Journal of Environmental Science and Engineering A 11 (2022) 101-120
doi:10.17265/2162-5298/2022.04.001

The Controversial Genesis of Thermogenic Gas—A Polemical Article

Andrzej Pawuła
Institute of Geology, Adam Mickiewicz University, Senior Academic Lecturer, Poznań 61-712, Poland

Abstract: The article contains a critique of the biogenic theory of natural gas, which incorrectly combines the phenomenon of methane formation in the anaerobic process of decomposition of organic matter with the phenomenon of methane expulsion in the process of pyrolysis and cracking. The view of the organic origin of methane is treated as a paradigm, despite the lack of thermal conditions to induce expulsion. The mineralized organic substance for which the name "kerogen" was created undergoes the process of carbonization and this process, under the conditions of the deposit, is a one-way process. The paradox of the petroleum geology methodology is the determination of the oil potential from the TOC (Total Organic Carbon) in the rock. In reservoir conditions, methane is produced by chemical reactions of igneous gases, mainly hydrogen, carbon and oxygen. These elements are formed in the process of hot plasma recombination in zone D" and the formation of basalt magma. The change in the structure of matter causes stresses in the rock mass and the formation of igneous intrusions. After lowering the temperature of post-igneous solutions, the release of igneous gases and a rapid increase in pressure occurs. In the created dislocation zones tectonic pressure in natural gas deposits is more than twice the hydrostatic pressure. The process of the evolution of igneous gases and reactions between them are, among others, methane explosions in hard coal mines. The inorganic origin of methane also has a positive aspect, the conclusion is that natural gas resources are renewable and that they are ubiquitous.

Key words: Igneous intrusion, thermogenic gas, dry gas, reservoir brine, mineral deposits, phenomenon of plasma recombination.

1. Introduction

The biogenesis of crude oil and natural gas is treated in petroleum geology as a valid theory, despite the fact that many hypotheses about the origin of hydrocarbons appeared in the geological literature. The presence of methane in some volcanic gases as well as traces of crude oil in volcanic lava showed the igneous origin of bitumens and asphaltites in pegmatite veins. As a hypothetical source of hydrocarbons, reaction of metal carbides with water. The reaction of metal carbides with water was also assumed as a hypothetical source of hydrocarbons. The arguments that denied the abiotic origin of hydrocarbons were too little methane in volcanic gases and organic traces in crude oil. On the other hand, the justification of the biotic theory was the relationship between crude oil and natural gas with flammable shales and coal deposits, the organic origin of which has not been questioned. Therefore, it should have been assumed that all bitumens and natural gas were of organic origin.

Following the indications of the biotic theory, oil exploration was limited to the exploitation level, directly under the salt layer. Deeper ground zones and shale rocks were not taken into account in the oil exploration plans. The conventional model of a hydrocarb on reservoir, assuming a biochemical methane generation process, was limited to the following system: bedrock-reservoir rock-anticlinal trap (accumulation zone), under an insulating salt layer. In general, the pressure system determines the vertical migration of hydrocarbons and the accompanying brine. The consequence of the high formation pressure in the tectonic dislocation zone is the ascension of brine and hydrocarbons as well as radon areoles, indicating the presence of natural gas and crude oil deposits.

Corresponding author: Andrzej Pawuła, doctor of technical sciences, mining geologist engineer, research field: planetary geology, environmental engineering, radio-ecology, hydrogeology.

The discovery of natural gas, locked in shales and sandstones, sparked a revival of the discussion on the origin of hydrocarbons. At great depth, under oil deposits, the occurrence of natural gas was found, closed in poorly permeable structures, the origin of which cannot be explained by the traditional biogenic theory. The answer to the discovery of tight gas deposits was the correction of the hydrocarbon generation scenario (Fig. 1). To the biogenic gas formation stage and the crude oil generation stage, a third stage—methanogenesis (gas window) has been added. The generation zone of this gas, in the modified scheme, corresponds to the depth range of 4-6.5 km, where the temperature exceeds 120 °C, and the gas generating activity limit is 200 °C. Since it was not possible to identify the newly discovered closed gas with the biogenic gas of conventional deposits, the term “thermogenic gas” was introduced.

Both the determination of the genesis of methane as biogas as well as the phenomenon of subsidence of layers with organic matter (Fig. 1) are accepted uncritically. Meanwhile, the situational analysis of the Poznań Basin contradicts such views. The geological cross-section shows the displacements of the bottom of the basin, sedimentary, but uplifting. The formation of deposits, hydrocarbons, as well as deposits of salts and non-ferrous metals, shows full correlation with volcanic activity (Fig. 2).

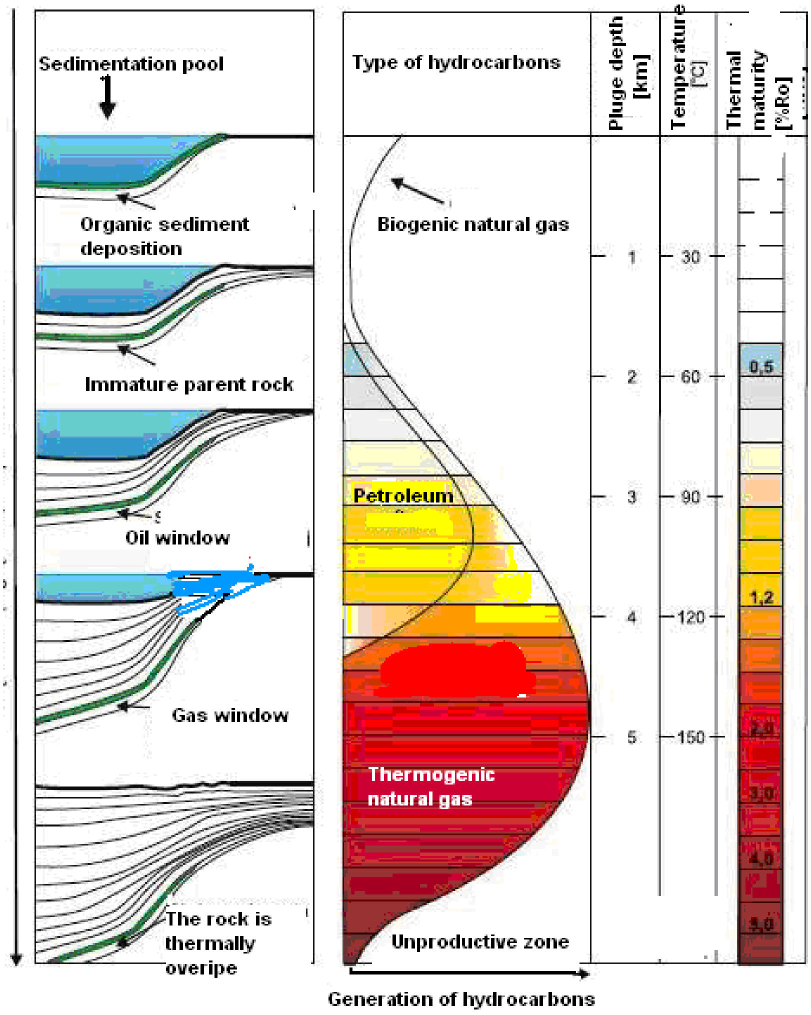

Fig. 1 Scheme of subsidence and hydrocarbon generation subsidence [1].

Comment to Fig. 1: Assumption of a constant lowering of the bottom of the sedimentation basin. A fictitious example, without explaining the reason forth.

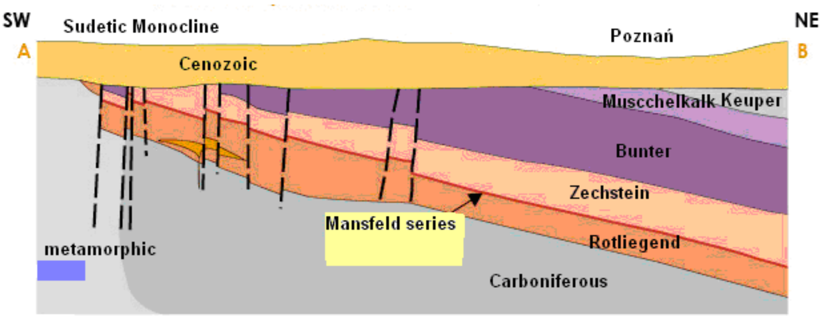

Fig. 2 Geological cross-section: Sudety Monocline—Poznań Basin.

Commentary on Fig. 2: Real Poznań-Sudetic Monocline sedimentary basin. There is no lowering of the subsoil, but the uplift of the mountain block (Sudetes) and the local increase in the density of the geothermal stream, a trace of the activity of igneous intrusion (Figs. 3, 4 and 5).

Thus, a paradox has arisen, the genesis of thermogenic gas is related to the bedrock layer, which is subject to the subsidence of the sedimentation basin. On the other hand, it is hypothesized that it is a mixture of "previously generated" crude oil and "newly formed" natural gas, which is a gaseous condensate derived from thermal cracking of already existing bitumens. Hypothesis about the share of "new" gas, condensate from thermal bitumen, ignores the fact that the temperature in the bed is much lower than the temperature required for the cracking process. As part of the research on unconventional natural gas deposits, an analysis of thermogenic gas was performed [1].

