Study of the features of brown coal by petrographic analysis

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Abstract. The paper presents the results of petrographic analysis of five samples of brown coals from the following deposits: Itatskoye, Munayskoye, Arkharo-Boguchanskoye, Kangalasskoye, Baganuur (Mongolia). It was found that the brown coal sample from the Itatskoye deposit (Ro, r = 0.388%) has the lowest vitrinite reflectance, while the brown coal from the Kangalasskoye deposit has the highest reflectance value (Ro, r = 0.490%). An increase in the genetic maturity of the studied samples is associated with a change in the technological properties of their organic matter. It is shown that with an increase in Ro, r, the carbon content (Cdaf) increases, the yield of volatiles decreases, as well as the atomic ratio of H/C and O/C. Visual analysis of polished sections made it possible to determine the maceral composition of the studied coals. The sample of brown coal from the Baganuur deposit (Mongolia) has the highest inertinite content (more than 60%), the sample of the Kangalasskoye deposit contains the largest amount of vitrinite group macerals (86%).

1. Introduction

Brown coal is low-metamorphosed coal with a noticeable structural structure of the plant matter from which it is formed. The material for the formation of brown coal was a variety of tree ferns, horsetails and plonks, deciduous trees, as well as the first gymnosperms and peat plants. Brown coal is widespread in deposits of various ages, starting from the Devonian and Carboniferous, but the richest deposits belong to the Mesozoic and Tertiary ages. There are 3 main varieties of brown coal: lignite (with a clearly distinguishable woody structure of mother plants), loose earthy and dense shiny [1].

Brown coal outwardly differs from bituminous coal in the color of a line on a porcelain plate - it is always brown. However, the most important difference is the lower carbon content and significantly higher volatiles and water. Brown coals include coals with a volatiles yield of more than 40% per combustible mass and a higher specific heat of combustion of the working mass of an ashless state of less than 24 MJ / kg, but more than 17.4 MJ / kg, with carbon content from 60 to 75%, hydrogen – up to 6%.

According to GOST 25543-2013, brown coals are recommended to be used as an energy fuel and as a chemical raw material for obtaining liquid fuel and various synthetic substances, gas and fertilizers. With special processing, brown coal can be used to produce coke suitable for metallurgical production. It should be noted that in order to predict technological properties [2-4] and select the main directions of using coals of a particular deposit, data on their material and petrographic composition are required [5-9]. This paper presents the results of studying the petrographic composition of brown coals from various deposits.

2. Results and discussion

As objects, we used five samples of brown coals taken from the collection of coals formed at the Institute of Coal Chemistry and Materials Science, Federal Research Center of Coal and Coal Chemistry SB RAS. The coals of the following deposits were investigated: Itatskoye – No. 1, Munayskoye - No. 2, Baganuur (Mongolia) - No. 3, Arkharo-Boguchanskoye - No. 4, Kangalasskoye - No. 5.

The Itatskoye brown coal deposit is located in the western part of the Kansk-Achinsky basin on the territory of the Itatsky and Tisulsy districts of the Kemerovo region. Of industrial interest is the Itatsky
seam, which has a simple structure and an average thickness of about 58 m, with fluctuations from 10 to 98 m. The coals of the deposit are low-sulfur, have low ash content, and are suitable for use in heat power engineering and as a chemical raw material [10, 11].

Munayskoye coal deposit is the only coal deposit located in the Solton district of the Altai Territory, 100 km from the city of Biysk. The deposit is represented by two industrial, horizontally lying at a depth of 41-57 m layers with an average thickness of 10-12 m, is part of the coal-bearing area “Nyanya-Chumyshskaya depression”. Inferred reserves are estimated at 250 million tons. Currently, two open-pit mines (Munaysky-1 and Munaysky-2) have explored reserves of 34 million tons. Brown coals in terms of properties (moisture, volatile matter yield, heat of combustion, etc.) are close to brown coals of the Kansk-Achinsk basin, however, they are somewhat inferior in ash and sulfur content [12].

