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# GEOCHEMICAL ANALYSES OF 12 HUNGARIAN COAL SAMPLES

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Twelve channel samples of coal collected from coal beds in Hungary were analyzed in the U.S. Geological Survey laboratories. The coal beds are Jurassic (Lias) and Tertiary age and are of lignite to bituminous rank. Unusually high sulfur contents and high organic sulfur concentrations characterize the coal from beds that are of Eocene and Miocene age. The coal and coal ash from coal beds of Lias (Jurassic) age are high in many trace elements. These geochemical data suggest a need for additional coal-quality data to resolve environmental concerns when coal from these coal beds are burned in power plants.

**Keywords: geochemistry, coal, environment protection, ultimate analysis, proximate analysis**

## 1. Introduction

The geochemistry of Hungarian coal was investigated under a cooperative agreement between the United States Geological Survey (USGS) and the Hungarian Central Office of Geology. The objectives of this study were: the interlaboratory comparisons of analytical data, increasing geochemical knowledge about Hungarian coal beds, and supplementing the USGS coal data base on world coal quality. Initially, twelve channel samples were sent to the USGS for a variety of analyses as shown in *Fig. 1.* Six additional samples were received by the USGS and are currently being analyzed. This paper reports on the analytical data for the chemical components and physical properties of the first 12 coal samples.

## 2. Description of coal samples

The location and a partial description of the coal samples are given in *Table I.* The coal beds sampled are Jurassic (Lias) and Tertiary in age and are lignite to bituminous rank. The older coal beds (Jurassic) are bituminous rank; the higher rank of these coal beds is caused in part by the thermal effects produced by intrusions of ultrabasic magmas into the underlying strata during Early Cretaceous time and in part by folding and faulting during Cretaceous time.

The coal samples can be grouped into four chronostratigraphic units. Samples H–11 and H–12 (Table I) are from the Mecsek coal basin in the

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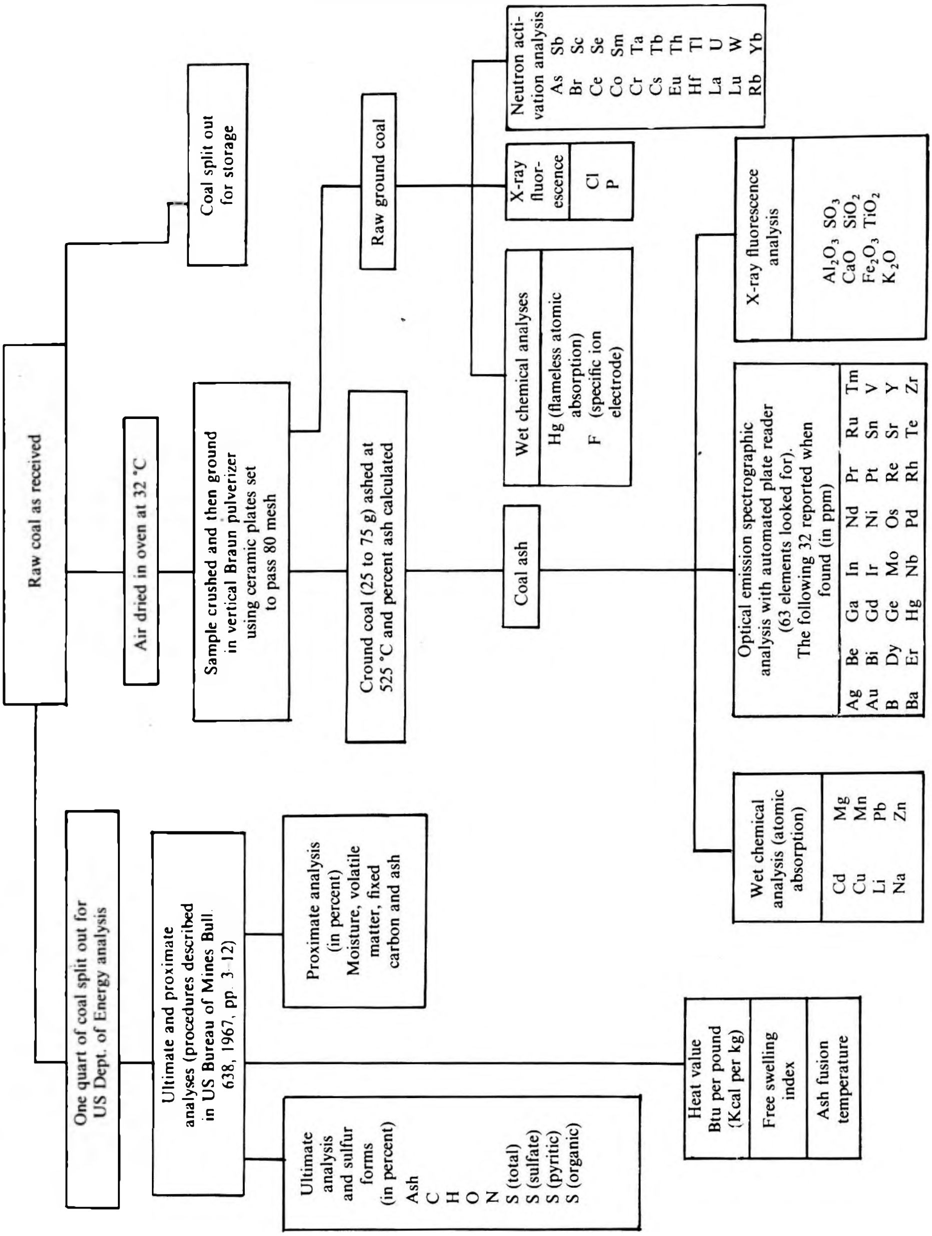