The discovery of dry methane, enclosed in shale and sandstone deposits, beneath petroleum deposits, led to a revival of the discussion on the origins of hydrocarbons. According to conventional views, however, no organic source has been found. Clinging to the bio-genetic theory, only the hydrocarbon generation scenario was revised. Thus, the third stage of the generation of "thermogenic" methane was drawn, which would be formed from liquid hydrocarbons. On the other hand, it is hypothesized that it is a mixture of "previously generated" crude oil and "newly-formed" natural gas, which is a gaseous condensate, derived from thermal cracking of already existing bitumens, The hypothesis about the share of "new" gas, condensate from the thermal treatment of bitumens, does not take into account the fact that the temperature in the bed is much lower than the temperature required for the cracking process.

In keeping with the biogenic theory, only the hydrocarbon generation scenario was adjusted. Thus, the third stage of "thermogenic" methane generation was drawn, which would be formed from liquid hydrocarbons (Fig. 1).

The chromatogram of this gas showed the presence of the gaseous alkanes: methane, ethane and propane, and smaller amounts of butane, pentane, hexane, and

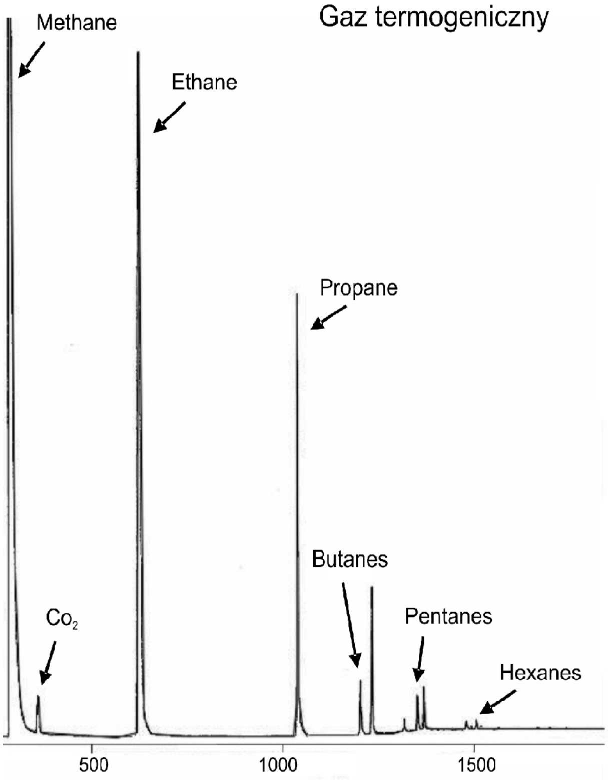

Fig. 3 Thermogenic gas chromatogram [2].

carbon dioxide. The thermogenic gas is therefore definitely a dry gas. In the classification of hydrocarbons, condensate gas is wet gas and occupies a position between dry gas and light crude oil. Therefore, the hypothesis that thermogenic gas is a condensing gas fails.

Traditionally, natural gas is made from kerogen. Most of the methane and higher gaseous hydrocarbons were produced in the early, low-temperature phase of thermogenic processes. The dolomites act as both the mother rock and the reservoir rock. Petrological studies indicate that the gas traps were already formed and sealed at the pre-microbial stage of metamorphosis of the fossil organic matter. These traps were successively filled with thermogenic hydrocarbons, which were formed at subsequent higher stages of the transformation of the same parent substance. On the other hand, the gas in a part of the deposit was produced from a different type of kerogen at a high-temperature stage of thermogenic processes and most likely came from Carboniferous deposits. Nitrogen, which is a component of gases, most likely was formed from the sea organic substance during its thermogenic transformation [4]. The complicated explanation of the formation of a biogenic gas deposit is unlikely and can be easily disqualified. Solving the problem and finding a convincing answer is not easy but possible. It is important to understand the phenomenon of spontaneous formation of a thermonuclear reactor in the Earth's core and the process of recombination of hot plasma, which produces basalt magma with an enlarged volume. The effect of the change in the structure of matter is the formation of tectonic fissures and igneous intrusion, as well as the separation of gases, which in chemical reactions create, among others, methane and water [5-8].

The phenomenon of transformation of alkanes leading to the formation of dry gas was investigated experimentally (Fig. 2). A sample of pure C3H8 propane was subjected to a pressure of 4,000 atmospheres at a temperature of 475 °C, which is similar to those at a depth of several kilometers. After several dozen hours, it was found that the propane had transformed into both lighter alkanes (CH_4 methane, C_2H_6 ethane) and heavier hydrocarbons (C_4H_{10} butane gas and C_5H_{12} liquid pentane). In conclusion, homogeneous dry gas inn oil field is a primary gas, not a transformed one.

The experiment confirms the possibility of transformation of alkanes under the influence of high pressures and temperatures. In the tested sample of pure propane, products of carbonization and decarbonization processes were obtained. The resulting gas composition corresponds to that of dry, thermogenic gas.

Under the influence of pressure and temperature, the carbon chain can be lengthened and the hydrogen atom removed. In the field of petroleum geology research, cracking and pyrolysis methods are used for sedimentary rocks containing kerogen. The cracking temperature (450-550 °C) corresponds to the methane synthesis reaction temperature (200-500 °C). In the pyrolysis process, the test sample is heated to 850 °C. Volatile hydrocarbons are released even at temperatures below 350 °C, and at a temperature of about 650 °C, hydrocarbons and carbon oxides are released from the most persistent fractions of organic matter. Further temperature increase to 850 °C causes the release of carbon dioxide from carbonate.

Based on these measurements, the content of organic carbon and the degree of maturity of the rock for the production of hydrocarbons are determined.

At the same time, the so-called maximum temperature $T_{\max}$ is determined, used to estimate the degree of maturity of organic matter. The hydrogen and oxygen index is also determined, indicating the type and origin of organic matter. The optimal degree of maturity of the parent rock for hydrocarbon expulsion, determined by the maximum temperature $T_{\max}$, is 436-496 °C [3]. When interpreting the measurements of carbon content, however, one should take into

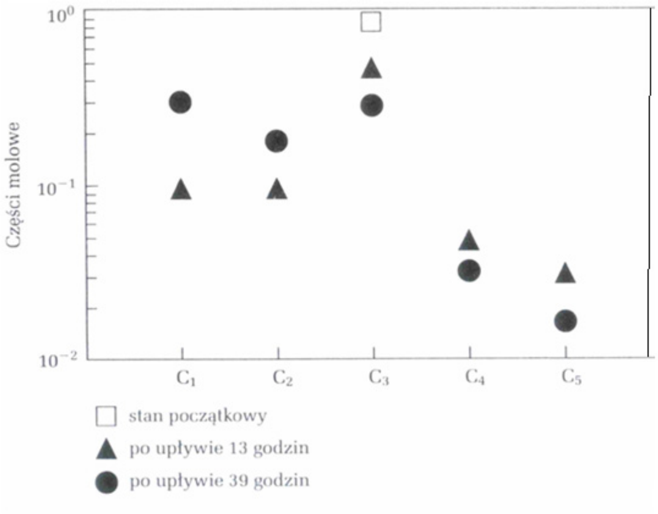

Fig. 4. Hydrocarbon transformation as a result of temperature and pressure changes [9].
On the vertical axis: minor parts; square: initial state; triangles: after 13 h; dots: after 39 h.

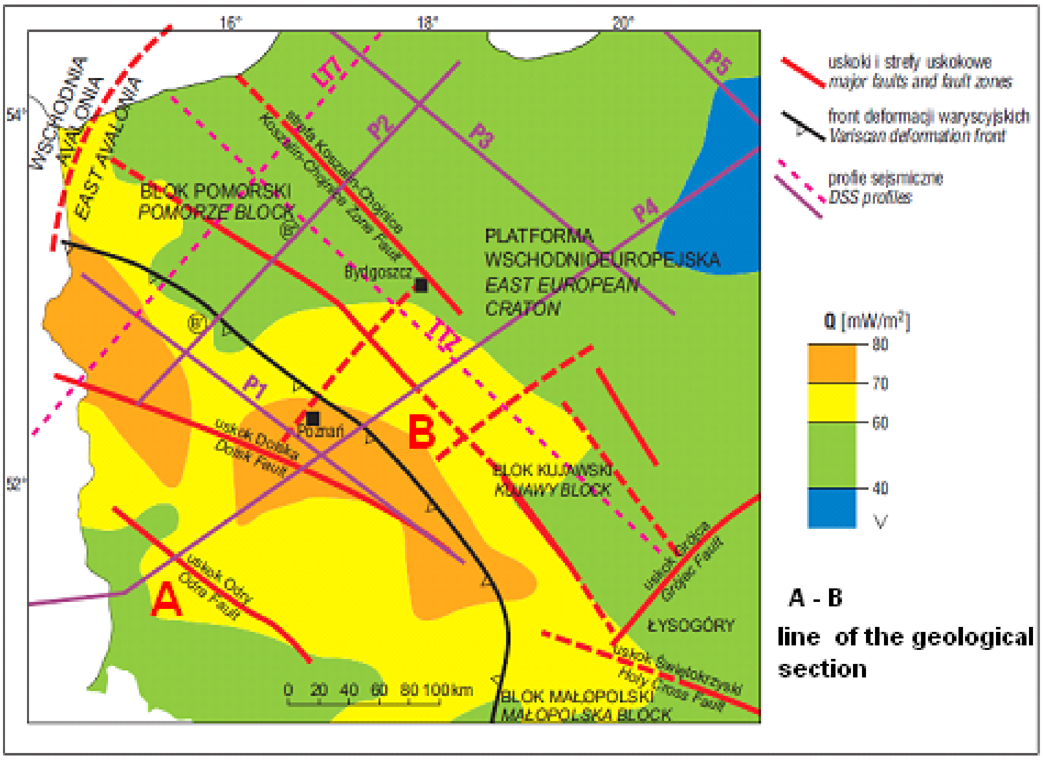

Fig. 5 Density of the geothermal stream in the western part of Poland [3]. Geological cross-section A-B: Sudety Monocline-Poznań Basin (Fig. 2).

