2%) due to thin dirt bands within the coal seam, high volatile matter (33.4, 37.3 and 38.9 %) and high total sulfur contents (2.15, 1.80 and 1.69 %). The total sulfur content in one sample reaches to 6.26 % (Table 1). The relatively higher total sulfur contents in the samples studied, as discussed by Karayigit and Celik (2003) for the Tuncbilek-Domanic coals, may be related to volcanic sulfur and/or accelerated microbial degradation in increased swamp water.

Vertical variations of moisture, ash, volatile matter and total sulfur contents within the two lignite seams at the three locations are depicted graphically in Figure 4, which show heterogeneity in vertical variation within the coal seams in general. However, vertical decreases in the moisture, volatile matter and total sulfur, from the top to the bottom of the two coal seams, have been recorded. The ash yield has the opposite tendency within the two

	DK-Lower Seam		S30-Lower Seam		S30-Upper Seam	
Analysis	(15 samples)		(16 samples)		(5 samples)	
	range	mean	range	mean	range	mean
As-received basis (as-rec)						
Moisture %	32.7-39.6	36,3	32.3-41.7	37,9	21.2-42.1	34,5
Calorific V kcal/kg	1385-2900	2564	2000-3300	2895	2875-4016	3255
Air-dried basis (adb)						
Moisture %	12.0-14.0	13,1	10.2-13.6	12,3	13.7-16.0	15,0
Volatile Matter %	22.6-36.7	33,4	30.0-41.0	37,3	37.8-40.6	38,9
Ash %	15.9-51.9	26,4	7.8-38.1	18,1	10.5-16.6	13,2
Fixed Carbon %	13.5-35.4	27,1	21.7-41.7	32,3	30.2-35.6	32,9
Total Sulfur %	0.94-3.87	2,15	0.74-6.26	1,80	1.25-2.48	1,69

Table 1. Range and mean values of proximate analysis results for the lower seam and upper seam at the three locations from the Seyitomer Basin.