*Fig. 1.* Analytical procedures performed by USGS on Hungarian coal samples

| Hungarian sample No. | USGS sample No. | County | Latitude (N) | Longitude (E) | Coal bed | Age | Rank | Sampled thickness (cm) |
|---|---|---|---|---|---|---|---|---|
| H-10 | W218560 | Komárom | 474500 | 184110 | Újebszőny | Eocene | Subbituminous | 350.0 |
| H-11 | W218561 | Baranya | 460800 | 181700 | Mecsek | Jurassic | Bituminous | 400.0 |
| H-12 | W218562 | Baranya | 460700 | 181800 | Mecsek | Jurassic | Bituminous | 800.0 |
| H-13 | W218563 | Nógrád | 480200 | 195100 | Mákvölgy | Miocene | Subbituminous | 200.0 |
| H-14 | W218564 | Heves | 475020 | 200200 | Visonta | Pliocene | Lignite | 1,000.0 |
| H-15 | W218565 | Heves | 475100 | 200300 | Visonta | Pliocene | Lignite | 1,000.0 |
| H-16 | W218566 | Borsod | 481800 | 202600 | Putnok | Miocene | Subbituminous | 370.0 |
| H-17 | W218567 | Komárom | 474000 | 181100 | Lencsehegy | Eocene | Subbituminous | 400.0 |
| H-18 | W218568 | Nógrád | 480400 | 195000 | Szorospatak | Miocene | Subbituminous | 250.0 |
| H-19 | W218569 | Komárom | 474500 | 184400 | Dorog | Eocene | Subbituminous | 300.0 |
| H-20 | W218570 | Komárom | 473500 | 182200 | Tatabánya | Eocene | Subbituminous | 400.0 |
| H-21 | W218571 | Fejér | 473200 | 181750 | Oroszlány | Eocene | Subbituminous | 250.0 |

*Table I.* Descriptions for 12 channel samples of coal from Hungary

*I. táblázat.* 12 db magyarországi szén résminta leírása

*Таблица I.* Описание 12 венгерских бороздовых проб southern part of the Transdanubian Region. These bituminous coal beds are of Jurassic age and are from the oldest industrial black-coal field in Hungary. The mined coal beds, in underground mines that extend to about 700 meters below the surface, range in thickness from less than 2 meters to 15 meters. The coal from the Mecsek coal basin generally has a high ash content and heating value. The coal beds and enclosing strata were folded and faulted by tectonic activity during Cretaceous time.

The second group samples (H–10, H–17, H–19, H–20 and H–21) are from brown coal (subbituminous) deposits of Eocene age. These deposits are in the central Transdanubian Region of Hungary. The thickness of the mineable coal beds ranges from 2 to 8 meters and the coal is recovered by underground mining techniques. Faulting and erosional features affect the mining/extraction process. The coal beds in this group have ash contents and heating values that range from low to high.

The third group of samples (H–13, H–16 and H–18) are from brown coal deposits of Miocene age. These deposits are located in the north and northeastern part of Hungary and generally consist of 3 to 4 thin coal beds. The coal beds are mined by underground methods and are located 50 to 200 meters below the surface. Coal beds included in this group have low heat values and high ash content.

The fourth group of samples (H–14 and H–15) are from lignite deposits of Pliocene age. These deposits are located in the northern part of the Hungarian lowland region. The coal is recovered by open-pit operation. The thickness of the coal beds ranges from 5 to 50 meters and locally the beds are covered by surficial material as much as 220 meters in thickness. Tectonic effects are not evident in these coal beds. Lignites from these deposits have very low heat values and a very high moisture content. Coal resources in these deposits are believed to be extensive.

## 3. Discussion of the analytical results

The analytical procedures performed on the coal and coal ash are shown in Fig. 1. Data on individual samples are listed in the tables. Interpretations described in this discussion are tentative because of the small number of samples. *Table II* gives the data on proximate, ultimate, and other analyses which are used to classify coal. Where there are two values given, the numbers on the left are values obtained by Hungarian laboratories for the Hungarian Geological Survey. *Table III* is a comparison of the average values of the data in Table II obtained by USGS laboratories with those obtained by the Hungarian laboratories. In both tables, the largest analytical differences are found in the moisture loss (by air-drying) and organic sulfur determinations. The smallest average percentage differences are found in the total sulfur, ash, moisture- and ash-free heat value, and moisture- and ash-free volatile matter and fixed-carbon determinations. For individual samples, there are large differences for ash and

| | | Eocene H-10 | | Lias H-11 | | Lias H-12 | | Miocene H-13 | | Pliocene H-14 | | Pliocene H-15 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ash | (R) | 34.9 | 36.1 | 23.0 | 15.5 | 12.2 | 13.6 | 15.9 | 6.6 | 9.4 | 16.3 | 9.4 | 11.7 |
| | (MF) | | 40.2 | | 15.9 | | 13.8 | | 8.6 | | 23.0 | | 15.3 |
| | (MAF) | | | | | | | | | | | | |
| Moisture | (R) | 13.0 | 10.3 | | 2.3 | | 1.4 | 29.8 | 23.5 | 51.4 | 44.5 | 51.0 | 49.2 |
| | (MF) | | | | | | | | | | | | |
| | (MAF) | | | | | | | | | | | | |
| Organic sulfur | (R) | 3.4 | 2.65 | | 0.95 | 2.78 | 1.08 | | 2.42 | | 0.75 | | 0.75 |
| | (MF) | | 2.96 | | 0.97 | | 1.10 | | 3.16 | | 1.35 | | 1.48 |
| | (MAF) | | 4.94 | | 1.16 | | 1.27 | | 3.46 | | 1.91 | | 1.92 |
| Total sulfur | (R) | | 7.3 | | 2.2 | 3.14 | 2.1 | 3.2 | 3.2 | | 1.2 | | 0.9 |
| | (MF) | | 8.2 | | 2.2 | | 2.2 | | 4.1 | | 2.2 | | 1.7 |
| | (MAF) | | 13.7 | | 2.6 | | 2.5 | | 4.5 | | 3.1 | | 2.2 |
| Heat value (Kcal/kg) | (R) | 3,251 | 3,330 | 5,728 | 6,730 | 6,768 | 7,150 | 3,206 | 4,720 | 2,062 | 2,490 | 2,010 | 2,470 |
| | (MF) | 3,479 | 3,710 | | 6,880 | | 7,250 | | 6,170 | | 4,480 | | 4,860 |
| | (MAF) | 6,671 | 6,210 | | 8,190 | | 8,410 | | 6,750 | | 6,330 | | 6,310 |
| Air-dried loss | (R) | 10.5 | 5.0 | | 1.1 | | 0.5 | | 18.2 | | 37.1 | | 42.5 |
| | (MF) | | | | | | | | | | | | |
| | (MAF) | | | | | | | | | | | | |
| Volatile matter | (R) | | 27.5 | | 29.3 | | 27.5 | 27.3 | 34.7 | | 23.6 | | 22.8 |
| | (MF) | 27.8 | 30.7 | | 29.9 | | 27.9 | | 45.3 | | 42.6 | | 44.9 |
| | (MAF) | | 51.4 | 33.0 | 35.6 | 31.4 | 32.4 | | 49.6 | | 60.2 | | 58.3 |
| Fixed carbon | (R) | | 26.0 | | 53.0 | | 57.5 | 27.0 | 35.2 | | 15.6 | | 16.3 |
| | (MF) | 24.3 | 29.1 | | 54.2 | | 58.3 | | 46.0 | | 28.2 | | 32.1 |
| | (MAF) | | 48.6 | | 64.4 | | 67.6 | | 50.4 | | 39.8 | | 41.7 |

