Subsoil Natural Physico-chemical Reactor: The Property of Deep Abiogenic Methane-Containing High-Thermobaric Fluid to Form Coal Seams

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Abstract: For the first time, the property of deep abiogenic methane-containing high-thermobaric fluid to decompose organic residues in the Earth’s crust and form coal seams was established.

Keywords: Abiogenic methane-containing high-thermobaric fluid, coal seams, organic residues, uncontrolled natural physicochemical processes, mass spectrometric research method.

This proposed scientific discovery belongs to the field of earth science, in particular, to the geology and geochemistry of combustible minerals and natural physicochemical processes of conversion of organic residues into coal seams and complex hydrocarbon-containing compounds. It can be used for their search and extraction in difficult thermodynamic conditions.

In the earth’s crust at depths of about 1,000 m there are coal seams (brands PS, P, NA, anthracite), such as Donbass with methane content in concentrations from 77.0% to 99%, formed under thermodynamic conditions ~240°C. At specific geological times at these depths this indicates the presence of abnormal thermodynamic and other conditions and processes that have not yet been elucidated. The source of thermal energy for the conversion of these residues into coal and heating of contact rocks with the regeneration of minerals and rocks at these depths has not been established.

The author experimentally modeled the decomposition of organic residues in the earth’s interior during the processes of their transformation into coal by heating peat in the temperature range of 20-1,000 °C. The test samples were heated according to the developed method using a device [1-3] made specifically for the study of volatile compounds isolated from minerals, rocks and other solids released by heating them in high vacuum using the mass spectrometric method.

Methodically, before each analysis, the device was heated to a temperature of 150-200 °C above the working temperature, and cooled under constant vacuum (10⁻⁵ Pa). After inserting the sample into the ampoule, mounting the device and connecting it to the nozzle of the mass spectrometer, the whole system was heated and evacuated to 1.3×10⁻⁵ Pa. During the gradual heating of the ampoule, volatile compounds were isolated from the test samples, the amount of which was previously monitored with a vacuum gauge. Studies were performed in the range of 20-850 °C, in some cases up to 1,000 °C and above. At each temperature point, the heating of the sample lasted up to 30 min then the temperature was reduced by 30 °C to avoid the release of additional portions of volatile compounds. The volatile compounds thus obtained were fed to the inlet of the mass spectrometer to obtain results. The temperature dependences of the

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yield of volatile compounds from peat are recorded. The percentage of volatile substances obtained in the decomposition of peat when heated is plotted along the ordinate axis, and the temperature change is plotted along the abscissa. From the sections parallel to the ordinate axis, the quantitative composition of volatile compounds for any interval temperature was determined. Carbon dioxide and water were released first and in the largest quantities. As the temperature increases, the emission of carbon dioxide also increases quantitatively and reaches a maximum value at temperature near 400 °C. The amount of water proportionally decreases and has its first minimum in this interval. As the temperature increases, the percentage of hydrocarbon compounds increases: CH₄, C₂H₆, C₃H₈—a total of 20.0% at a temperature of 800 °C, noting in particular, methane at this temperature of about 10.0%, hydrogen—up to 6.0%. The release of sulfur-containing gases and oxygen has a wave character in the whole range, not exceeding 1.0%. Nitrogen evolution reaches a maximum value in the region of 700 °C, not exceeding 5.0%. Brown coal was similarly investigated. It is known that this type of coal differs from peat because its structure does not contain carbohydrates, fiber in particular. The test sample was also pre-evacuated, which allowed us to get rid of adsorbed gases and moisture and then heat the sample in the range of 20-800 °C and monitor the behavior of the isolated volatile compounds with increasing temperature. Water and carbon dioxide were the first to stand out in significant quantities. H₂S and SO₂ in total did not exceed 0.5%. The amount of hydrocarbon gases (CH₄, C₂H₆, C₃H₈, etc.) did not exceed 12.0%. The behavior of hydrogen and carbon monoxide with nitrogen is quite close. A sharp redistribution of the isolated volatile compounds occurred in the range of 600-800 °C and above when the amount of hydrogen and carbon monoxide with nitrogen increased the most. The percentage of methane in this area is at the maximum and within 9.0-10.0%.

An analysis of research results of volatile compounds obtained by heating peat, brown coal, etc. and their comparison with the compositions of volatile compounds present in the coal seams of Donbass (PS, P, NA), formed under thermodynamic conditions up to 240 °C with a methane content in concentrations from 77.0 to 99.0%, indicates a significant difference. It was experimentally established that up to a temperature of 300 °C, less than 5.0% of all hydrocarbons were released. If due to some not yet clear natural conditions and processes the concentration of this biogenic methane could increase to 99.0%, then the concentration of carbon dioxide, for example, should increase to 1,500%. Under these conditions, rocks containing coal seams and contact rocks must be almost completely sealed, i.e. single crystals with a minimum of dislocations-defects in the crystals, to store for tens of millions of years a compound such as methane. For example, each ton of deposits Lviv-Volyn basin contains ~15.0 m³/t without CO₂“lakes”, which should be within 2,250.0 m³/t, but in fact there is little or none.