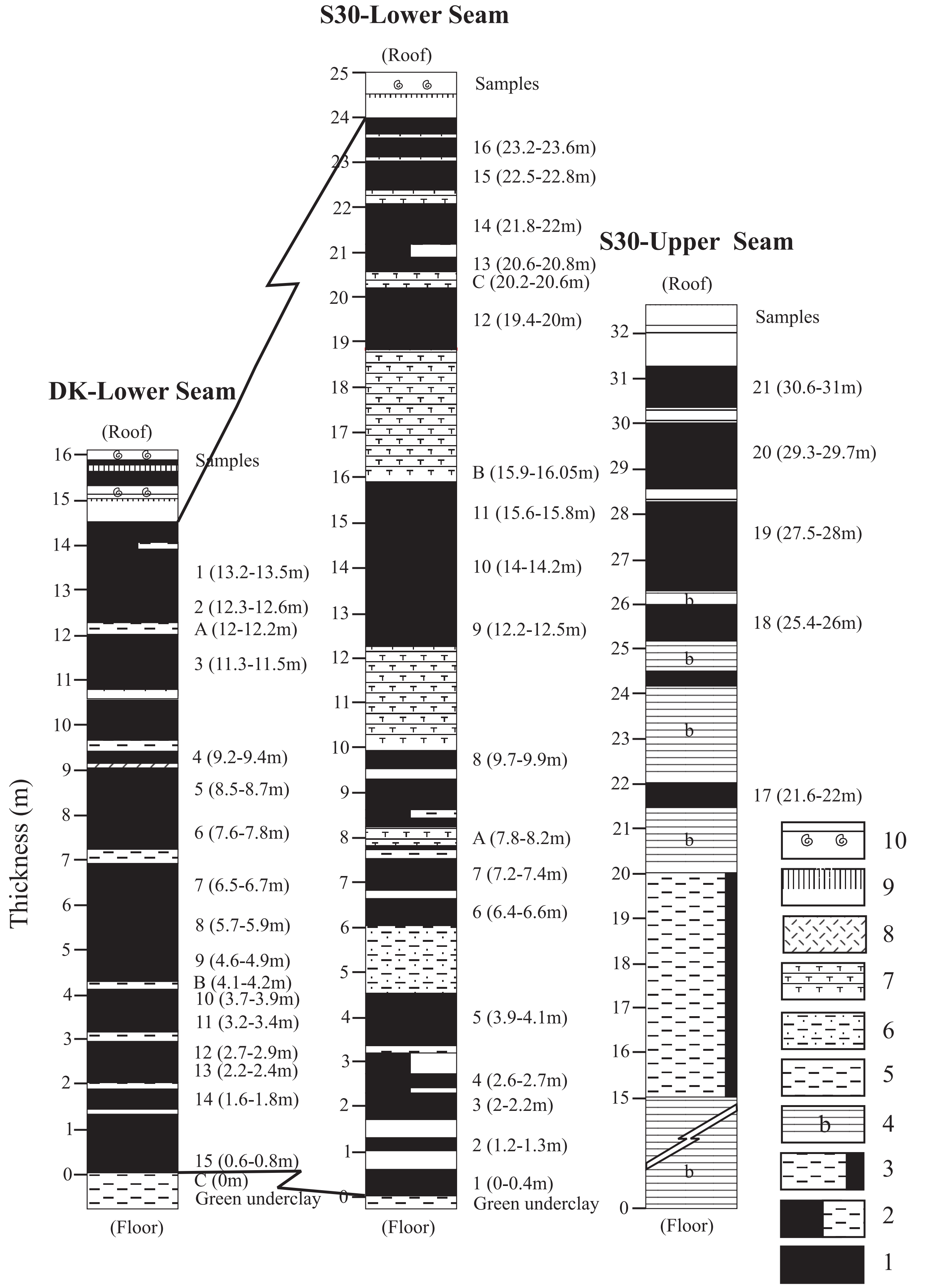

Figure 3. Macroscopical seam sections of the two seams at the three locations and sample locations from the Seyitomer Basin. Abbreviations: 1) lignite, 2) clayey lignite, 3) claystone with lignite, 4) bituminous marl, 5) claystone, 6) silty claystone, 7) tuffaceous claystone, 8) tuffite, 9) chert, 10) fossiliferous marl.

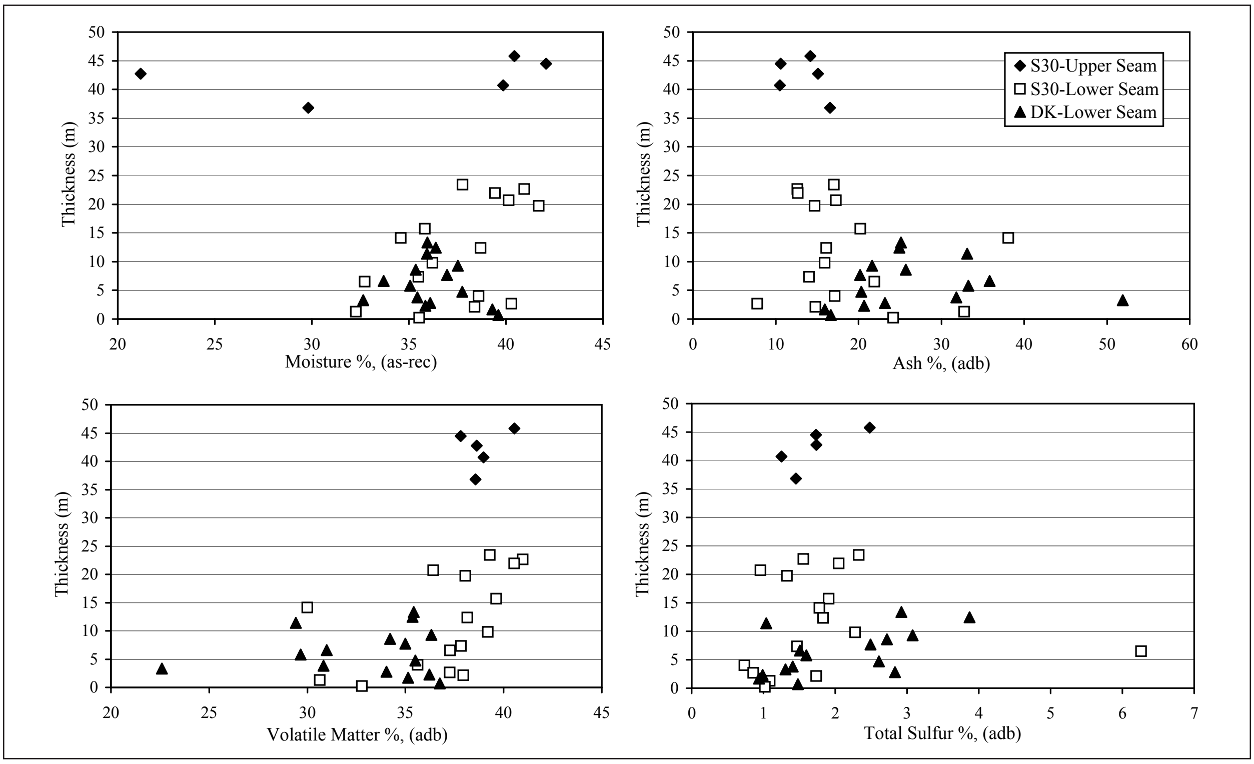

Figure 4. Vertical variations of moisture, ash, volatile matter and total sulfur contents within the two lignite seams at the three locations. Abbreviations: as-rec=as-received basis, adb=air-dried basis.

lignite seams. It is thought that some are mainly related to detrital input into peat forming lacustrine environment.