| | | Miocene H-16 | | Eocene H-17 | | Miocene H-18 | | Eocene H-19 | | Eocene H-20 | | Eocene H-21 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ash | (R) | 20.0 | 11.4 | 9.5 | 26.0 | 37.0 | 22.4 | 5.7 | 17.8 | 7.9 | 5.3 | 14.5 | 9.2 |
| | (MF) | | 15.3 | | 28.7 | | 25.3 | | 19.7 | | 6.0 | | 11.3 |
| | (MAF) | | | | | | | | | | | | |
| Moisture | (R) | | 25.6 | 15.0 | 9.5 | 13.3 | 11.6 | 15.0 | 9.7 | 13.7 | 12.1 | 19.5 | 18.9 |
| | (MF) | | | | | | | | | | | | |
| | (MAF) | | | | | | | | | | | | |
| Organic sulfur | (R) | | 2.58 | | 5.91 | | 0.33 | 4.7 | 3.36 | | 2.28 | | 2.97 |
| | (MF) | | 3.47 | | 6.53 | | 0.37 | | 3.72 | | 2.59 | | 3.66 |
| | (MAF) | | 4.09 | | 9.16 | | 0.50 | | 4.63 | | 2.76 | | 4.13 |
| Total sulfur | (R) | 2.0 | 3.0 | 7.0 | 7.3 | | 0.4 | | 8.1 | | 2.5 | | 3.0 |
| | (MF) | | 4.0 | | 8.0 | | 0.4 | | 9.0 | | 2.9 | | 3.7 |
| | (MAF) | | 4.7 | | 11.3 | 0.7 | 0.6 | | 11.2 | 4.6 | 3.1 | | 4.2 |
| Heat value (Kcal/kg) | (R) | 3,246 | 4,110 | 5,112 | 4,480 | 3,198 | 4,710 | 5,459 | 5,040 | 5,398 | 6,720 | 4,377 | 5,110 |
| | (MF) | | 5,530 | | 4,950 | 3,424 | 5,330 | | 5,580 | 5,709 | 7,130 | | 6,310 |
| | (MAF) | | 6,530 | | 6,940 | 6,888 | 7,130 | | 6,950 | 7,280 | 7,580 | | 7,110 |
| Air-dried loss | (R) | | 16.9 | | 5.1 | | 6.5 | | 5.9 | | 5.3 | | 8.9 |
| | (MF) | | | | | | | | | | | | |
| | (MAF) | | | | | | | | | | | | |
| Volatile matter | (R) | | 33.0 | 35.8 | 36.6 | 22.9 | 26.1 | 37.8 | 35.0 | | 47.5 | | 40.6 |
| | (MF) | | 44.3 | | 40.4 | | 29.6 | | 38.8 | | 54.0 | | 50.0 |
| | (MAF) | | 52.3 | | 56.7 | | 39.6 | | 48.3 | | 57.4 | | 56.4 |
| Fixed carbon | (R) | | 30.1 | 39.7 | 27.9 | 26.8 | 39.9 | 41.5 | 37.5 | | 35.2 | | 31.4 |
| | (MF) | | 40.4 | | 30.9 | | 45.1 | | 41.5 | 37.2 | 40.0 | | 38.7 |
| | (MAF) | | 47.7 | | 43.3 | | 60.4 | | 51.7 | | 42.6 | | 43.6 |

*Table II.* Classification data for 12 Hungarian coal samples (*R*, as received; *MF*, moisture free; *MAF*, moisture and ash free)

*II. táblázat.* 12 db magyarországi szénminta technológiai jellemzői (*R* = nyersszén; *MF* = száraz szén; *MAF* = száraz, hamumentes szén)

*Таблица II.* Технологические характеристики 12 венгерских угольных проб (*R* = сырой уголь, *MF* = обезвоженный уголь, *MAF* = обезвоженно-беззольный уголь)

| Determination (content) | HGS | USGS | Difference % |
|---|---|---|---|
| Ash (R) | 16.6 | 16.0 | 3.7 |
| Moisture (R) | 24.6 | 21.0 | 17.1 |
| Organic sulfur (R) | 3.6 | 2.4 | 50.0 |
| Total sulfur (R) | 3.8 | 3.9 | 2.6 |
| Heat value (R) | 4,151 | 4,718 | 12.0 |
| (MF) | 4,204 | 5,390 | 22.0 |
| (MAF) | 6,949 | 6,973 | 0.3 |
| Air-dried loss | 10.5 | 5.0 | 110.0 |
| Volatile matter (R) | 31.0 | 33.1 | 6.3 |
| (MF) | 27.8 | 30.7 | 9.5 |
| (MAF) | 32.2 | 34.0 | 5.3 |
| Fixed carbon (R) | 33.8 | 35.1 | 3.7 |
| (MF) | 37.2 | 40.0 | 7.0 |
| (MAF) | 44.6 | 47.6 | 6.3 |