Table 1 Carbonation index of alkanes (saturated hydrocarbons).

Distribution of alkanes	Summary formulas	C/H ratio
Gas (C -C_4)	CH_4-C_4H_{10}	0.25-0.40
liquid (C_5 -C_{17})	C_5H_{12}-$C_{17}H_{36}$	0.416-0.472
solids (C_{18}-C_{38})	$C_{18}H_{38}$-$C_{39}H_{80}$	0.473-0.487

account the fact that in the determination of carbon by the TOC (Total Organic Carbon) method, elemental carbon was mistakenly included in the organic carbon group[1].

The phenomenon of hydrocarbon expulsion from kerogen-containing rocks relates to laboratory or industrial conditions aimed at obtaining hydrocarbons from mined bituminous shale. Such temperature does not occur in the conditions of the deposit. The kerogen created from methane carbonization is stable and does not change under the conditions of the deposit. The stated amount of organic carbon is therefore only an assessment of the potential productivity of hydrocarbons and not the resources that can be obtained under the conditions of the deposit. At the same time, it should be assumed that in sedimentary rocks, whose age is determined at millions of years, the process of mineralization of the organic substance has been completed. Detailed geochemical studies of kerogen in sedimentary rocks and determination of the parentage of these rocks as well as determination of the oil potential of the deposit [4] do not negate the thesis about the inorganic origin of hydrocarbons. The assessment of the deposit conditions shows that the dry thermogenic gas is of inorganic origin and is generated in the process of post-magmatic gas synthesis. As a confirmation of this conclusion, the lack of natural gas in rocks with high oil potential can be considered. Geochemical studies with the use of cracking and pyrolysis methods show only theoretical possibilities of hydrocarbon expulsion from the rock.

The presence of thermogenic gas does not depend on the presence of kerogen in rocks, because this gas comes from a different source. This is because methane is generated, at greater depth, in the synthesis of magmatic gases. This explains the presence of natural gas deposits in the aeolian sandstones and the opposite, where kerogen is abundant and gas is absent. The presented arguments allow the conclusion that not only thermogenic gas but also conventional gas and crude oil are of inorganic origin. The presence of biogenic gas is limited to the near-surface zone. Hydrocarbons occurring under conditions of high reservoir pressure, under a tight salt layer, do not come into contact with the surface area, and the hydrochemical index of reservoir brine $r_{\mathrm{Na}}/r_{\mathrm{Cl}} < 1$ provest.

2. Arguments of the Igneous Origin of Hydrocarbons

The abiotic theory proves that the source of the carbon atoms that make up the structure of the hydrocarbon molecule in gas and oil deposits is coal from post-magmatic gases. An objection to the theory of the inorganic origin of bitumens was the presence of hopanoids in oil deposits. The presence of traces of living organisms in crude oil was considered to be evidence of its organic origin. The abiotic theory refutes this argument because it does not exclude the presence of biological material in oil deposits. There is evidence that methanotrophs can feed on hydrocarbons of inorganic origin, leaving traces of their activity.

An example is the organisms living at the sources of hot help solutions in the rift zone, at the bottom of the ocean (Hydrothermal black smoker chimney). In the solution at a temperature of about 400 °C, the presence of methane, hydrogen gas, carbon monoxide and ammonia as well as sulfur compounds in the form of hydrogen sulfide and heavy metal sulphides was found. Despite this, there are organisms whose life processes are based on chemosynthesis. The second allegation that there was too little methane in the volcanic gases was also rebutted. The lack of methane in volcanic gases is explained by its combustion during a volcanic eruption, and the trace of this reaction remains in the form of water vapor.

---

[1] For many years, the chemical determination of carbon forms was carried out using the wet method with the use of acids or indirectly through the determination of inorganic carbon. Apart from the disadvantages associated with the use of acids, this method introduced a systematic elemental carbon error (EC). Elemental carbon has always been miscalculated as TOC (Total Organic Carbon) Source.

The process of methane synthesis in the reaction of hydrogen with carbon monoxide, known since 1902, is an important argument in the discussion of the genesis of hydrocarbons. The first experiment concerned the synthesis of methane in a catalytic reaction with nickel at a temperature of 200-300 °C. Paul Sabatier and Jean-Baptiste Senders synthesized methane from a mixture of hydrogen and carbon oxides, in the presence of nickel, at a temperature 200-300 °C [10].

$$CO + 3H_2 \xrightarrow{Ni} CH_4 + H_2O$$

The second method of obtaining methane concerned the reaction of elemental carbon with hydrogen, which took place at a temperature of 500 °C:

$$C + 2H_2 \rightarrow CH_4$$

Hydrocarbon synthesis reactions have been the subject of research by the Institute of Organic Chemistry and Technology of the Cracow University of Technology [15] (Figs. 6, 7 and 8). The research concerned the thermodynamics and kinetics of the hydrocarbon synthesis reaction from carbon and hydrogen oxides. In the reactions of carbon monoxide and hydrogen, which are dominant compared to the reaction of hydrogen with carbon dioxide, where n is the number of carbon atoms in the molecule: $nCO + (2n+1)H_2 \Leftrightarrow C_nH_{2n+2} + nH_2O$

The purpose of the first plot is to determine, for alkanes the temperature above which the synthesis reactions cannot take place. The critical point is the parameter ΔG^o, which means free enthalpy. According to the second law of thermodynamics, all spontaneous processes are irreversible. The lower the ΔG^o value, the more durable the relationship. A negative value of ΔG^o indicates that the reaction (A→B), under standard conditions, is spontaneous. A positive value, ΔG^o indicates that this reaction is impossible. As the number of carbon atoms in the molecule increases, the temperature increases, above which the free energy value of the corresponding synthesis reaction becomes a positive value, i.e. the reaction ceases to be spontaneous.

On the example of the synthesis of saturated hydrocarbons from the H_2/CO_2 mixture, at high temperatures, obtaining lighter compounds within one group of homologues is more privileged than the heavier synthesis products. At low temperatures, the tendency of changes is opposite, the reactions of heavy hydrocarbons formation are more pronounced. A clear increase in the intensity of spontaneous synthesis reactions is marked below the temperature of 523K.

At high temperatures, obtaining lighter compounds within one group of homologues is preferable to heavier synthesis products, as opposed to low temperatures, where the tendency is opposite.

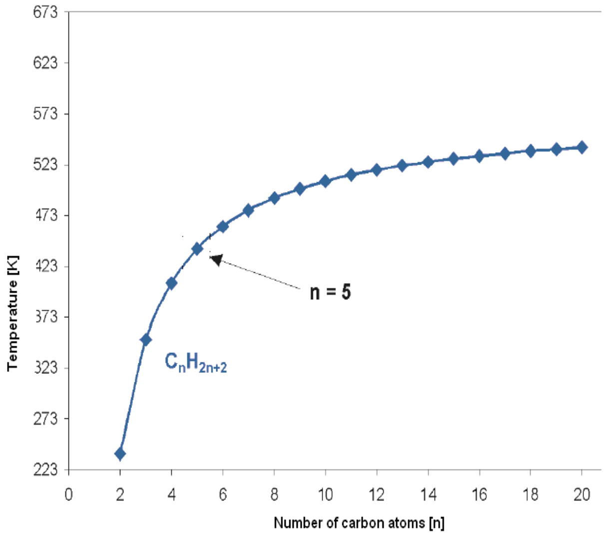

Fig. 6 The relationship between the number of carbon atoms in an alkane molecule and the temperature above which ΔG^o (kJ/mol) becomes greater than zero [11].

Table 3 The temperature above which a spontaneous synthesis reaction is impossible.

Alkane name	Summary formula	Temperature* below which $\Delta G^o < 0$
Ethan	C_2H_6	-40 °C
Propane	C_3H_8	+80 °C
Butane	C_4H_{10}	+130 °C
Pentane	C_5H_{12}	+180 °C
Dekan	$C_{10}H_{22}$	+240 °C
Eikosan	$C_{20}H_{42}$	+280 °C

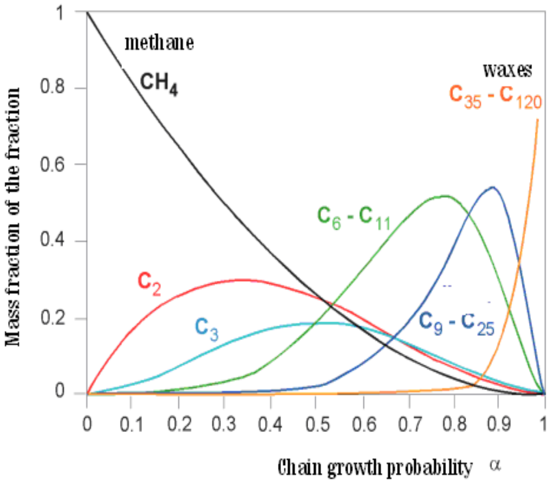

Fig. 7 Distribution of hydrocarbon synthesis products according to the Anderson-Shulz-Flory model [11].