4.2. Mineralogy

The mineral matter of the whole-coal samples, as noted earlier, was identified by X-ray powder diffraction, and selected XRD traces are presented in Figure 5. The mineral matter of the lignite samples shows that the samples are mainly made up of clay minerals, quartz, feldspar and pyrite, minor/trace amounts of siderite, dolomite, calcite, opal-CT and gypsum. Similar minerals in the coals from the Tuncbilek-Domanic Basin were also identified (Karayigit and Celik, 2003). Tuffaceous claystones within the lower lignite seam includes smectite, illite, kaolinite, quartz and feldspar and trace amounts of chlorite; but smectite is much higher in the green claystones. Kaolinite is the most common non-detrital mineral, i.e. of diagenetic origin in coals. Smectite is generally rare in coals, although it often exists in the coals near intercalated tuff, roof tuff and tuffaceous shale seams (Kimura *et al.*, 1994). This suggests that the smectite was originally introduced to the peat as pyroclastic material, as referred Karayigit and Whateley (1997), Karayigit and Celik (2003). Quartz, feldspar and illite in the samples are thought that they are of detrital origin. Gypsum was probably derived from the secondary oxidation (weathering) of sulfides.

5. Conclusions

The Seyitomer basin contains the two seams, lower and upper, in the Lower-Middle Miocene lacustrine Seyitomer Formation. The lower seam in this basin is extensively exploited by open-cast methods and produced lignites are generally consumed in coal-fired power plants. This study implies that the two lignite seams include high moisture, volatile matter, ash and total sulfur and relatively low calorific values. The mineral matter of the selected lignite samples with X-ray powder diffraction shows that the samples are mainly made up of clay minerals, quartz, feldspar and pyrite, minor/trace amounts of siderite, dolomite, calcite, opal-CT and gypsum. These minerals identified are similar to the coals in the Tuncbilek-Domanic Basin. Tuffaceous claystones within the lower lignite seam includes smectite, illite, kaolinite, quartz and feldspar and trace amounts of chlorite; but smectite is much higher in the green claystones.

6. Acknowledgements

This work was supported by the Scientific Research Unit of Istanbul University under a project study (Project No.1535/16012001). The authors gratefully acknowledge Istanbul University for project support and Seyitomer Lignite Enterprise for logistic supports.