*Table III.* Comparison of USGS and Hungarian Geological Survey data for 12 samples of Hungarian coal. Heat value in Kcal/kg, all other data in percent; *R*, as received; *MF*, moisture-free; *MAF*, moisture- and ash-free

*III. táblázat.* 12 db magyarországi szénmintán a USGS-ben és a MÁFI-ban végzett összehasonlító elemzéseinek eredményei. Fűtőérték Kcal/kg-ban, egyéb adatok százalékos formában;*R* = nyersszén; *MF* = száraz szén; *MAF* = száraz, hamumentes szén

*Таблица III.* Результаты сравнительных анализов, выполненных в ГСА и ВГИ на 12 венгерских угольных пробах. Теплоотдача в ккал/кг, другие данные в %%; *R* = сырой уголь, *MF* = обезвоженный уголь, *MAF* = обезвоженно-беззольный уголь

total sulfur contents. It is evident from Table II, that a systematic loss of moisture occurred in the coal samples that were shipped to the USGS laboratories. This moisture loss affected other analytical results reported on an "as-received" basis. This effect is evident for heat value and volatile matter (Table III). The differences between data from USGS and Hungarian laboratories are smaller on a moisture- and ash-free basis compared to the "as-received" basis.

An evaluation of these analytical data by chronostratigraphic groups is given in *Table IV*. The results in column 5 ("Composite") are averages of columns 1 through 4. The "Nat. Inv." column gives the average data for ash and heat values of coals enumerated in the Hungarian Annual National Inventory of Coal Reserves. The high ash contents and low heat values in the National Inventory reflect contamination of samples by incorporation of roof and floor rocks during the mining process.

*Figure 2* shows the correlation between the heating value and ash + moisture. There are no characteristic differences among the chronostratigraphic groups. By eliminating the moisture, better correlation functions are obtained between ash and heating values as shown in *Figure 3* and the following equations

Pliocene........................................ Kcal/kg = 77(39–A) (1)

Miocene........................................ Kcal/kg = 91(54–A) (2)

Eocene........................................ Kcal/kg = 63(80–A) (3)
Lias............................................ Kcal/kg = 111(76–A) (4)

where A is the percent ash.

| Content | | Pliocene | Miocene | Eocene | Lias | Composite | Nat. Inv. |
|---|---|---|---|---|---|---|---|
| Ash | (R) | 11.7 | 18.9 | 16.7 | 16.1 | 16.3 | 22.9 |
| | (MF) | 26.2 | 20.0 | 21.2 | 17.0 | 19.8 | |
| Moisture | (R) | 49.0 | 20.8 | 13.7 | 1.9 | 20.9 | |
| Organic sulfur | (R) | 0.75 | 1.78 | 3.61 | 1.60 | 2.39 | |
| | (MF) | 1.42 | 2.33 | 3.89 | 1.04 | 2.61 | |
| | (MAF) | 1.91 | 2.68 | 5.12 | 1.22 | 3.33 | |
| Total sulfur | (R) | 1.1 | 2.4 | 5.9 | 2.5 | 3.5 | |
| | (MF) | 2.0 | 2.8 | 6.4 | 2.2 | 4.1 | |
| | (MAF) | 2.6 | 3.3 | 8.7 | 2.6 | 4.9 | |
| Heat value | (R) | 2,258 | 3,865 | 4,783 | 6,594 | 4,435 | 2,592 |
| | (MF) | 4,670 | 5,113 | 5,267 | 7,065 | 5,386 | |
| | (MAF) | 6,320 | 6,824 | 6,964 | 8,300 | 7,019 | |
| Air-dried loss | (R) | 39.8 | 13.9 | 6.8 | 0.8 | 12.6 | |
| Volatile matter | (R) | 23.2 | 28.8 | 37.3 | 28.4 | 31.8 | |
| | (MF) | 43.8 | 39.7 | 40.3 | 28.9 | 38.9 | |
| | (MAF) | 59.3 | 47.2 | 54.0 | 33.1 | 47.3 | |
| Fixed carbon | (R) | 16.0 | 31.8 | 34.2 | 55.3 | 33.9 | |
| | (MF) | 30.2 | 43.8 | 34.5 | 56.3 | 39.0 | |
| | (MAF) | 40.8 | 52.8 | 46.0 | 66.0 | 50.1 | |

*Table IV.* Averages of classification analyses for the different chronostratigraphic groups. Heat value in Kcal/kg, all other values in percent; *R*, as received; *MF*, moisture free; *MAF*, moisture and ash free

*IV. táblázat.* Különböző korú szenek technológiai elemzésének eredményei. Fűtőérték Kcal/kg-ban, egyéb adatok százalékos formában; *R* = nyersszén; *MF* = száraz szén; *MAF* = száraz, hamumentes szén

*Таблица IV.* Результаты технологических анализов углей различного возраста. Теплоотдача в ккал/кг, другие данные в %, *R* = сырой уголь, *MF* = обезвоженный уголь, *MAF* = обезвоженно-беззольный уголь

These functions are important to the evaluation of the level of contamination during mining. One of the principal problems of mining operations is the high contamination rates. According to the National Inventory, planned dilution rates are: Pliocene coal beds, 4%; Miocene coal beds, 6%; Eocene coal beds, 5%; and Lias coal beds, 18%. Real dilution rates can be obtained by using values in Figure 3 and equations 1–4 for real heating values (Lias, 4783 Kcal/kg;