The Arkharo-Boguchanskoye brown coal deposit (Nizhne-Zeya basin) is located in the Arkharinsky administrative region, 15 km from the Arkhara station of the Amur region. 4 coal seams (from bottom to top) were opened at the deposit: Nizhny, Dvoynoy, Intermediate and Velikan. The depth of their occurrence in the industrial contour of the field is from 5 to 80 m. The Intermediate, Dvoynoy and Nizhny seams are composed mainly of dense black coal with a brownish and brown tint. Soft, friable, earthy brown coals are rarely observed. The organic mass of coal is characterized by a high content of microcomponents of the vitrinite and fusinite groups; microcomponents of the lipinite group are slightly spread in the coal. The mineral part is represented by pelitomorphic clay and siliceous matter, detrital quartz, and iron sulfides [13]. Mining and geological conditions of the Arkharo-Boguchanskoye deposit make it possible to mine it in an open pit.

The Kangalasskoye brown coal deposit is confined to the southeastern wing of the Vilyui syncline and forms the southern part of the Yakutsk-Kangalassky coal-bearing region of the Lena basin. The reserves of the Kangalasskoye brown coal deposit make up the bulk of the fuel produced in the Republic of Sakha (Yakutia). The most valuable are two close, often merging coal seams - Lower and Upper. Coal resources are estimated at 24-30 billion tons, explored reserves amount to 1 billion tons. Mining and geological conditions are favorable for open-pit mining. Coals are typically humic, mostly vitrinite, dense, medium-ash (from 6 to 25%), low-sulfur (about 0.3%), have a high heat of combustion (up to 28.3 MJ / kg) [10, 14, 15]. Freshly mined coals have high moisture content, low lump strength, are unstable during storage and, quickly losing moisture, decay, turning into fines and dust.

The Baganuur brown coal deposit is located in the central aimag, 110 km east of Ulan Bator, and is one of the largest and most industrially significant deposits in Mongolia. The natural boundaries of the field are the outcrops of stratum 2 under the Quaternary deposits. The thick strata horizon includes strata 2, 2a and 3, which are suitable for open-pit mining. Coals are black and dark-brown in color, with a resinous sheen, dense and strong, with a conch-like fracture. When stored on the surface, they acquire a matte sheen and disintegrate into many sharp-angled fragments. The main amount of brown coal is mined at the Baganuur open pit with industrial reserves of 515 million tons. Coal is consumed mainly in the domestic market for electricity generation and heat supply [16].

Technical analysis of coals was carried out using standard methods. The composition of organic matter was determined by elemental analysis.

Coal samples in the initial state are dense with alternating matte and shiny stripes. Petrographic and reflectogram analysis was carried out in accordance with GOST 9414.1–94, GOST R 55662–2013, GOST R 55663–2013, and GOST R 55659–2013. These standards apply to lignite, bituminous and anthracite coals (coals of low, medium and high stages of metamorphism). Determination of the stage of metamorphism of the tested coals was carried out in accordance with GOST 21291–76.

Petrographic analysis was carried out on an automated complex for assessing the grade composition of coals of the SIAMS-620 system (Russia) in an oil immersion environment. A portion of the air-dry sample, ground according to GOST R 55663–2013, was mixed with a binder (shellac), one side of which was ground and polished on a grinding and polishing machine until a smooth surface was obtained. Macerals were identified in the immersion environment by their reflection index, color, morphology, microrelief height, structure, degree of its preservation, as well as size. The microcomponents were counted manually at a magnification of 300 times in reflected light, and their quantitative ratio was determined by the point counting method. The results of petrographic research are given for “clean coal”, excluding minerals.

The characteristics of the studied coal samples are given in Table 1.
Analytical data show that the ash content of the studied samples practically does not exceed 10%. However, it should be noted that the coal samples from the Kangalasskoye and Arkharo-Boguchanskoye deposits had an ash content of 13.5% and 14.6%, respectively. For correct petrographic analysis, they were enriched in carbon tetrachloride according to GOST 1186–2014, Appendix A. For analytical studies, a fraction with a density of less than 1.5 g/cm³ was used.