Heavier hydrocarbons are synthesized by hydrogenating carbon monoxide. The picture of the transformation of hydrocarbons, starting from gaseous C_1 methane to the solid C_{120} wax shown in Fig. 7, is explained by the authors of the research as follows: "Both the increase in pressure and the increase in the H_2/CO_2 ratio will favor the formation of heavier synthesis products. Under the process conditions, larger molecules are not formed directly from H_2/CO_2 mixture, but due to the gradual increase in the hydrocarbon chain. The final composition of the synthesis products will correspond to the so called ASF decomposition (Anderson-Schulz-Flory), described by the equation $Wn = n (1- \alpha) 2\alpha n-1$, where Wn is the weight of the product is at carbon atoms, and α is the chain growth probability. A graphic representation of this equation shows the predicted distribution of the most important products."

The genesis of thermogenic gas can be explained by the synthesis of methane in the reaction of hydrogen and inorganic carbon. The comparison of the composition of volcanic gases, hot gas springs and natural gas indicates a common source of origin and shows the presence of components involved in the generation of methane, i.e. hydrogen and carbon oxides. Methane is formed in the synthesis of hydrogen, carbon and carbon oxides under conditions of high temperatures and high pressure. The methane generation process takes place in two post-magmatic stages, pneumatolytic and hydrothermal, according to Niggli's scheme. Assuming a linear increase in temperature in the lithosphere and assuming a geothermal degree of 30 m/°C, the following scenario of methane generation and the formation of natural gas deposits can be predicted: gases from post-magmatic solutions and pressure increase in the rock medium. It is the first phase of methane generation. The chemical reaction of elemental carbon with hydrogen produces methane and its homologues, which form a dry gas. Therefore, it is justified to call dry gas thermogenic. If the blast gases meet semipermeable rocks, they enter the pore space of the rock, elemental carbon and hydrogen, and then form methane particles in accordance with the reaction presented above. The resulting methane particles, due to their geometrical dimensions, are trapped in the rock, creating a closed gas, dry-type bed, devoid of underlying water. $C + 2H_2 \rightarrow CH_4$

The next reactions take place at a lower temperature (200-300 ° C) at a depth of 6-9 km:

$$CO + 3H_2 \rightarrow CH_4 + H_2O$$

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

The second phase of methane generation (hydrothermal stage according to Niggli) is accompanied by the formation of liquid hydrocarbons (wet gas) and juvenile water, which together with other components of the post-magmatic solutions forms the reservoir brine. During migration, hydrocarbons accumulate in the traps of semi-permeable rocks, creating unconventional closed deposits, or they accumulate in anti-clonal traps, creating conventional deposits.

The general assessment of natural gas resources, broken down into types of deposits and gas types, is characterized by the graph which shows that the resources of unconventional gas deposits exceed the resources of conventional deposits many times over. Among unconventional deposits, the largest resources

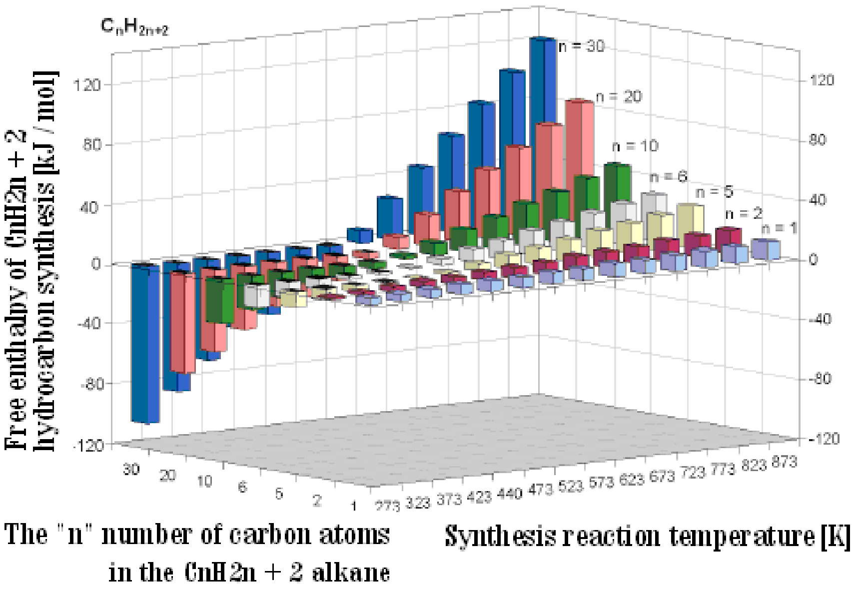

Fig. 8 Relationship between temperature and number of carbon atoms [11].

are found in methane hydrates, and then in bituminous shales. The next place is gas closed in sandstones. The increase in natural gas resources along with the depth proves that the source of methane is magmatic gases. The conducted research [11] showed, theoretically and experimentally, the possibility of generating hydrocarbons through the synthesis of hydrogen, as well as carbon monoxide and dioxide.

3. Relationship of Hydrocarbons with Reservoir Brine

The formation of juvenile water in the hydrocarbon synthesis reactions is also the basis for formulating the genesis of the reservoir brine. The abiotic theory recognizes this problem, the solution of which leads to a change in the stereotypical view of brine as "Zechstein salt lyes" [12]. A characteristic phenomenon related to the generation of methane and affecting the direction of migration of hydrocarbons and reservoir brine is reservoir overpressure. The phenomenon of overpressure observed in Permian natural gas deposits in the tectonic dislocation zone [1] is most likely caused by the impact of the pneumatological post-magmatic process, located at a depth of 12-18 km (Table 2). The normal formation pressure gradient is in the range of 1.0-1.25 atm/10 m, while in the tectonic dislocation zone it increases to 2.25 atm/10 m. This means that the formation pressure is more than twice as high as the hydrostatic pressure. This pressure system occurs in a large area of the Polish Lowlands.

The brine accompanying hydrocarbon deposits penetrates the rock layers of the overburden under high pressure. Mineral compounds present in the solution undergo selective precipitation and create zones of clogging. In turn, these zones, which hinder the migration of brine and auxiliary gases, create a closed gas trap (Pressure Seal). Thermogenic gas traps are associated with limited rock permeability and primarily affect shale rocks as well as sandstone formations.

The fissures formed in the tectonic dislocation zones are paths of facilitated migration and are the cause of the formation of pressure anomalies above the clogged zone. In the central part of the Poznań Basin, the ceiling insulation layer consists of layers of Zechstein anhydrite and gypsum as well as rock salt, occurring in the depth range of 2,636-3,393 m. In addition, anhydrite and gypsum inserts occur in Triassic claystones, in the depth range of 1,406-2,636. The total thickness of the insulating layer is therefore 2,000 m. Assuming the evaporative genesis of the salt structure, the oldest layers are in the floor and the youngest in the roof of this structure.

Adopting the magmatic genesis of methane and brine changes the interpretation of the formation of the salt structure. The magmatic genesis of Zechstein salt and reservoir brine leads to the conclusion that the leaching of Zechstein salts does not occur, but the reverse process, precipitation of salt from the hot solution. An unequivocal answer about the age of each layer and its position in the cyclothem can be obtained by dating rocks using the presence of uranium, thorium and potassium in them.

The pressure system is an argument justifying the conclusion about the formation of a salt structure in the process of salt precipitation from the brine, and not in the process of evaporation of sea water. At the level of the main dolomite (depth zone 3,021-3,051 m), the formation pressure is very high and ranges from 607 to 754 atm, so it is twice as high as the hydrostatic pressure. With such a system of pressures, it is impossible to descend the water and thus the leaching of the structures by atmospheric waters is excluded. The genesis of brine is generally associated with the leaching of salt structures, high reservoir overpressure, however, excludes such a possibility in the area of the Polish Lowlands, where there are high pressure gradients. The brine, occurring in the Zechstein Dolomite and the Red Landing Sandstone of the Poznań Basin, is characterized by the metamorphic index $r_{\mathrm{Na}}/r_{\mathrm{Cl}} \approx 0.50$. Such a low value of the genetic index of brine characterizes closed geological structures [13].

As part of the research on the radioactivity of natural gas, at Laboratoire de Physique Subatomique in Nantes analytical tests of brine from the production well in Piekary, near Poznań, were performed. The mineral composition and the content of radioactive isotopes in the reservoir brine were tested. The sample was taken from the depth of 2,900 m. The chromatographic analysis showed high concentrations of strontium and bromine, calcium, iron and copper for the selected spectrum from 0 to 23 keV (medium elements) (Fig. 9).