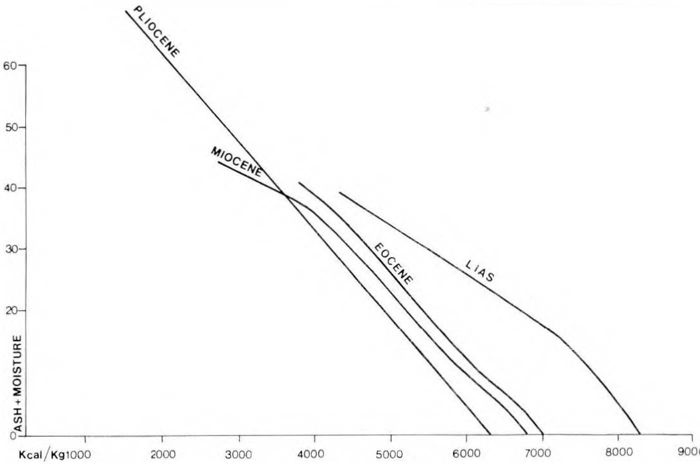



*Fig. 2.* Ash + moisture—heating value relationship

*2. ábra.* Hamu + nedvesség — fűtőérték függvény

*Рис. 2.* Зависимость: зольность + влажность — теплоотдача

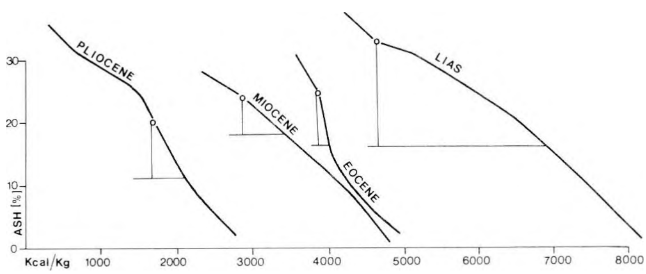



*Fig. 3.* Ash—heat value relationship

*3. ábra.* Hamu — fűtőérték függvény

*Рис. 3.* Зависимость: зольность — теплоотдача

Eocene, 3916 Kcal/kg; Miocene, 2908 Kcal/kg; and Pliocene, 1963 Kcal/kg). Comparison of the real and planned contamination rates for coal beds of Pliocene and Eocene age shows higher dilution rates than expected in the National Inventory:

| Age | % Ash* |
|---|---|
| Pliocene | 13.5 |
| Miocene | 22.0 |
| Eocene | 17.8 |
| Lias | 32.9 |

* Calculated from Equations 1–4.

*Figure 4* shows the relation between total sulfur and heat values; these relations are important to making decisions about the environmental consequences of coal mining. The coal beds of Eocene age are very high in sulfur and the data indicate that the sulfur content increases as the heating value rises. Hence measures should be implemented to control sulfur emission when these coals are used in power plants.

*Table V* shows the major element concentrations in the ash of the different coal groups and averages for each element. Coal beds of Tertiary age are lower in $SiO_2$, $K_2O$, $TiO_2$, and $Al_2O_3$ and higher in CaO and MgO than coals of Jurassic (Lias) age. These data suggest different environments of deposition for the coal beds during the Jurassic and the Tertiary.

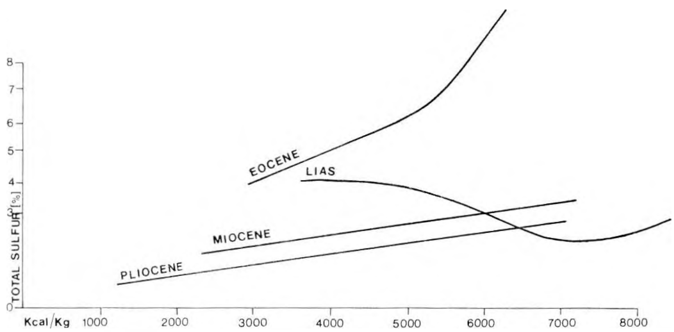



*Fig. 4.* Total sulfur—heating value relationship

*4. ábra.* Összes kén — fűtőérték függvény

*Рис. 4.* Зависимость: общее содержание серы — теплоотдача

| | Composite | | Pliocene | | Miocene | | Eocene | | Lias | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | disp% | Mean | disp% | Mean | disp% | Mean | disp% | Mean | disp% |
| $SiO_2$ | 36.7 | 43.6 | 43.0 | 1.0 | 39.0 | 47.2 | 25.2 | 43.6 | 55.5 | 1.0 |
| $Al_2O_3$ | 16.4 | 44.1 | 17.0 | 1.0 | 15.7 | 10.8 | 13.1 | 66.5 | 25.0 | 16.0 |
| CaO | 11.5 | 81.3 | 11.9 | 18.1 | 9.3 | 74.4 | 16.3 | 66.9 | 2.4 | 80.3 |
| MgO | 1.9 | 56.8 | 2.8 | 1.8 | 2.0 | 50.8 | 2.1 | 47.6 | 0.4 | 5.7 |
| $Na_2O$ | 1.1 | 80.9 | 0.2 | 7.3 | 1.9 | 33.6 | 1.3 | 64.3 | 0.3 | 4.4 |
| $K_2O$ | 1.4 | 67.2 | 1.0 | 2.1 | 2.0 | 55.3 | 0.8 | 69.2 | 2.3 | 4.3 |
| $Fe_2O_3$ | 10.1 | 85.8 | 6.2 | 29.0 | 8.6 | 78.9 | 12.8 | 91.2 | 9.5 | 5.8 |
| $TiO_2$ | 0.5 | 56.2 | 0.4 | 7.5 | 0.3 | 7.4 | 0.5 | 58.6 | 0.9 | 8.3 |
| $P_2O_5$ | 0.1 | 107.0 | 0 | – | 0.1 | 46.8 | 0.1 | 44.6 | 0.2 | 75.0 |
| $SO_3$ | 13.5 | 90.8 | 10.6 | 13.2 | 15.3 | 70.1 | 18.5 | 76.0 | 1.1 | 36.4 |