The yield of volatile substances ($V_{\text{daf}}$) in the studied samples ranges from 40 to 50% (Table 1). The highest $V_{\text{daf}}$ value was determined for the coal sample of the Itatsky deposit (48.5%), the lowest for the Kangalassky brown coal (41.4%).

The characteristics of the petrographic composition of brown coal are given in Table 2.

The presented data show that the vitrinite reflectance ($R_o, r$) varies from 0.388% (sample No. 1 of the Itatsky deposit) to 0.490% (sample No. 5 of the Kangalassky deposit). The reflectograms obtained as a result of petrographic analysis for all samples have no discontinuities; they are characterized by a minimum indicator of petrographic heterogeneity ($\sigma_R = 0.03$ and 0.05), which indicates the stability of the chemical and petrographic parameters of the studied coals.

The revealed reflectance of vitrinite for the studied brown coals was compared with the content of carbon $C_{\text{daf}}$ and oxygen $O_{\text{daf}}$ in their organic mass, the values of which are given in Table 1. Graphical analysis showed the existence of a close correlation between the vitrinite reflectance index ($R_o, r, %$) with $C_{\text{daf}}$ and $O_{\text{daf}}$ (Figure 1). The results obtained are consistent with the existing idea that with an increase in the degree of coal metamorphism, the yield of volatiles and the value of the H/C and O/C atomic ratios decrease [5, 6].

![Figure 1](image1.png)

![Figure 2](image2.png)
Figure 1. Relationship between the reflection index of vitrinite of brown coals (Ro, r,%) and the content of carbon C intermittent (a) and oxygen O intermittent (b) in their organic mass.

The study of coal samples in reflected light made it possible to determine their petrographic features. According to the research results, brown coals are a complex mixture of macerals of the vitrinite, semivitrinite, inertinite and liptinite groups. However, it should be noted that the content of liptinite is not so significant and its amount in coals ranges from 1 to 6% (Table 2). Macerals of the liptinite group are identified as cutinite and resinite, which in reflected light have a dark gray color, shape and sharp relief in comparison with the cementing bulk of coals.

The largest amount of macerals of the vitrinite group (Vt) is determined in sample No. 5 of brown coal from the Kangalasskoye deposit (86%) and in sample No. 2 of the Munayskoye deposit (62%) (Table 2). Macerals of the vitrinite group in reflected light have a fairly uniform surface and a dark gray color. The largest amount of semivitrinite (Sv) of about 42% is determined in samples No. 1 of the Itatskoye deposit and in sample No. 4 of the Arkharo-Boguchanskoye deposit.

Figure 2. Micrographs of the surface of polished sections (reflected light, oil immersion, magnification 300) of the studied samples of brown coal with macerals of the inertinite group:
- a - fusinite in a sample of the Itatskoye deposit;
- b - fusinite in a sample of the Munayskoye deposit;
- c - interlayering of fusinite in vitrinite in the sample of the Kangalasskoye deposit.

The largest amount of inertinite (I) contains sample No. 3 of brown coal from the Baganuur deposit in Mongolia (about 63%) (Table 2). It should be noted that macerals of the inertinite group are determined in all samples of brown coal mainly in the form of fusinite. The color in reflected light of this maceral is yellow. Fusinite has all kinds of cellular structure and sometimes occurs in the form of lens fragments or elongated areas of various widths (Figure 2).

3. Conclusion
A study of the petrographic composition of 5 samples of brown coal from various deposits was carried out. It was found that the brown coal sample from the Itatskoye deposit (Ro, r = 0.388%) has the lowest vitrinite reflectance, while the brown coal from the Kangalasskoye deposit has the highest value (Ro, r = 0.490%). An increase in the genetic maturity of the studied samples is associated with a change in the technological properties of their organic matter. It is shown that with an increase in Ro, r, the carbon content increases, the yield of volatile substances decreases, as well as the atomic ratio of H/C and O/C.

Visual analysis of polished sections made it possible to determine the maceral composition of the studied coals. The brown coal sample from the Baganuur deposit (Mongolia) contains the highest inertinite content (more than 60%); the sample from the Kangalassky deposit contains the largest amount of vitrinite group macerals (86%).

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