The presence of copper in brine at a temperature of 100 °C is associated with the copper-bearing shale layer in the base of the Zechstein salt series. The brine accompanying natural gas deposits contains minerals of igneous origin, including copper. The rock mineralization process is still active, as shown by the studies in the Sieroszowice S-1 borehole [14]. In the mineralization zone, including the lower part of the Zechstein limestone layer (thickness 2 m), the copper-bearing shale layer T1 (thickness 1 m) and the underlying layer of the white floor standing Bs (thickness 1 m) there are metals: copper, zinc, lead, cobalt, molybdenum, nickel. It should be noted that the mineralization covers not only the shale rock layer but also the lower part of the basic limestone. It

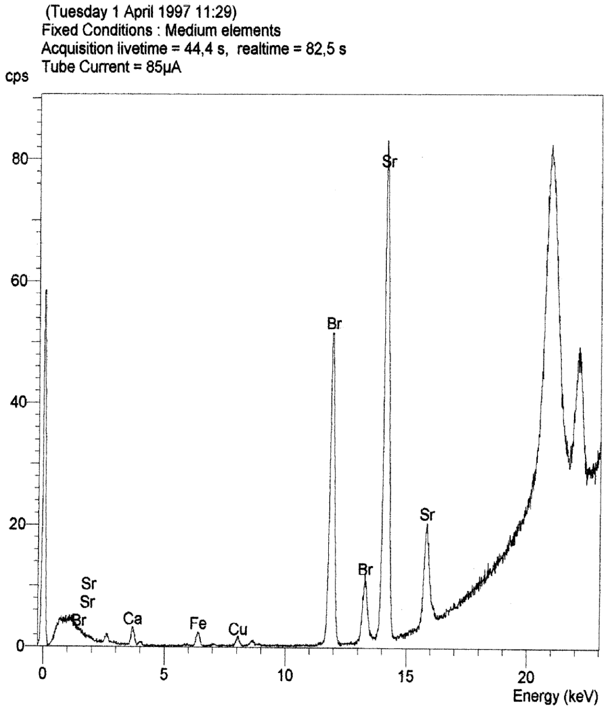

Fig. 9 Chromatographic analysis of Zechstein brine from Piekary near Poznań [Laboratoire de Physique Subatomique, Nantes].

proves the continuous activity of the process of minerals precipitation from the brine and formation of the salt structure. However, tectonic dislocations and framework structures in the geological cross-section indicate the syngenetic nature of the deposit. The Zechstein copper-bearing series is also found in the central part of the sedimentation basin.

The second fact that proves the active process of precipitation of mineral compounds from the brine is the detection of igneous radionuclides in the brine and rocks. In the studied sample of Zechstein brine from Piekary near Poznań (analyses were performed at Laboratoire de Physique Subatomique in Nantes), radionuclides from the following series were detected:

- uranium-radium: radium Ra-226, lead Pb-214, bismuth Bi-214 and lead Pb-210;
- uranium-actinium: uranium U-235, radon Rn-219 and bismuth Bi-211;
- thorium: actin Ac-228, radium Ra-224 and lead Pb-212;
- a separate radioactive potassium isotope K-40 and mercury were detected.

However, no primary isotopes were detected in these series: uranium U-238 and thorium Th-232 [17] Supplementary material that explains the lack of uranium U-238 and thorium Th-232 in the brine is the results of the content of these primary radionuclides in Triassic, Permian and Carboniferous rocks. It can be concluded that the primary isotopes of uranium U-238 and Th-232 thorium precipitated from the brine at the optimal temperature of 100 °C. This confirms the thesis about the process of metal and salt precipitation from brine and the origin of salt structures from this process.

The discussion on the genesis of hydrocarbon deposits and reservoir brine is important not only for the rationalization of the exploration and development program for these deposits, but also for the verification of global geotectonic theories. The presented thesis about the igneous origin of crude oil and natural gas as well as reservoir brine is associated with a more general problem, the causes of geological activity. The reason lies in the center of the Earth, in thermonuclear reactions. The phenomenon of the formation of thermonuclear reactors is explained by the theory of the primal forces of nature, universal gravity, electromagnetic forces and nuclear forces. The consequence of gravitational accretion of the globe is an increase in the density of matter, an increase in temperature and ionization. Initially, a low-temperature plasma is formed, the electromagnetic properties of which create a magnetic field. As a result of the increase in temperature, ionized matter particles collide and hot plasma is formed, the surplus of which is expelled outwards, where it forms atomic matter. Basalt magma is such matter. The dominant light nucleons in the plasma: hydrogen, carbon, nitrogen and oxygen, form volcanic gases and as elements react with each other, forming chemical compounds, first of all methane.

Therefore, a different scenario of shale gas formation than in the case of biogenic gas is probable: At a depth of approx. 12-18 km, at a temperature of 400-600 °C, there is a rapid release of gases from the blasting solutions and pressure increase in the rock medium. The post-chamber gases penetrate the encountered rocks and take part in mutual reactions and metasomatic processes. At a temperature of about 500 °C, chemical reactions of elemental carbon and carbon monoxide take place with hydrogen, the product of which, in the first case, is only methane. If the post-blasting gases meet semi-permeable rocks, a special case of penetration into the pore space of the rock—elemental carbon and hydrogen, and then formation of methane particles in accordance with the reaction presented above is possible. The resulting methane particles, due to their geometric dimensions, are trapped in the rock, creating a closed gas, dry-type bed, devoid of underlying water. In the event of encountering rocks with good permeability, the gases migrate and, under their characteristic conditions, take part in the exchange and deposition reactions.

The migrating carbon monoxide reacts with the hydrogen to produce methane and water. Water, along with other minerals, forms the brine. The effectiveness of methane and brine migration depends on the porosity and permeability of these rocks [17]. So shale gas and conventional natural gas come from the same source, the difference between them is in the type of reservoir rock. Conventional natural gas occurs from reservoir rock, most often in sandstones, with good reservoir and filtration parameters. The porosity of the reservoir rock exceeds 15% and the threshold diameter, determining the permeability of the medium, is greater than 20 μm (2E-5 m). The threshold diameter determines the pore size at which the continuous flow of fluid begins. The gas particles are several orders of magnitude smaller and can easily penetrate the rock. Therefore, the formation of a conventional natural gas deposit requires the creation of a top insulation layer in the form of a salt structure. Mineral compounds present in the brine precipitate under appropriate conditions and cause cementation of the pore space of the reservoir rock.

The rocks are clogged with clay minerals, calcium carbonates and sulphates, and then with sodium and potassium chlorides [16]. The migration or blockage of gas molecules depends on their size and dimensions *p*. Shale rock corresponds to the filtration conditions of a semi-permeable rock. The porosity of semi-permeable rocks exceeds 10% and the threshold diameter is in the range of 1-10 μm (1E-6~10E-6 m). In rocks with such permeability, methane molecules with a bond length of 3.5E-9 m have migration difficulties. Semi-permeable rocks with a porosity of less than 10% and a pore diameter in the range (1E-6~1E-5 m) allow for the transport of H_2 hydrogen molecules (2.5E-10 m) and carbon monoxide CO (1.13E-10 m), but they retain CH_4 methane molecules (1E-5 m). The diameter of the CH_4 methane molecule is ten times larger than that of carbon monoxide CO (1.13E-10 m), hydrogen H_2 (2.3E-10 m) and even the water molecule H_2O (2.6E-10 m). Impermeable rocks are rocks with a porosity below 10%, a pore diameter of less than 3 μm (3E-6 m) and zero permeability. Under these conditions, the flow in the pore space is only diffusive. Semi-permeable rocks with a porosity of less than 10% and a pore diameter in the range (1E-6~1E-5 m) allow for the transport of H_2 hydrogen molecules (2.5E-10 m) and carbon monoxide CO (1.13E-10 m), but they retain CH_4 methane molecules (1E-5 m).

As the research results show, the formation pressure depends on the contact with the zone of gas evolution from the post-treatment solutions. The probability of the pneumatolytic effect is confirmed by the anomalous formation pressures in the tectonic dislocation zone [17]. The normal formation pressure gradient is in the range of 1.0-1.25 atm/10 m, while in the tectonic dislocation zone it increases to 2.25 atm/10 m. This means that the formation pressure is more than twice as high as the hydrostatic pressure. Such a system of pressure occurs in a large area of the Polish Lowlands and is clearly related to the distribution of salt structures (Fig. 10).

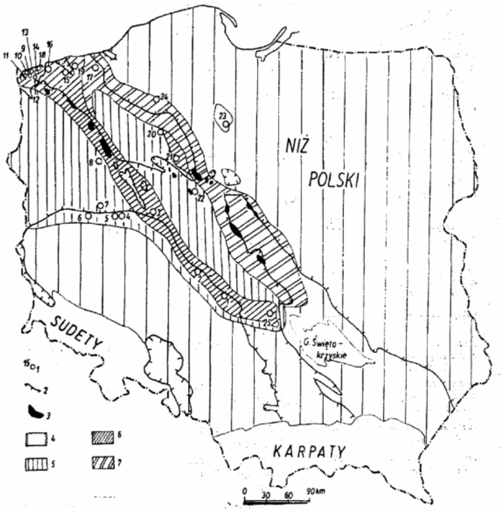

Fig. 10 Map of formation pressures [17].