*Table V.* Averages (in percent) of major elements in the ash. Disp % = (standard deviation × 100)/mean

*V. táblázat.* Főelemek átlagértékei a hamuban. Disp = (standard szórás × 100)/átlag

*Таблица V.* Средние значения главных элементов в золе. Disp. = (стандартное рассеяние × 100)/среднее значение

*Table VI* gives data on average trace element contents in the coal ash by chronostratigraphic group. The coal beds of Jurassic age have higher concentrations of 30 of the 36 elements tested than the Tertiary coal beds. B, Ba, Mn, Rb, Sc, and Sr are lower in the Jurassic coal beds while Be, Ce, Hg, La, Mo, Nb,

| | Composite | | Pliocene | | Miocene | | Eocene | | Lias | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | disp% | Mean | disp% | Mean | disp% | Mean | disp% | Mean | disp% |
| Ag | 0.2 | 56.2 | 0.1 | – | 0.1 | – | 0.2 | 42.3 | 0.3 | 34.5 |
| B | 575.0 | 100.8 | 91.0 | 9.2 | 973.0 | 20.2 | 688.0 | 138.0 | 180.0 | 22.2 |
| Ba | 738.0 | 113.0 | 210.0 | 9.5 | 790.0 | 55.3 | 992.0 | 116.5 | 555.0 | 51.3 |
| Be | 18.4 | 167.4 | 11.8 | 36.2 | 3.9 | 37.8 | 2.6 | 63.0 | 860.0 | 10.5 |
| Cd | 0.3 | 76.6 | 0.2 | 16.6 | 0.1 | 45.0 | 0.3 | 64.6 | 0.5 | 67.3 |
| Ce | 181.0 | 135.0 | 60.0 | 1.7 | 84.0 | 21.8 | 71.0 | 68.5 | 720.0 | 11.1 |
| Co | 15.6 | 68.3 | 23.5 | 48.9 | 11.4 | 59.8 | 9.9 | 78.4 | 28.0 | 3.6 |
| Cr | 92.0 | 54.2 | 98.0 | 2.6 | 45.0 | 41.6 | 109.0 | 56.3 | 114.0 | 14.5 |
| Cs | 12.6 | 70.0 | 7.8 | 3.8 | 16.1 | 79.6 | 9.1 | 59.7 | 21.0 | 9.5 |
| Cu | 56.0 | 42.8 | 51.0 | 23.5 | 45.0 | 31.1 | 50.0 | 31.3 | 94.0 | 28.3 |
| Eu | 3.0 | 70.6 | 2.0 | 5.0 | 1.2 | 55.6 | 3.4 | 64.9 | 5.7 | 13.2 |
| Ga | 21.0 | 58.1 | 18.0 | 2.9 | 17.0 | 29.2 | 18.0 | 68.7 | 40.0 | 24.1 |
| Ge | 10.0 | 110.0 | 9.0 | 50.5 | 5.0 | 3.9 | 6.0 | 52.6 | 30.0 | 53.3 |
| Hg | 8.8 | 159.1 | 3.3 | 9.1 | 2.9 | 14.9 | 2.1 | 43.2 | 40.0 | 5.0 |
| La | 92.0 | 139.8 | 30.0 | 1.7 | 37.0 | 48.9 | 37.0 | 56.2 | 375.0 | 12.0 |
| Li | 65.0 | 64.3 | 36.0 | 8.3 | 55.0 | 14.3 | 72.0 | 72.9 | 89.0 | 46.9 |
| Lu | 1.0 | 108.5 | 1.3 | 38.5 | 0.4 | 28.8 | 0.3 | 47.8 | 3.3 | 3.0 |
| Mn | 282.0 | 67.7 | 545.0 | 15.6 | 323.0 | 40.3 | 210.0 | 80.6 | 140.0 | 72.0 |
| Mo | 20.4 | 160.2 | 4.8 | 37.5 | 7.3 | 53.2 | 11.7 | 102.8 | 92.5 | 8.1 |
| Nb | 43.0 | 172.3 | 9.0 | 17.6 | 12.0 | 23.6 | 10.0 | 22.4 | 205.0 | 12.2 |
| Ni | 97.0 | 77.1 | 118.0 | 53.2 | 49.0 | 65.1 | 81.0 | 96.1 | 190.0 | 0 |
| Pb | 14.1 | 117.5 | 5.5 | 9.1 | 11.0 | 70.8 | 5.2 | 7.7 | 49.5 | 7.1 |
| Rb | 128.0 | 76.2 | 65.0 | 3.1 | 182.0 | 77.5 | 129.0 | 67.5 | 110.0 | 9.1 |
| Sc | 18.3 | 54.1 | 28.0 | 10.7 | 11.0 | 7.8 | 15.5 | 72.5 | 26.5 | 1.9 |
| Sm | 11.6 | 79.4 | 5.9 | 3.4 | 5.3 | 41.5 | 5.3 | 66.8 | 42.5 | 10.5 |
| Sr | 1,890 | 96.8 | 445 | 7.9 | 1,183 | 33.5 | 3,020 | 73.9 | 1,570 | 71.9 |
| Ta | 0.7 | 117.3 | 0.2 | 41.5 | 0.2 | 47.9 | 0.6 | 116.0 | 2.1 | 7.3 |
| Tb | 2.6 | 85.2 | 1.9 | 18.9 | 2.0 | 37.6 | 1.4 | 50.1 | 7.3 | 10.3 |
| Th | 26.3 | 93.6 | 22.0 | 0 | 19.3 | 27.2 | 11.8 | 60.1 | 77.5 | 20.0 |
| U | 25.0 | 122.8 | 5.8 | 3.4 | 12.2 | 80.5 | 24.3 | 147.5 | 65.0 | 13.8 |
| V | 120.9 | 60.6 | 130.0 | 7.6 | 60.7 | 45.2 | 115.8 | 70.2 | 215.0 | 2.3 |
| W | 0.9 | 94.4 | 0.6 | 0 | 0.6 | 23.6 | 0.5 | 41.1 | 2.8 | 23.6 |
| Y | 58.2 | 91.8 | 60.5 | 25.6 | 31.0 | 22.5 | 28.8 | 66.4 | 170.0 | 5.9 |
| Yb | 8.2 | 100.6 | 9.7 | 34.0 | 3.9 | 17.9 | 3.3 | 48.2 | 25.5 | 5.9 |
| Zn | 60.1 | 72.6 | 79.0 | 7.6 | 35.7 | 57.1 | 50.0 | 68.4 | 103.0 | 65.0 |
| Zr | 346.5 | 168.9 | 123.5 | 21.4 | 126.7 | 7.4 | 66.2 | 65.9 | 1,600 | 25.0 |

