The main factors determining the petrographic composition and quality of coal are the partial pressure and activity of the oxygen in the organic system. The partial pressure \( p_{O_2} \) acts at an early stage of diageneesis and is associated with the decomposition of biological macromolecules (biopolymers) to monomers. These monomers serve as the initial material for the subsequent condensation of heterocyclic polymers—heterocondensates—in conditions without free oxygen access. Such condensation is controlled by the oxygen activity or the oxygen concentration in an aqueous medium [1]. These processes continue until the lithification of the organic matter and correspond to late diagenesis. They initiate transformations in the organic system.

In the strict sequence by which the redox conditions develop from being controlled by the oxygen partial pressure to being controlled by the oxygen activity, the physicochemical conditions largely depend on the degree of closure of the organic system. The degree of closure, in turn, is determined by the lithological and hydrodynamic characteristics of sedimentation, which may be expressed in numerous ways. For example, the transformation of organic matter may occur in parallel with the accumulation of uranium in the organic system. In that case, uranium-bearing coal will be formed, in uranium—coal deposits [2, 3]. As a result, the petrographic and other characteristics of the coal will be profoundly different than in normal conditions. The study of such coal and associated developmental processes forms part of coal petrology.

**REDOX CONDITIONS OF THE ORGANIC SYSTEM AND MICROCOMPOSITION OF COAL**

Petrographic and analytical data show that the transformation of plant matter to coal is a redox process, which is specified by the oxygen conditions and, in turn, determines the microcomposition of the coal’s organic matter. In this process, the oxygen potential is an important characteristic of the organic system, and its variation determines the range of petrographic types of coal.

Plant matter consists of biopolymers that differ in composition and structure. These polymers express different degrees of affinity for oxygen. Carbon materials (cellulose, hemicellulose, pectins, mono- and polysaccharides, etc.), which account for >50% of the plant matter, break down enzymatically in the biochemical transformation of plant matter, to form monomers. From these monomers, heterocyclic polymers—heterocondensates (humic acids)—are formed. The lignin also breaks down to monomers, with subsequent transformation to humic acids and humus. However, lignin is more stable in humification and partially overcomes the oxidative barrier at the peat-forming level, and is completely broken down at the stage of solid lignites (long-flame coals). Lipoid material behaves passively in the biochemical series, bypasses the oxygen barrier, and is retained until the formation of high-quality coal.

These transformations of plant matter are controlled by the oxygen conditions (with the participation of microorganisms), which are specified by the external conditions, and the oxygen activity characterizes the state of the organic system. Each petrographic type of coal is determined by the dominant oxygen conditions in the organic system. The primary petrographic components determining the petrographic types of coal are the microcomponents of the vitrinite and fusinite groups, which are formed by transformation of the plant matter, whereas lipoids are present in the coal as inherited biochemical products. The formation of microcomponents of the vitrinite and fusinite groups is functionally related to the redox conditions of the organic system and serves as an indicator of these conditions. Their ratio \( F/Vt \) character-
izes the oxygen conditions in the system. This relationship may be expressed in functional form
\[ \frac{F}{Vt} = f(O_2). \] (A)

The value of \( f(O_2) \) does not depend on the organic system itself. It is specified by the oxygen potential of the external medium and characterizes the state of the organic system. Variation in \( f(O_2) \) is accompanied by linear variation in \( \frac{F}{Vt} \) and thereby determines the petrographic composition of the system. The lipoid microcomponents, by contrast, are biochemically stable during changes in the oxygen conditions over most of the coal series and behave like inert materials.

The transformation of the plant matter to coal occurs in two stages:

1. On the basis of the oxygen partial pressure, which is created with free access of oxygen to the organic system;
2. On the basis of the oxygen activity, when the redox conditions in the organic system are sealed off from oxygen access and the oxygen activity is determined by the external medium.

The oxygen partial pressure is established in the surface layer of the organic system—the peat-forming level—and is specified by the atmospheric pressure. In coal petrology, this state of the organic system is said to be aerobic. The depth of the level is between 1 and 10 m, depending on the hydrodynamics, the groundwater level, etc. Saturation with free oxygen maintains the biochemical cycle of the microorganisms in the organic system. Their enzymatic activity determines the breakdown of biogenic polymers in the plant matter to monomers. However, this decomposition is not complete and only affects 50–60% of the organic mass. On account of the instability of the oxygen partial pressure in the peat-forming level, the variation in thickness of the level, and other factors, the transformation of the plant matter by the end of the peat-forming level is very uneven. For the main microcomponents in the organic system, such conditions may be described by the relation
\[ \frac{F}{Vt} = \omega_0 p_{O_2}, \]
where \( \omega_0 \) is a constant of proportionality; \( p_{O_2} \) is the oxygen partial pressure in the system.

Below the peat-forming level, there is no free-oxygen access to the monomers and residual plant matter that have fallen there from the peat-forming level. The result is suppression of the population of aerobic microorganisms and reduction in the rate of destruction of biopolymers from the plant tissues. This is an anaerobic level. Nevertheless, 40–50% of the plant matter that withstands the aerobic medium passes through the same path of biochemical decomposition to monomers before being converted to solid lignite. Carbon materials (cellulose, hemicellulose, pectins, mono- and polysaccharides, starch, etc.) break down completely. Phenols (lignin, tannin) are stable and disappear later, at the lignite stage. All these transformations are oxidative and may be completed in the presence of oxygen. In coal petrology, it is assumed that the reserve of oxygen is created by different sources: redox reactions within the molecules [4], oxide mineral inclusions, etc. However, this oxygen does not characterize the state of the organic system.

In an anaerobic medium, without free oxygen access, the oxygen activity is specified by the external conditions and characterizes the state of the organic system. The most important factor is the basicity of the aqueous medium, which is directly related to the oxygen activity. The basicity is indicated by the calcium—magnesium profile of the ash. The redox conditions of the medium may be characterized by the following reactions.

For an alkaline (basic) medium:
\[ 2H_2O + O_2 + 4e^- = 4OH^- \]

with equilibrium constant
\[ K_{al} = \frac{[\text{OH}^-]^4}{[O_2][\text{e}^-]^4}. \] (1)

Hence the oxygen activity in the aqueous medium is
\[ [O_2] = \frac{[\text{OH}^-]^4}{K_{al}[\text{e}^-]^4}. \] (2)

Correspondingly, for an acidic medium:
\[ 2H_2O = O_2 + 4H^+ + 4e^-; \]

\[ K_{ac} = [O_2][H^+][\text{e}^-]^4, \] (3)

and hence
\[ [O_2] = \frac{K_{ac}}{[H^+][\text{e}^-]^4}. \] (4)

Substituting Eqs. (2) and (4) into Eq. (A), we find that
\[ \frac{F}{Vt_{al}} = \varphi_a \frac{[\text{OH}^-]^4}{K_{al}[\text{e}^-]^4}; \] (5)

\[ \frac{F}{Vt_{ac}} = \varphi_b \frac{K_{ac}}{[H^+][\text{e}^-]^4}. \] (6)

These equations permit an interesting conclusion regarding the development of the organic system. Equation (5) characterizes the organic system in an alkaline (basic) medium. The change in basicity directly determines the microcomposition. In other words, increases in basicity sharply intensify fusinization, which develops over the textinite tissues and telinite structures. This process is very intense, since the alkalinity is raised to the fourth power. A slight increase in basicity significantly shifts the \( \frac{F}{Vt_{al}} \) ratio...