1. boreholes;
2. limit of the Cretaceous;
3. salt structures;
4. pressure gradients 1.0-1.25 atm/10 m;
5. pressure gradients 1.25-1.50 atm/10 m;
6. pressure gradients 1.50-1.80 atm/10 m;
7. pressure gradients 1.80-2.25 atm/10 m.

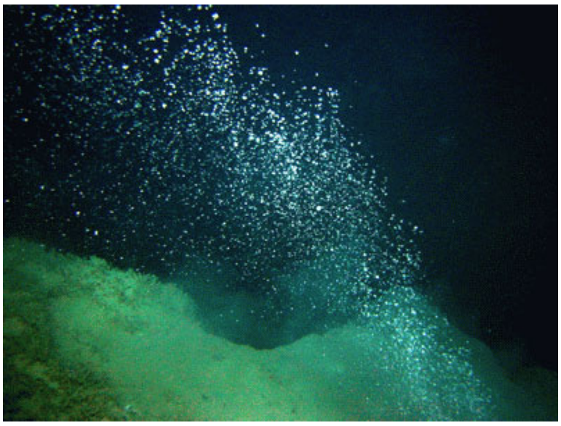

Fig. 11 Submarine jets of methane (National Oceanographic Data Center).

The cause of the formation pressure anomaly may be the easier contact, through fault fissures, with the deeper ground, where pneumatolytic processes are probably taking place at a depth of 12 km. In the pneumatolytic phase, the water formed appears in the form of steam and in the hydrothermal phase, at temperatures below 400 °C, it condenses. If the reaction of methane formation takes place in rocks with good porosity and good filtration conditions, natural gas and brine accumulate in structural traps, under the salt insulating layer.

In the central part of the Poznań Basin, the ceiling insulation layer consists of layers of Zechstein anhydrite and gypsum as well as rock salt, occurring in the depth range of 2,636-3,393 m. In addition, anhydrite and gypsum inserts occur in Triassic claystones, in the depth range of 1,406-2,636 m. The total thickness of the insulating layer is thus almost 2,000 m.

In conclusion, it can be concluded that the methane present in natural gas deposits comes from igneous solutions. It is formed by chemical reactions from hydrogen and elemental carbon or carbon monoxides. Methane, like other alkanes, undergoes the carbonization process and the process is unidirectional. This means that the carbon chain grows larger and does not shorten. Under log conditions, methane forms waxes, bitumens, asphalts, and there is no vice versa. Therefore, the assessment of the amount of organic matter TOC cannot be used to assess methane resources. The methane in natural gas deposits comes from a different source!

4. Discussion about the Origin of Mineral Deposits

I recently participated in a scientific meeting where petrographic research on copper deposits was recently presented. For uninitiated readers, I will add that apart from copper, these deposits also contain silver, gold, platinum and many other elements. The microscopic images of the minerals were interesting and one of them added a comment that probably this mineral was formed under reducing conditions, with the participation of bacteria in an anaerobic environment. After the lecture, a discussion on the genesis of these minerals began. Two opposing views emerged, one about the evaporation of seawater and the other about the precipitation of minerals from hot igneous solutions. I noticed that already 60 years ago, during the deposit geology lectures, I heard about this dispute about the conditions for the formation of copper deposits. It seems that establishing the truth does not matter much. In fact, the determination of the actual conditions for the formation of mineral deposits has an impact on the deposit search methodology and the maintenance of the logical order. This is important in terms of professional ethics or simple honesty.

The difference of views on the specific phenomena, which is the formation of different types of deposits, results from the adoption of different general assumptions. In short, the interpretation of the specific conditions depends on the acceptance or negation of the thermonuclerotic georeactor in the Earth’s core. In discussions with professors of physics, I encounter negation or doubts about the formation of such a reactor. There are theoretical arguments that deny the possibility of a thermonuclear reactor forming on Earth. I oppose, I refuse, a strong justification for the existence of such a reactor [6].

By denying the existence of a thermonuclear reactor in the center of the Earth, the appearance of juvenile matter in the rock cycle is excluded. At the same time, there is a logical contradiction in the interpretation of the origin of the brine and salt deposits. In the traditional interpretation, the reservoir brine comes from the leaching of salt structures. The term "Zechstein" salt is taken for granted. The monograph regional hydrogeology states that "Leaching of salt structures in zones where contact with modern or older waters from precipitation infiltration is possible, is the cause of chloride-sodium mineralization of groundwater". In other publications on brines and mineral waters, the Geological Institute informs: "In the area of the Precambrian and Palaeozoic platform, a significant part of brines owes their formation to leaching (dissolving) of Zechstein salt structures by groundwater from the infiltration of atmospheric precipitation (modern or older)". However, a more detailed analysis of the deposit conditions precludes such an interpretation. Very high pressure, twice the hydrostatic pressure, excludes the inflow of waters from Cenozoic levels.

Logical is an alternative interpretation based on the theory of expansion and the hypothesis of the creation of basalt pramagma, according to which the brine in natural gas deposits is a post-treatment solution. The genesis of brine and methane is explained by the synthesis reaction of igneous gases, hydrogen and carbon monoxide. The presence of trace elements, including heavy metals of uranium and thorium, confirms the igneous origin of hydrocarbons and reservoir brine.

As it cools, the various minerals that make up the deposits selectively separate. The remaining brine and the gases dissolved in it migrate towards the surface. The differentiation process of magma and post-treatment solutions increases the concentration of elements precipitating at low temperatures, mainly uranium and mercury. Igneous gases and thermal waters penetrate the surrounding rocks and create deposits of various elements within the igneous intrusion, in the surrounding rocks or in tectonic crevices. Crystallization of uranium oxides occurs only in the hydrothermal phase, below the temperature of 400 °C. During migration, hydrocarbons accumulate in the traps of semi-permeable rocks, creating unconventional closed deposits, or they accumulate in anti-clonal traps, creating conventional deposits. We can conclude that the source of methane-forming gases and mineral compounds is inexhaustible and the resulting deposits are renewable. Helping processes last all the time and the stages of this process depend on temperature and pressure.

Hydrocarbons are present under a tight layer of salt, they do not come into contact with the surface zone. High formation pressure excludes not only the possibility of natural gas moving deeper into the surface in accordance with the subsidy pattern, but also excludes the process of leaching of salt deposits by fresh waters from the ground surface. The consequence of the high formation pressure is the brine assessment and traces of bitumens near the ground surface. It can therefore be argued that the surface hydrocarbons are also of igneous origin. High formation pressure excludes the possibility of surface water infiltration into Zechstein structures and leaching of salt deposits. Zechstein brine, at a depth of about 3 km, contains besides sodium, calcium and magnesium chlorides, nitrogen gas, carbon dioxide, hydrogen sulfide, hydrogen, helium and radon, as well as heavy metals mercury and transuranides. This confirms the thesis about the precipitation of metals and salt from brine. Uranium and mercury compounds remain in the brine, because the optimal uranium precipitation temperature is around 100 °C, and 50 °C for mercury. Thus, not only mercury and uranium come from post-treatment solutions, but also other ores, and the brine itself is of igneous origin. Copper, other ores and salts constituting the mineral suit of the deposit brine migrate towards the ground surface, overcoming filtration obstacles and successively creating mineral deposits.

The hot brine migrates under tremendous pressure. In the zone of tectonic faults, there is hydraulic contact with the area of the pneumatolite phase, located at a depth of several kilometers. At a depth of 3 km, the formation pressure is twice as high as the hydrostatic pressure. The brine penetrates the roof rocks and the minerals dissolved in it selectively precipitate from it.

The mineralization zone above the red sandstone sands includes a slate layer and a fragment of basic limestone. It should be noted that the mineralization covers not only the shale rock layer but also the lower part of the basic limestone. This indicates the penetration of all rocks by brine containing these metals, which is under high pressure. This proves the continuous activity of the process of minerals precipitation from the brine and formation of the salt structure. It can be seen that the mineralization does not depend on the type of rock, but is a subsequent process, depending on the penetration of the brine migrating upwards. In the mineralization zone, including the lower part of the Ca1 Zechstein limestone layer (thickness 2 m), the copper-bearing shale layer T1 (thickness 1 m) and the underlying layer of the white floorstand Bs (thickness 1 m) there are metals: copper, zinc, lead, cobalt, molybdenum, nickel. The salt roof layers sealing the Zechstein natural gas field are over 100 m thick. These are not salts resulting from the evaporation of seawater, but the salts precipitating from the help brine.

The presence of mercury and uranium in natural gas and reservoir brine is the crowning proof of the post-smelting origin of methane in the Greater Poland deposits. Both heavy metals come from post-treatment solutions. By asking a simple question why there is mercury and uranium in natural gas, we got the answer that heavy metals, such as mercury and uranium, come from post-magmatic solutions, just like other ores, salts and methane. In the post-treatment process, juvenile water is also created, which together with dissolved minerals is a reservoir brine. The pressure in the deposit is high, twice the hydrostatic pressure, which excludes the leaching of Zechstein salts and the deep direction of hydrocarbon migration.