*Table VI.* Averages (in ppm) of minor and trace elements in ash. Disp% = (standard deviations × 100)/mean

*VI. táblázat.* Ritka és nyomelemek koncentráció értékei a hamuban. Disp = (standard szórás × 100)/átlag

*Таблица VI.* Значения концентраций редких элементов и в следах. Disp. = (стандартное рассеяние × 100)/среднее значение

Sm, and Zr are four or more times higher. It should be noted that volatile elements such as Hg are calculated from whole coal data to the ash basis; it is doubtful whether any Hg (or other volatile elements) survives the ashing procedure.

On a whole-coal basis, the individual samples from coal beds of Jurassic age exhibit higher trace element contents, but to a lesser extent than on an ash basis. The high trace element contents in the ash and on a whole-coal basis is additional evidence of a different depositional environment of these coals compared to the others.

## 4. Conclusions

Data for twelve samples of coal from Hungary show some very unusual concentrations of chemical components. These components range from high organic sulfur content in coal beds of Miocene and Eocene age and the high trace element content in coal beds of Jurassic age. To corroborate these preliminary findings, detailed studies of the depositional environments of the Hungarian coal fields should be undertaken and additional samples should be collected and analyzed in order to relate depositional changes to geochemical differences. Care should be taken to minimize moisture losses in the future collection and shipment of additional coal samples.

## 12 MAGYARORSZÁGI SZÉNMINTA GEOKÉMIAI ANALÍZISE

SOMOS László, Peter ZUBOVIC és Frederick O. SIMON

A MÁFI — USGS kétoldali együttműködés során 12 db magyarországi szénmintát vizsgáltak meg az USGS központi geokémiai laboratóriumában (Reston). A rendkívül széles körű elemzések során a hagyományos technológiai és minősítési vizsgálatokon túlmenően környezeti szennyezőanyag-tartalom és széles körű nyomelem, illetve ritkafém tartalom meghatározásra is sor került.

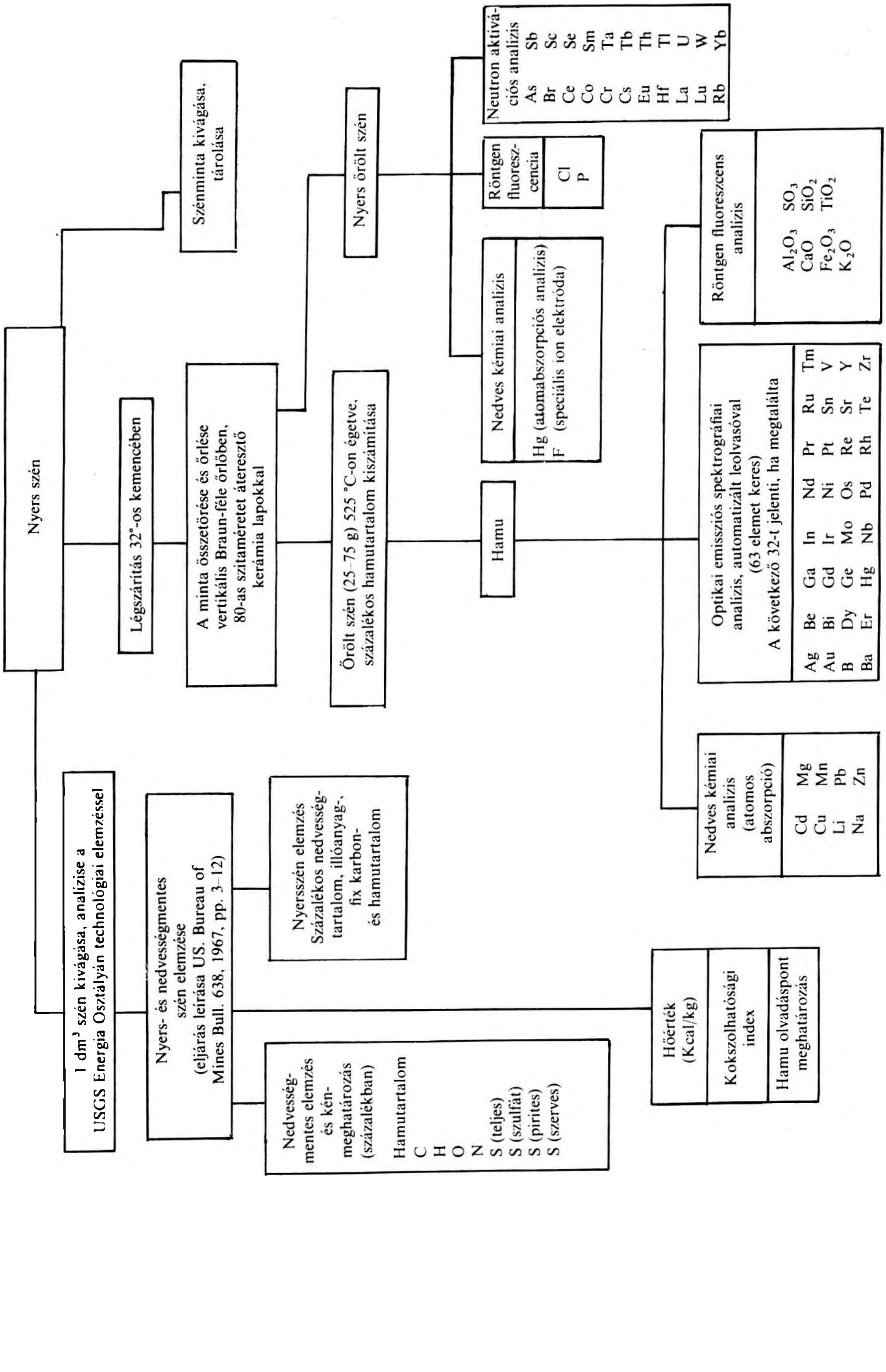
A kisszámú mintavételezés eredményének MÁFI — USGS közös módszertani értékelése elsősorban szénminősítési és környezetvédelmi feladatokra ad konkrét megoldási ötleteket. A minták kis száma miatt az eredmények csak kvalitatíve értékelhetők.

