Petrographical and Chemical Properties of Mus Coals

Orhan Kavak 1

1 Dicle University, Faculty of Engineering Department of Mining Engineering, Division of General Geology Diyarbakir, Turkey

kavakorhan@gmail.com

Abstract One of the most important natural energy resources of our country stands to be as coal; our reserve with the newly discovered bed exceeds more than 14 billion tons. Although the higher quality coals are located at the western and inner part of Anatolia, there are some coal beds in the eastern Anatolia as well. The coals near Muş city are one of them. The coals are Tertiary (Pliocene) aged coals. Petrographical and chemical properties, as moisture, volatile matter, fixed carbon, ash content of the coals were determined in this study. The coals are of many thin layers and of a total thickness varying between 0.9-3.6 meters. The original coals contain of an average lower calorific value about 1200 Kcal/kg. Their ash content changes between 17-30 %, moisture with 30% average. The coals exhibit higher moisture content which is thought to be derived from high ground water level and of surfical water inputs. The dominant maceral of the coals is huminite, changing between 28 to 61 % amount. Gelinite is the most common huminites. Liptinite content changes between 2-5% and inertinite, between 2-11 %. The huminite reflectance (Ro) were measured as changing between 0.10 - 0.29 % (standard deviation as 0.01 - 0.02%) and corresponds to lignite rank. The low reflectance values are probably resulted from their shallow burials and their being remote to tectonic activities in the region. The coals comprise of 3-6% pyrite and 14-62 clay and other inorganic materials. Muş coals were classified as poor quality lignite, based on organic petrography, coal quality data and their low maturity index. Detail coal petrographical analysis seems to indicate depositional environment of the coals to be as limnic swamps. Total reserve of the coals is about 6.2 million metric tons.

1. Introduction
The study area covers a vast area of Muş City, located in the eastern region of Anatolia. The lignite occurrences which known for long periods and nowadays counted as uneconomical in the East Anatolia, cannot be correlated with each other. In this study, petrographical properties of the Muş Pliocene aged lignite situated in Zırnak Formation were tried to be revealed. To enlighten further studies for exploring the economic lignite occurrences, field work and collection of the samples were made by our team and there is an aid of S.Toprak for petrographical observations. There has been studies by Mercier [1], Durrich [2], İlker [3], Lebküchner [4,5], Elnaif [6], Staesche [7], Şaroğlu [8], Akay and others, [9], Şengüler and Toprak [10], in the region.

2. Stratigraphy
A sedimentary unit, deposited in Upper Cretaceous-Pleistocene time interval, covers the basic rocks of the region which are Paleozoic aged metamorphites and Cretaceous aged ophiolites. Undistinguished Tertiary deposits (Paleocene-Middle Eocene aged Toraman Formation, Upper Eocene aged Ahlat
Formation, and Oligocene aged Yazla Formation) lie on the basic rocks in the region. There are the Lower Miocene aged Adilcevaz Formation (laterally passing to Aktuzla Formation at North), Upper Miocene aged Alibonca Formation in the vicinity of Horasan and Zırnak Formation which vertically and horizontally passes to Upper Pliocene aged Solhan volcanites, in the whole region, over the Tertiary deposits. The Upper Pliocene-Pleistocene aged Bulanık Formation cover the whole units unconformable.

In the Upper Miocene-Quaternary time interval, the volcanism continued to exhibit its activity in the Eastern Anatolia, with intercalated deposition with sediments, occasionally as interfingered, sometimes as covering the vast areas. In the region, the Lower Pliocene-Upper Pliocene aged coal bearing Zırnak Formation lays uncomfortably on the Upper Miocene aged Alibonca Formation which includes occasional basalt flow deposits. The Upper Pliocene-Pleistocene aged Bulanık Formation which overlies Zırnak Formation uncomfortably also comprises of some occasional lignite levels and peat occurrences alternated with conglomerate, sandstone and tuffite sequences.