5. The Probability of Thomas Gold's Hypothesis on the Biotic Genesis of Carbon

The astrophysicist Thomas Gold (1920-2004) made an attempt to formulate the "theory of deep-earth gas" and link it to the genesis of hard coal [9]. Gold does not discuss the issue of matter creation, but does comment on the origin of hydrocarbons and the interrelationship between methane, crude oil and hard coal. He presents an abiogenic theory of the origin of carbon compounds. According to the commonly accepted view, hard coal is an organic sedimentary rock, formed from the carbonization of plant debris. The argument of the supporters of the biotic origin of coal, that fern leaves are found in coal, can be easily refuted. It is impossible for such delicate parts of plants as fern spores to be preserved under the high temperature conditions of the contact metasomatosis process. The presence of carbonized plant leaves in coal can be explained by a process similar to the silicification of wood, in which silica is substituted for cellulose. According to the abiogenic theory, hard coal was not formed from the carbonization of plant matter, but crystallized from inorganic methane in the natural environment and with the participation of methanotrophic bacteria.

So far, the carbon isotope index $^{12}C/^{13}C$ has been used to determine the origin of carbon. The argument for the biogenic origin of carbon was the similarity of this indicator for carbon and plant biomass. However, a more detailed analysis of this indicator questions its reliability. For example, the similarity of indices exists between diamond and atmospheric carbon dioxide, which shows that such comparisons are random.

The carbon isotope index method does not exclude Thomas Gold's hypothesis. Using the $^{12}C/^{13}C$ ratio, one can find a justification for the relationship of methane, crude oil and carbon: Carbon is the fourth most abundant element in the Solar System, only hydrogen, helium and oxygen are ahead of it. On the planets of the solar system, carbon exists mainly in the form of compounds with hydrogen. Depending on the temperature and pressure, hydrocarbons can take any state of aggregation: gas, liquid or solid.

It should be noted that methane, crude oil and hard coal are compounds of elemental carbon and may be transformed in chemical reactions, or, which is more likely in biogeochemical reactions, involving microorganisms, e.g. methanotrophs. According to Thomas Gold, methane and crude oil come from great depths (100-300 km) and as the gases rise inside the magma, a chemical equilibrium between hydrocarbons and magma is achieved, and this usually promotes the oxidation of gaseous hydrocarbons (Gold, 1999). The violent oxidation process occurs at the time of a volcanic eruption, hence it can explain why volcanoes usually emit carbon mainly as CO_2 and only a small part as methane (CH_4). The conducted tests showed the presence of methane and paraffinic hydrocarbons, carbon oxides, hydrogen, hydrogen sulphide, nitrogen, helium, mercury and radon in natural gas. The volcanic gas is dominated by water vapor, moreover, there are carbon oxides, fluorine and hydrogen, hydrogen chloride, chlorides, sulfur, nitrogen and rare gases.

When gases press through the rocks, hydrocarbons do not oxidize as quickly. In this case, there is no chemical equilibrium between the rock and the gas. Methane in the rock medium combines with the molecules of potential oxidants only in contact with the surface of the pores, and therefore with a small volume of the entire rock. If the stream of hydrocarbons passes through the pores and rock fractures for a long time, it will use up all the available oxygen, allowing the gases to pass without loss, which will later follow the same path.

Complex hydrocarbons formed at great depths lose stability at surface pressures, even if they are stable at pressures in the upper mantle. In the rocks above, as well as in regions devoid of volcanism, the temperatures are too low to force the breakdown of molecules, but this will be a slow process of methane oxidation, which is expressed in the shedding of hydrogen. As the hydrocarbon mixture gradually adjusts to the pressures at shallow depths, macromolecular forms of hydrocarbons are formed by the detachment of successive hydrogen atoms. Asphalt is an example of weathered crude oil.

The methane that is forced into the shale rock under high pressure comes from deep in the earth's crust and there are reasons to believe that it is a gas emitted from magma. Methane is the most stable compound among all hydrocarbons, a large part will survive at any depth of up to 300 km. Abiogenic hydrocarbons, overcoming the resistance of the rocks they encounter, flow from the depths of the Earth, and this inflow is constant. In conclusion, there must be conditions for the formation of hydrocarbons deep within the Earth. The second assumption of the hypothesis of the abiogenic origin of hydrocarbons is the activity of methanotrophs. The zone of action of the bacteria, which Gold calls "hot underground biosphere", probably reaches a depth of 10 km.

The abrupt loss of hydrogen is the main cause of the characteristic storied structure of oil fields: huge resources of methane at the greatest depths, slightly higher-light oil, and near the surface—the heaviest oil and methane residues. Sometimes hard coal appears above oil layers, ranging from bituminous coal to anthracite. The blacker it is, the greater the loss of hydrogen and the greater the final carbon to hydrogen ratio. The scenario of hydrocarbon transformations, culminating in hard coal crystallization, can be summarized as follows: abiotic methane is formed from hydrogen and carbon oxides, gaseous magma components, and under pressure migrates towards the Earth's surface, saturating the encountered rocks, including shale rocks. Part of the shale gas is released and migrates higher, taking advantage of the porosity of the encountered rocks (most often sandstones). Hydrocarbons, methane and the resulting crude oil accumulate in anti-clonal traps, creating conventional deposits. The migration of hydrocarbons is accompanied by brine, which also comes from post-treatment solutions. Clay minerals, carbonates and chlorides precipitate from the brine, causing clogging of the reservoir rocks of the migrating gases. Under certain conditions, these compounds precipitate and form salt layers that constitute a hydrocarbon-impermeable layer. The deposits of $CaSO_4$ anhydrite are the most common among the salts. Part of the methane, which passes through the insulating layers under high pressure, migrates further towards the surface, with the participation of methanotrophs bacteria, it forms coal deposits. Oil and natural gas are often found in claystone, limestones and carbonates under the coal deposits.

On the schematic geological cross-section, Gold marks three levels of methane accumulation [9]. Closest to the earth's surface, methane is found in hard coal deposits. In mining, the term "methane mine" is used. Deeper down is the conventional oil and gas reservoir formed in the traps of porous reservoir rock under an impermeable layer of salt. Even deeper is the unconventional gas field, also known as tight gas, without a tight layer of salt and without anti-clonal traps. Although the gas is under considerable pressure and has no salt seal, it remains "locked" in poorly permeable shales.

The closed methane deposit is the result of clogging of the rocks by the already mentioned mineral brine compounds. Methane, which has crossed the sealing barrier of salt layers and reached the zone of methanotrophic bacteria, is transformed into hard coal. Traces of bacterial activity are not evidence of the organic origin of carbon, but participation in the transformation of inorganic methane into crystalline carbon. This interpretation is confirmed by the presence of a whole range of elements in hard coal. The presence of these elements, especially heavy metals, is evidence of a relationship with post-helper processes.

The abiogenic methane hypothesis gave impetus to exploration and led to the effective exploitation of shale gas deposits. The fact of the inorganic origin of methane and the process of its continuous inflow from the depths of the Earth also result in the rejection of the view about the finite nature of crude oil and natural gas resources and accepting the thesis about the renewal of natural gas deposits.

Regarding the interpretation of the results obtained by the TOC method, the question arises whether the method used distinguishes organic carbon from inorganic carbon, or whether each carbon is a priori called organic (analogy to the traditional division of chemistry into inorganic and carbon chemistry, i.e. organic chemistry). The second doubt concerns the assumption that methane is an indigenous gas that forms with the rock. It is a static model of the formation of a natural gas deposit, which does not explain the large fluctuations in the formation pressure and the presence, in addition to methane, of other gases: hydrogen, nitrogen, helium and radon. Only the probability of the presence of carbon was taken into account as an indicator of the selection of the search site. Moreover, the adopted criterion does not differ from the criterion used in the search for conventional natural gas deposits. Yet there are fundamental differences between these types of deposit. Therefore, the term "unconventional" shale gas is used, because its occurrence does not comply with the traditional criteria of exploration for deposits.

As in the case of brine and natural gas, the presence of heavy metals in hard coal indicates the influence of post-treatment solutions. The discovery of "unconventional" natural gas deposits confirms the view about the inorganic origin of methane and its transformations. The unconventionality consists in finding methane deposits which, according to the current theory of deposit geology, should not exist.

Interpretation of the genesis of shale gas is important for determining the correct direction of exploration for hydrocarbons. In the case of the information oficiels, the indications are as follows: "The most promising shale rocks in Poland, which may contain unconventional oil and gas deposits, occur in three sedimentary basins: the Baltic, Podlasie and Lublin, and represent the Ordovician-Silurian stratigraphic interval." The shallow sea area in the Ordovician and Silurian periods was adopted as the main criterion for selecting a prospective area for shale gas exploration. According to this criterion, the Lower Silurian and Upper Ordovician shales, occurring at a depth of 2.5 to 4 km, in the above-mentioned sedimentation basins, are considered the most favorable shale gas exploration zones.

The presence of heavy metals in natural gas, including radioactive isotopes, requires clarification. The tests performed concerned the content of mercury and radon, beta and gamma radiation in natural gas and reservoir brine. Moreover, the identification analysis of radioactive isotopes in Zechstein brine, collected in Piekary near Poznań, from a depth of 2,900 m was performed [6].