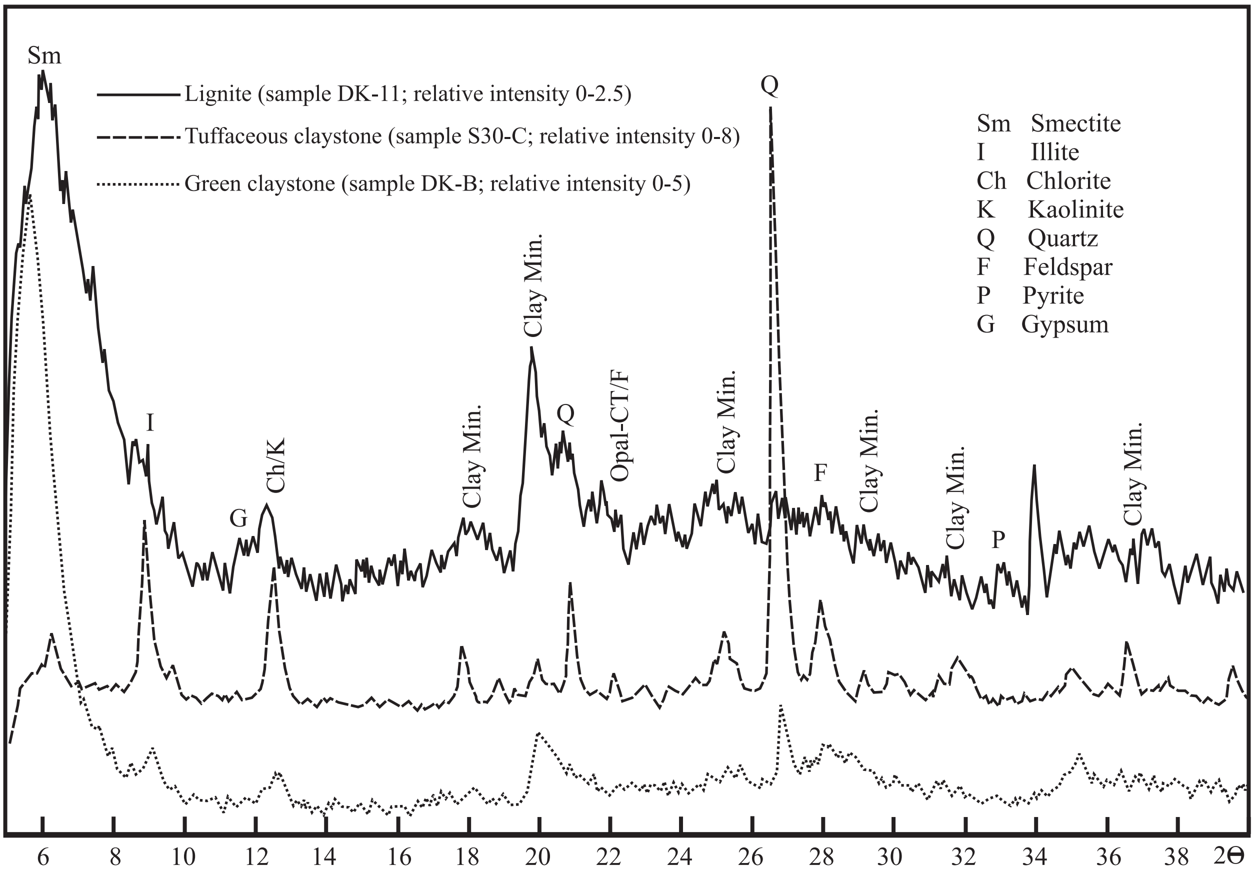

Figure 5. Selected X-ray powder diffraction traces of lignite, tuffaceous claystone and green claystone from the Seyitomer Basin.

7. References

AMERICAN SOCIETY FOR TESTING AND MATERIALS, 1991. Annual book of ASTM standards. Section 5: Petroleum Products, Lubricants, and Fossil Fuels. 5.05: Gaseous Fuels: Coal and Coke.

ALTAS, M., FIKRET, H. & CELEBI, E., 2000. 1998 Energy Statistics. 8th Energy Congress of Turkey, 8-12 May 2000, Ankara, (in Turkish).

BAS, H., 1986. Tertiary geology of the Domanic-Tavsanlı-Kutahya-Gediz Region. *Geological Engineering,* 27: 11-18, (in Turkish with English abstract).

CELIK, Y., 2002. Depositional environments of the Seyitomer (Kutahya) Basin, coal geology, coal potential and coal geochemistry. Scientific Research Unit of Istanbul University, Project No. 1535/16012001, (unpublished).

GOKMEN, V., MEMIKOGLU, O., DAGLI, M., OZ. D. & TUNCALI, E., 1993. Turkish Coal Inventory, MTA Publication-Ankara, (in Turkish).

KARAYIGIT, A.I. & WHATELEY, M.K.G., 1997. Properties of a lacustrine subbituminous (k1) seam, with special reference to the contact metamorphism, Soma-Turkey. *International Journal of Coal Geology,* 34: 131-155.

KARAYIGIT, A.I., GAYER, R.A. QUEROL, X. & ONACAK, T., 2000. Contents of major and trace elements in feed coals from Turkish coal-fired power plants. *International Journal of Coal Geology,* 44: 169-184.

KARAYIGIT, A.I. & CELIK, Y., 2003. Mineral matter and trace elements in the Miocene coals of the Tunçbilek-Domaniç Basin, Kutahya, Turkey. *Energy Sources*, 25: 339-357.

KIMURA, T., KAWASHIMA, H. & SAITO, I., 1994. Smectite and illite/smectite mixed-layer clay minerals in the Ashibetsu coals. *International Journal of Coal Geology,* 16: 215-231.

LEBKUCHNER, R.F., 1959. Report on geology of the Seyitomer-Kutahya Neogene Basin and investigations of lignite deposits. MTA Report No 2985, (in Turkish and unpublished).

SENGULER, I & SONEL, N., 1999. Stratigraphic features and economic importance of the Seyitomer (Kutahya) bituminous marls. Proceedings of the 52nd Geological Congress of Turkey, 10-12 May 1999, Ankara.

STACH, E., MACKOWSKY, M.-Th., TEICHMULLER, M., TAYLOR, G.H., CHANDRA, D. & TEICHMULLER, R., 1982. Coal Petrology, Gebruder Borntraeger, Berlin.

YAVUZ, N., 2001. Palynological investigation of the Seyitomer coals. Fourth International Turkish Geology Symposium, Adana. Abstracts, pp 253.

Manuscript received on 17.10.2002 and accepted for publication on 16.10.2003.