Thus, it is one of the most important and complex problems of natural science “The problem of genesis, synthesis of natural hydrocarbons and in particular, methane and its role in the transfer of thermal energy, mineral components of fluid, in the formation of oil and gas deposits and coal seams, etc.”.

The origin of methane is established by the “new technology for determining the genesis of hydrocarbon gases” developed by Svorenet al. [4, 5]. The technology belongs to the geochemistry of gases and can additionally be used to search for oil and gas in the bowels of the earth, to clarify the nature of streaked mineralization, and so on. The technology is based on the theoretical research and experimental data developed by authors in the study of the content of syngenetic defects-inclusions in diamond crystals from the tube “Mir” (Yakutia), quartz minerals of different temperatures (Transcarpathia, Volyn, Central Asia, etc.) and epigenetic—in sedimentary rocks,
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Pre-Carpathian Depression (Pynyanske gas field, ch. 2,150 m, Lower Sarmatian deposits), DDZ and other oil and gas areas and metallogenic provinces. According to the technology of determining the genesis of hydrocarbon gases, including drilling, sampling of minerals and rocks, and similarly in the mine during coal mining and other works in the directions of deeper formations and towards more thermodynamic impact on the formation, determine the composition and amount of volatile compounds in inclusions in solids. Conclusions about the genesis of methane and other hydrocarbons can be made by the types of fluid inclusions in minerals and the presence and diversity of their composition and quantitative ratios of volatile compounds of different origins.

Methane in the form of CaO·H₂O·CH₄ with water vapor and “lime milk” and a temperature of > 580 °C carries these and other components of the fluid over long distances, which mineralizes the porous cavities, different crack sizes, etc. With decreasing temperature are cured-cemented carbonates, which by their defects capture the carbonate-forming medium itself together with CH₄. Similarly, screens of traps are formed, in which oil and gas are stored to this day.

So, research has shown:
  * double abiogenic-biogenic nature of coalbed methane, while the abiogenic share predominates in the hermetically well-roofed-mineralized-cured coal seam and newly formed minerals and rocks may be under abnormally high pressure;
  * a previously unknown property of abiogenic methane-containing high-thermobaric fluid to decompose organic residues in the coal series with the formation of coal seams;
  * the statement that methane present in coal seams and surrounding rocks has only a biogenic origin is incorrect both theoretically and experimentally;
  * coal seams were formed under the influence of and with the participation of deep high-thermobaric methane-containing fluid.

As for the coal seam, methane with water vapor and “lime milk” in the form of CaO·H₂O·CH₄, embodied in sedimentary rocks with a strong layer of organic residues, subjected them to a powerful physicochemical effect. Since the methane-containing fluid was embodied in the region of organic residues with a temperature above 580 °C and adiabatically, the total initial temperature there increased abruptly to 700-800 °C. Due to the fact that the heating lasted for some time, the organic residues were also heated to temperatures much higher than the homogenization temperature of inclusions in the newly formed minerals, which were formed in the processes of stabilization of physicochemical conditions. At these high heating temperatures, the residues decomposed into carbon and volatile compounds: CO₂, H₂O, SpHm, N₂, H₂, H₂S, SO₂, etc., which at the initial stage were pushed out of the future formation until the stabilization of physicochemical conditions with compaction-mineralization of the surrounding contact rocks and coal formation. Since methane came from the rupture, its concentration in the direction of it should increase and ultimately be associated with the gas deposit-field [3, 6, 7]. Events in the mines of Zasyadko and Stepova confirm the obtained conclusions.

Coal deposits in the bowels of the earth contain maximum methane (CH₄) and minimum other volatile compounds, which in solving both the nature of coalbed methane and the establishment of physicochemical conditions for the formation of coal seams in the upper crust, do not play a significant role.

The existing long-term problem is successfully solved by the scheme developed by the author: a high-thermobaric deep fluid is embodied in gaps from deep into the upper layers of the earth’s crust, in which parts of the molecules are in this form of CaO·H₂O·CH₄. Due to the fact that these CaO·H₂O·CH₄ molecules are small, they initially migrate through loose rocks without obstacles, including peat, gradually heat its strata with the displacement of CO₂ and H₂O released from peat. In
parallel, Ca(OH)$_2$ will chemically interact with these CO$_2$ and H$_2$O released from peat and form carbonate molecules, which during stabilization of physicochemical conditions will cement the surrounding loose rocks and create hermetic traps in which the final masses of the embodied deep canned are preserved under considerable pressure, sealing in these strata as the coal deposits or deposits, and methane, and other substances in them, which under these conditions have survived to this day.

Thus, the previously unknown property of deep abiogenic methane-containing high-thermobaric fluid to decompose-convert natural organic residues into coal seams with their simultaneous methane saturation and its conservation in the earth’s crust has been established.

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