Zırnak formation starts with conglomerate and coarse sandstone succession at its base and passes to lignite seam bearing sandstone, marl, claystone, siltstone succession at the upper levels. There is occasional limnic eolithic limestone levels outcrops at the upper parts of the unit. The volcanic rocks found at different levels of the succession are basalt, tuff and agglomerates [10].

Seven lignite seams outcropped in the Muş region are situated within a deposit of the marl, claystone and siltstone succession. During the drillings taken place in the years between 1972 and 1976, lignite levels changing between 0.05 to 3.50m. were cut [11].

The age of the unit was determined by Akay and others [9] as Lower Pliocene-Upper Pliocene.

3. Results and discussions

Pellet samples were produced from the lignite samples of Zırnak Formation which were taken as with channel sampling form the outcrops. Special coal microscope working with reflected and fluorescence lights were used to determine reflectance values and maceral contents of the coals. Oil objective with 32x were used. The nomenclatures and classifications of the ICCP (The International Committee for Coal Petrology) were used for maceral analysis. The maceral analysis revealed the nature of the coals and implied possible depositional environments of the lignite.

The coals are of many thin layers and of a total thickness varying between 0.9-3.6 meters. The original coals contain of an average lower calorific value about 1200 Kcal/kg. Their ash content changes between 17-30 %, moisture with 30% average. The coals exhibit higher moisture content which is thought to be derived from high ground water level and of surfical water inputs.

The dominant maceral of the coals is huminite, changing between 28 to 61 % amount. Gelinite is the most common huminites. Liptinite content changes between 2-5% and inertinite, between 2-11 %. The huminite reflectance (Ro) were measured as changing between 0.10 - 0.29 % (standard deviation as 0.01 - 0.02%) and corresponds to lignite rank (Table 1, Table 2).

The coals comprise of 3-6% pyrite and 14-62 clay and other inorganic materials. The coalification degree of the coals in the region was found to be lignite and their huminite reflection values (Ro, %) are less than 0.3. Maceral contents of the coals are the organic ingredients of coals which are grouped as huminite, liptinite and inertinites Figure 1 and 2, [12].
Figure 1. Particulate coal ingredients [Huminite (gray zones), Pyrites (shiny white ones), Clays (dark zones)].

Figure 2. Complex ingredients of Muş coals [Densinite and Attrinites (particulated gray color ones), Funginites (white coloured circular fossil like structures), pyrites (shiny white ones)].
All maceral analysis of the coals is exhibited on the Table 1. In petrographic analysis, iron containing minerals such as pyrites, clay-silicate minerals as well as inertinite and liptinite ratios of the coals are considerably high.

Table 1. Maceral analysis values (as %) of Mus coal samples

| Sample | HÜMINITE | LIPTINITE | INERTINITE | PYRITE | INOR (Cl+Qz+Ca) |
|--------|----------|-----------|------------|--------|-----------------|
|        | HTEL     | DHUM      | HCOL       | TOT HUM|                 |
|        | Tx       | At        | Dn         | Gel    | Cr              |
|        | Sp       | Al        | Ct         | Ld     | TOT LIP         |
|        | Fs       | Ma        | Fn         | Id     | TOP INER        |
|        | Fr       | Eu        | TOT PYR    |        |                 |
| 1      | 2        | 4         | 4          | 14     | 43              | 3 0 0 0 1 4 5 2 0 4 11 5 1 6 36 |
| 2      | 6        | 7         | 7          | 12     | 16              | 2 1 0 0 3 5 1 1 3 10 4 1 5 37 |
| 3      | 8        | 9         | 5          | 16     | 18              | 2 0 0 0 3 5 1 0 1 7 4 0 4 28 |
| 4      | 11       | 12        | 2          | 10     | 16              | 2 0 0 0 1 3 5 0 0 2 7 5 1 6 32 |
| 5      | 11       | 13        | 2          | 11     | 12              | 3 0 0 0 0 3 5 2 0 1 8 5 0 5 35 |
| 6      | 7        | 10        | 5          | 10     | 18              | 2 0 1 1 4 4 2 0 2 8 3 1 4 33 |
| 7      | 6        | 8         | 2          | 7      | 19              | 2 1 0 0 3 3 2 0 2 7 4 1 5 41 |
| 8      | 6        | 9         | 3          | 12     | 28              | 2 2 0 1 5 4 3 1 3 11 4 0 4 19 |
| 9      | 2        | 3         | 0          | 3      | 20              | 1 1 0 0 2 3 0 0 1 4 4 0 4 62 |
| 10     | 1        | 2         | 0          | 2      | 26              | 1 1 0 0 2 1 1 0 0 2 5 0 5 60 |
| 11     | 5        | 9         | 3          | 10     | 14              | 2 1 0 0 3 2 3 0 0 5 3 0 3 48 |
| 12     | 4        | 10        | 3          | 10     | 15              | 2 1 2 0 5 3 2 0 1 6 3 1 4 43 |
| 13     | 4        | 11        | 3          | 11     | 13              | 2 2 1 0 5 3 2 1 1 7 5 1 6 40 |
| 14     | 4        | 12        | 4          | 11     | 15              | 2 1 1 1 5 3 3 1 1 8 5 1 6 34 |