## ГЕОХИМИЧЕСКИЙ АНАЛИЗ 12-И ВЕНГЕРСКИХ УГОЛЬНЫХ ПРОБ

Ласло Г. ШОМОШ, Петер ЗУБОВИЧ и Фредерик О. САЙМОН

В ходе двустороннего сотрудничества между Венгерским геологическим институтом (ВГИ) и Геологической службой США (ГСА) 12 венгерских образцов углей исследовались в центральной геохимической лаборатории ГСА (Рестон). В течение необычайно широкого круга исследований помимо традиционных технологических и качественных анализов было проведено определение содержания веществ, загрязняющих окружающую среду, и содержания многочисленных редких металлов и в следах.

Совместное (ВГИ—ГСА) методическое оценивание результатов исследования небольшого количества образцов дает идеи для возможного разрешения задач, в первую очередь, в областях качественной оценки углей и защиты окружающей среды. Результаты, вледствие малого количества образцов, могут быть оценены только квалитативно.




*1. ábra.* Mintavizsgálati folyamatábra

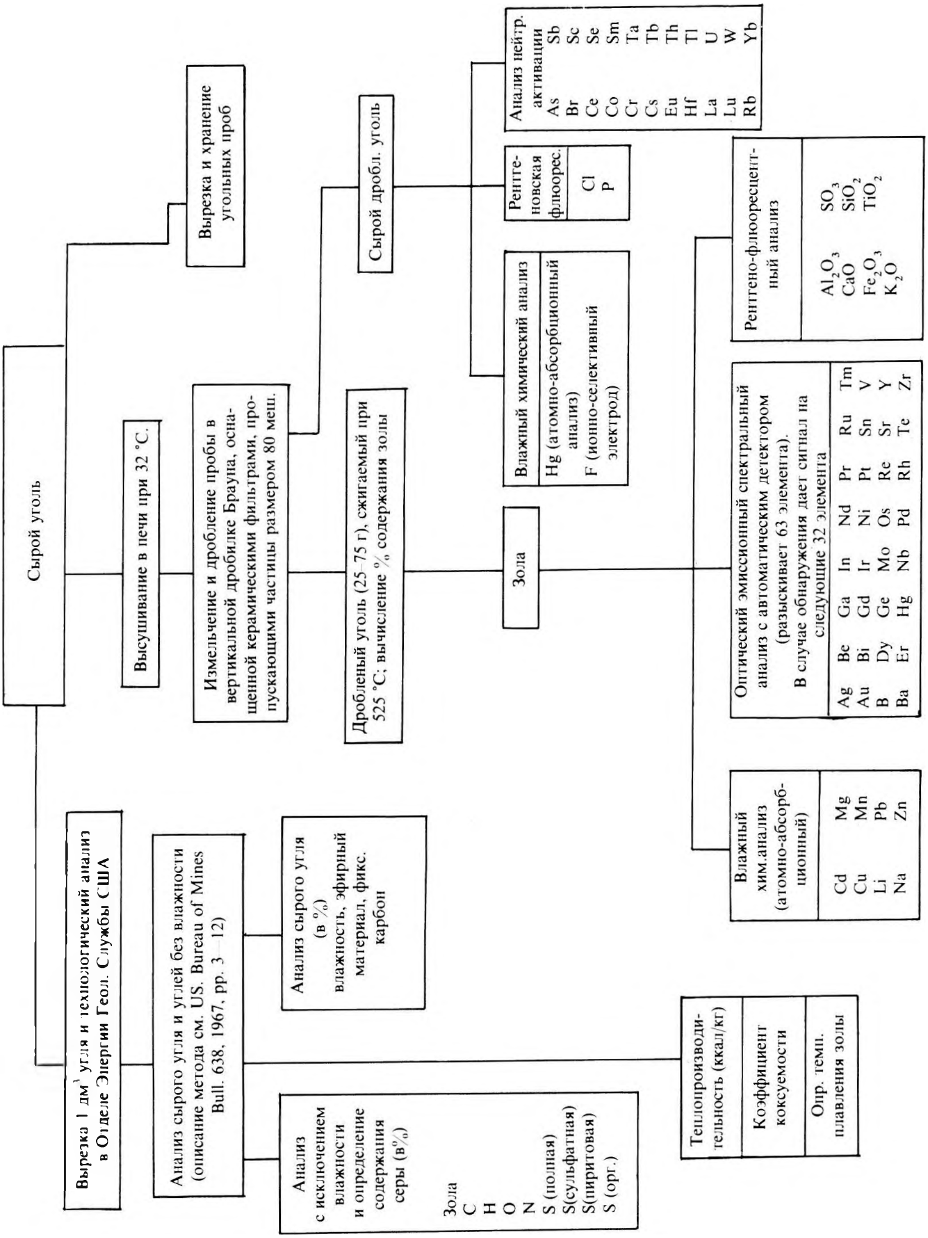



*Рис. 1.* Непрерывное изображение исследования образцов