In addition to the radioactive potassium ^{40}K and radionuclides from the uranium-radium series ^{234}Th thorium, ^{226}Ra radium, ^{214}Bi bismuth, ^{214}Pb and ^{210}Pb lead, also the presence of 2 ± 1 Bq/dm^3, uranium ^{235}U, actinium ^{228}Ac and radium ^{224}Ra from the thorium series. The lack of uranium ^{226}U-238 in brine was explained by the process of its precipitation at a temperature of about 100 °C, confirmed by the detection of this radioisotope in the rock. The presence of these radionuclides is essential for determining the origin of the brine. As with the natural minerals of brine, the role of dehydration or leaching of existing salt structures can be found, the presence of heavy metals and a whole range of radionuclides can only be explained by the influence of igneous processes. The same is true for the gaseous components, molecular hydrogen, carbon oxides, hydrogen sulfide and methane.

Hence the conclusion that the brine present in the Zechstein and Rotliegen structures comes from magmatic solutions and is juvenile water. During the Lower Permian volcanic activity, the brine contributed to the formation of the copper deposit. The impact of igneous intrusion is now remote and limited, but still present. The expression of this influence is the constant pressure on the surrounding rocks of the post-treatment solutions and the gases emitting from them—methane, nitrogen, carbon oxides, hydrogen sulphide. Heavy metals present in the solutions simultaneously cause mineralization of the rocks.

Table 4 below lists the components of volcanic gases, gaseous sources, and natural gas, arranged in order that emphasizes the common source and the presence of the gases, carbon monoxide and hydrogen, involved in the formation of methane and juvenile water. The lack of methane in volcanic gases is explained by the combustion of methane during a volcanic eruption, but a trace of this reaction remains in the form of water vapor, present in an amount of 40% to 80% vol. The presented results of the analyses are evident evidence of the inorganic origin of carbon compounds as well as hydrogen, nitrogen and juvenile water. The genesis of methane and the formation of juvenile water can be described by the reaction of carbon monoxide and hydrogen, components of magma gases and natural gas:

$$CO + 3H_2 \rightarrow CH_4 + H_2O$$

This reaction can take place in the pneumatolytic step according to the Nigglie scheme, i.e. at a temperature below 600 °C. Assuming a linear geothermal profile in the lithosphere and assuming a geothermal degree of 30 m/1 °C, characteristic for central Wielkopolska, the temperature range of 400-600 °C corresponds to the depth interval of 12-18 km.

The probability of the pneumatolytic effect is confirmed by anomalous deposit pressures in the zone of tectonic dislocations (Fig. 11). There, the formation pressure gradient reaches 2.25 atm/10 m, compared to

Table 4 Post-igneous stages corresponding to the depth zones (according to Niggli)*.

Post-igneous stage	Temperature range	Depth zone
Hydrothermal	100-400 °C	3-12 km
Pneumatolytic	400-600 °C	12-18 km
Pegmatite	600-1,000 °C	18-30 km
Igneous	>1,000 °C	> 30 km

* where the geothermal degree is approx. 30 m/1 °C.

the normal value of 1.2 atm/10 m. In the pneumatolytic phase, water appears as vapor and condenses at temperatures below 400 °C, i.e. at a depth of less than 12 km. The formed water together with the minerals and gases dissolved in it constitutes the juvenile reservoir brine. According to such a scenario, the brine together with the gases dissolved in it, including the methane of interest to us, press under high pressure through the adjacent rocks, usually shales. The poorly permeable rock causes the gases and brine to be closed in the pores of the rock and a shale gas zone is created. So shale gas and conventional natural gas come from the same source, the difference is in the type of gas bearing rock. Unconventional gas is a gas confined in shale-type rocks, with low permeability, and some of the gas, which is released from the shale under the influence of high pressure, migrates towards the ground surface, creating conventional hydrocarbon deposits.

The condition for the formation of a conventional gas deposit is the encounter with an impermeable layer. Mineral compounds from post- magmatic solutions together with juvenile water form brine and under their characteristic conditions they precipitate, forming salt structures. In central Wielkopolska, in the interval covering the Triassic and Zechstein deposits, a salt structure with a total thickness of 1 km was formed. In the final demineralization stage, chloride anions and sodium cations remain the dominant ones in the brine. The phenomenon of salt water ascension or acratopegs, observed in the drainage zones of the waters of the tertiary level in central Wielkopolska, is therefore the result of high reservoir pressure and migration of Na-Cl juvenile brine. Thus, in the geological conditions of the Polish Lowlands, the role of the process of leaching of Zechstein salts by atmospheric waters is negate.

According to the criteria based on the theory of igneous origin of methane, the prospective direction of shale gas exploration is the substrate with a high geothermal gradient, which may indicate an increased activity of post-magmatic processes. The increased density of the geothermal stream, over 80 mW/m^2, occurs in the area of south-western Poland, and more specifically the Fore-Sudetic Monocline. However, other areas as prospective are not excluded as the source of methane has a global dimension. Contrary to the theory of the organic origin of shale gas, which limits the area of its exploration, the theory of abiogenic shale gas, which is still produced from post-magmatic gases, offers an optimistic variant of the natural gas exploration plan.

6. Conclusion

The interpretation of geological phenomena, based on the theory of the primal forces of nature and taking into account the laws of physics and the principles of rock mass mechanics, proves the formation of a spontaneous thermonuclear synthesis reactor in the Earth’s core. Views that do not take this fact into account lead to erroneous conclusions. An example is the views on the so-called rock cycle and methane formation in natural gas deposits and the origin of reservoir brine. Kerogen, defined as a mineralized organic substance, does not transform into hydrocarbons and the brine does not come from the leaching of the Zechstein salt. On the contrary, the kerogen undergoes the process of carbonization and the brine is an igneous solution from which salts and other mineral compounds precipitate. Unconventional. deposits of natural gas become conventional after explaining the relationship between the permeability of the rock and its porosity and the size of the formed methane molecules. The program of studies in the field of petroleum geology, which does not include the formation of elements in the process of basalt magma creation, should be changed.

References

[1] Grotek, I., and Janas, M. 2017. *The Impact of Thermal Maturity of Organic Matter on Gas Exploration*. Information service of the Polish Geological Survey.

[2] Matyasik, I., and Słoczyński, T. 2010. *Unconventional Gas Deposits—Shale Gas*. Oil-gas.3.

[3] Majorowicz, J., Wróblewska, M., Krzywiec, P., 2002. *Interptretation and Modeling of the Earth, s heat flux in the area of the POLONAISE'97 seismic experiment*; Przegląd Geologiczny, vol.50. no 11.

[4] Kotarba, M. J., Więcław, W., and Stecko, Z. 2000. *"Composition, Genesis and Environment of Natural Gas Generation in the Main Dolomite Formations of the western Part of the Fore-Sudetic Region."* Przegląd Geologiczny 48 (3): 429-35.

[5] Karnkowski, P. 1993. *Natural Gas and Crude Oil Deposits in Poland.* GEOS Publishing House. Kraków.

[6] Pawuła, A. 1997. *"Contribution á l'explication des anomalies du radon Rn-222 dans le milieu naturel.* " Séminaire SUBATECH, Laboratoire de Physique Subatomique et des Technologies Associées, Ecole des Mines de Nantes.

[7] Pawuła, A. 2021a. "*The Phenomenon of a Natural Thermonuclear Reactor."* Journal of Geoscience and Environment Protection 9: 92-109. https://doi.org/10.4236/gep.2021.92006.

[8] Pawuła, A. 2021b. *"The Problem of Natural Radioactive Elements."* Journal of Geoscience and Environment Protection 9: 176-94. https://doi.org/10.4236/gep.2021.940113.

[9] Gold, T. 1999. *The Deep Hot Biosphere.* New York: Springer. Verlag.

[10] Sabatier, P., and Senders, J.-B.1902. *Synthesized Methane from a Mixture of Hydrogen and Carbon Oxides, in the Presence of Nickel, at a Temperature 200-300 °C.*

[11] Skrzyńska, E., and Ogonowski, J. 2010. *"New Ways of Carbon Dioxide Management. Part III: The Synthesis of Hydrocarbons from Carbon Dioxide and Hydrogen."* Institute of Organic Chemistry and Technology, Cracow University of Technology.

[12] Paczyński, B., and Sadurski, A. 2007. *Monograph—Polish Regional Hydrogeology* (*Volume II: Mineral, Healing, Thermal and Mine Waters).* Warsaw: PIG-PIBP. (in Polish)

[13] Macioszczyk, A. 1987. *Hydrogeochemistry*. Warsaw: Geological Publishers.

[14] Oszczepalski, S., and Chmielewski, A. 2017. "*Ore Mineralization in the Sieroszowice S-1 Open-Pit Borehole, in the Light of New Research."* Przegląd Geologiczny 65 (5): 321-38.

[15] Pawuła, A. 2022. *"Discourse on the Evolution of the Earth."* Journal of Environment and Pollution CCSE 11 (1): 65-78. http://doi:10.5539/ep.v11n1p65.

[16] Such, P., Leśniak, G., and Słota, M. 2010. *"Quantitative Characteristics of Porosity and Permeability of Rotliegen Deposits Potentially Containing Closed Natural Gas."* Przegląd Geologiczny 58 (4): 347-51.

[17] Bojarski, L., Pazdro, J., and Sobol, K.1977. *Anomalous Reservoir Pressures in the Polish Lowlands*. Poland: Geological Institute.