Table 2. Reflection values of Mus coal samples and their corresponding ranks

| Sample | Rmax % | Ro (%) | Standart Variations (%) | Coalification Degree |
|--------|--------|--------|--------------------------|----------------------|
| 1      | 0.290  | 0.224  | 0.01                     | Lignite               |
| 2      | 0.136  | 0.124  | 0.013                    | Lignite               |
| 3      | 0.21   | 0.194  | 0.015                    | Lignite               |
| 4      | 0.196  | 0.172  | 0.012                    | Lignite               |
| 5      | 0.105  | 0.102  | 0.016                    | Lignite               |
| 6      | 0.209  | 0.173  | 0.014                    | Lignite               |
| 7      | 0.158  | 0.152  | 0.012                    | Lignite               |
| 8      | 0.187  | 0.159  | 0.01                     | Lignite               |
| 9      | 0.104  | 0.092  | 0.011                    | Lignite               |
| 10     | 0.293  | 0.180  | 0.014                    | Lignite               |
| 11     | 0.109  | 0.096  | 0.009                    | Lignite               |
| 12     | 0.176  | 0.110  | 0.010                    | Lignite               |
| 13     | 0.124  | 0.102  | 0.011                    | Lignite               |
| 14     | 0.130  | 0.107  | 0.012                    | Lignite               |
When the maceral contents of the coals are considered, they exhibit high amount of various macerals as a result of fluctuation of the lake water levels during deposition. As the lake water level decreased, the coal forming plant material were probably oxidized to form inertinites and as the coal forming material were submerged, high amount of huminite were formed. The liptinite population was probably increased when the lake has water inputs and pH values of the lake increased. The low reflectance values were probably resulted from their shallow burials and their being remote to tectonic activities in the region.

In some cases, inorganic contents; e.g. clay and silicate contents of the coals become higher while the maceral contents decreased implying much inorganic influx or contributions of the associated rocks during deposition. The sudden change of the maceral content also has an implication of sediment influx as well. In addition to this, based on the low content of the liptinites, it can be estimated that a terrestrial swampy environment took place to form the coals [13]. High amount of liptinites indicate open moor depositions [14].

When compared the coal petrographical properties of the coals with the coals located in the vicinity of the area, Muş lignites do not exhibit much differences (Table 1). Generally, the clay-silicate mineral ratios of Bulanık-Elmakaya, Malazgirt-Nurettin, and Muş-Ziyaret and Varto-Kayadelen lignites are considerably higher. Based on these, it can be estimated that erosion probably took a place in the region during the coal formation period and possible detrital sediment inputs, therefore, became considerably higher [10]. Inorganic content of the lignite and their chemical analysis imply that the coals seem to have poor qualities. The coals are advised to be used in power plants.

Plant remnants may easily be observed on the coals as crushed into small pieces. The particulate forms of the ingredients and the high content of inorganics also indicate that these coals may have been transported [14]. Mixture of various macerals and high huminite ratios also imply that they were probably products of swamps at a lake margin [10].

4. Conclusions
When the maceral content of the coal is considered and put on an environment indicating diagram, the coals exhibit to be formed in a limnic environment and most of them have dull as well as semi-dull properties.

The coals have abundant of huminite maceral group and dominancy of gelinite macerals. The coals have considerably high ratio of the other macerals as well. It indicates the coals were deposited in tertiary coal forming swamps. But the inorganic content, resultantly ash contents as they are burned, of the coals are high which cause them to be of poor qualities. It is estimated that the formation of the coal levels at the top have developed after the transgression took place with increase of the water level in the region. Aside from Zırnak hill, the other coals were probably formed in limnetic region and open moor environments [13]. As a result; although there is not much differences of petrographical properties of Muş lignites, compared with the other coals in the region, the coal forming environment of Muş coals seem to be different when high huminite content and clay-silicate content of the coals are considered. Muş lignite was dominantly formed in terrestrial moor environments but the others deposited in open moors [13].

Acknowledgments
The author is thankful to Assoc. Prof. Ph.D. Selami Toprak, General Directorate of Mineral Research and Exploration of Turkey | MTA and Mehmet TUNÇ to help the sampling.

References

[1] J. Mercier, “Malazgirt-Bulanık bölgesinde jeolojik gözlemler”: TJK Bülteni, Cilt 2, Sayı 1, 1949.
[2] A. Durrich, “Malazgirt, Bulanık, Ahlat bölgesinin linyit etüdü”: MTA Rap. No. 6098, 1967, yayımlanmamış.
[3] S. İlker, “Erzurum-Muş Bölgesinde Karaköse J 48 a4, d1 paftalarının 1: 25000 ölçekli detay petrol etüdü”, MTA Rap., No : 4177, 1967, yayımlanmamış.
[4] R.F. Lebküchner, “Erzurum vilayeti, Hınıs kazası, Zırnak civarında bir linyit zuhurunun prospeksiyonu1 : MTA Rap., No. 3990, 1967, yayımlanmamış.
[5] R.F. Lebküchner, R.F, “Erzurum, Bitlis ve Muş vilayetlerine ait linyit prospeksiyonu” : MTA Rap., No. 4002, 1968, yayımlanmamış.
[6] S. Elnaif, S, “Muş kuzey sahasının petrol etüdü raporu” : MTA Rap., No. 4286,1969, yayımlanmamış.
[7] U. Staesche, U, “Hınıs-Ağrı-Malazgirt bölgesinin linyit etüdü”: Lignite survey of the Hınıs-Ağrı-Malazgirt region, MTA Rap., No. 6382, 1969, yayımlanmamış.
[8] F. Şaroğlu, 1985, Doğu Anadolu’nun neotektonik döneminde jeolojik ve yapısal evrimi: Geological and structural evolution of Eastern Anatolia during the neotectonic period Doctoral thesis, İ.Ü. Fen Bil. Ens. Jeo. Müh. Ana Bilim Dalı, İstanbul.
[9] E. Akay, E. Erkan, E. Ünay, E, “Muş Tersiyer Havzasının Stratigrafisi”: MTA Derg. No. 109, 1989”.
[10] I, Senguler, S.Toprak, “Varto, Hınıs, Bulanık, Malazgirt yöresi linyitlerinin petrografik özellikleri”, Türkiye Jeoloji Bülteni, C. 34, 15-22, Ağustos, 1991.
[11] B.Selvi, “Erzurum-Hınıs-Zırnak kömür havzasının raporu”: MTA Rap., No. 6379, 1977, yayımlanmamış.
[12] E. Nakoman, “Kömür “: MTA Enstitüsü Yayınlarından, Eğitim Serisi, No: 8, Ankara.1971
[13] S. Toprak, “Kozlu kömürlerinin petrografik özellikleri”: Petrographic properties of Kozlu coals “ Master thesis, Pittsburgh University, USA.1985.
[14] E.Stach, M. Mackowsky, M.Teichmüller, G.H. Taylor, D. Chandra, R. Teichmüller R,
[15] “Stach’s textbook of coal petrology”: Gebrüder Borntraeger Berlin, Stuttgart,1982.