# ON EFFICIENCY OF COAL SEAM METHANE EXTRACTION GEOTECHNOLOGIES INVOLVING CAVITY GENERATION AROUND WELLS

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*An approach based on reverse (from rock mass to well) coal mass impaction is proposed to improve the efficiency of coal seam methane extraction. As cracks grow and reach fundamental length, coal methane emission and permeability increase simultaneously and step-wise. The author has developed several technologies to extract coal methane. One of them involves coal and methane extraction and transport to the surface by means of controlled outburst energy. The extracted methane and coal are to be burnt at heat power plants that may be situated practically in the well mouth. Special equipment is used to prevent methane emission to the air. The extracted methane is free from air and may be utilised individually. The minced coal undergoes enrichment and is used as a water-coal mixture.*

The author started study of coal seam methane emission mechanisms more than 20 years ago at the Institute of Complex Exploration of Mineral Wealth (IPKON RAN). At first, the study objective was to develop effective coal seam degassing technologies. In 1981 the author discovered that abnormal sudden gas emissions (coal, rock, gas outbursts) were caused by self-destruction of rock mass edge [1] and developed the phenomenological basis for a theory of methane emission control [2-5]. In 1989 [6] we proposed to extract methane as the principal product and coal as an accessory product. Georeactors operating on the basis of controlled coal and gas outburst was a tool to effect this idea. Technologies involving hole boring in coal mines were widely applied in the USA at that time. They resulted in methane production of 5 billion $m^3$ in 1990, 15 billion $m^3$ in 1992, 21 billion $m^3$ in 1993, and 25 billion $m^3$ in 1995 [7].

There was much dispute about the US technologies at international symposia held by Moscow Mining Institute during 1997-2000. However, the mechanism of coal impaction by the American technologies was unclear. Some investigators believe that virgin coal seams are impermeable below gas erosion. Then it is unclear how methane penetrates into cracks at great depth, since coal is impermeable for gas filtration in the vicinity of cracks. Gas diffusion is not taken into consideration for quite understandable reasons. Desorption of adsorbed methane on the surface, generated by growing cracks, is an infinitesimal value. We believe that high methane debits may be produced only if a rather large cavity is generated around the well in the coal seam. What is characteristic of our approach is creation of conditions for rock mass reverse self-impaction on the well.

There are lots of Russian publications, invention certificates, and patents (including those by the author) for ways to increase gas extractability using degassing holes from underground openings. The expected result is achieved by creation of cavities around degassing wells (Figure1), e.g., by reboring existing wells in the abutment rock pressure areas [10, 11]. Other techniques involve side wall cleft [12] or helical path [13] cutting to widen degassing seam wells. The “rock mass-opening” (cavity) is an open system that may be far from mechanical equilibrium at great depth. The coal seam edge self-destruction is a typical synergetic problem . The fact that mining science does not consider methane emission as a function of technogenous crack self-organization leads to a crisis of conventional knowledge about coal methane. The main signs of the crisis are as follows.

1. The theory treats methane emission from coal seams as filtration, while mine experiments demonstrate that coal seams are gas-proof everywhere below gas erosion level.

2. It follows from the theory that the maximum gas amount of methane contained in coal is lower than the amount of methane emitted during coal and gas outbursts by one order of magnitude. If the seam gas bearing capacity is 20-40 $m^3$/t, the gas yield from the cavity and its gas-proof vicinity is 200-500 $m^3$/t.
3. The theory fails to explain generation of pear-shaped cavities sometimes seen after coal and gas outbursts.
4. The theory explains the extra gas generation only by slow processes caused by thermodynamic unbalance, while in fact the extra gas is emitted in a step-wise manner (instantaneously). The gas collector is generated at a close-to-sound rate and grows by leaps with any time interval between the leaps.

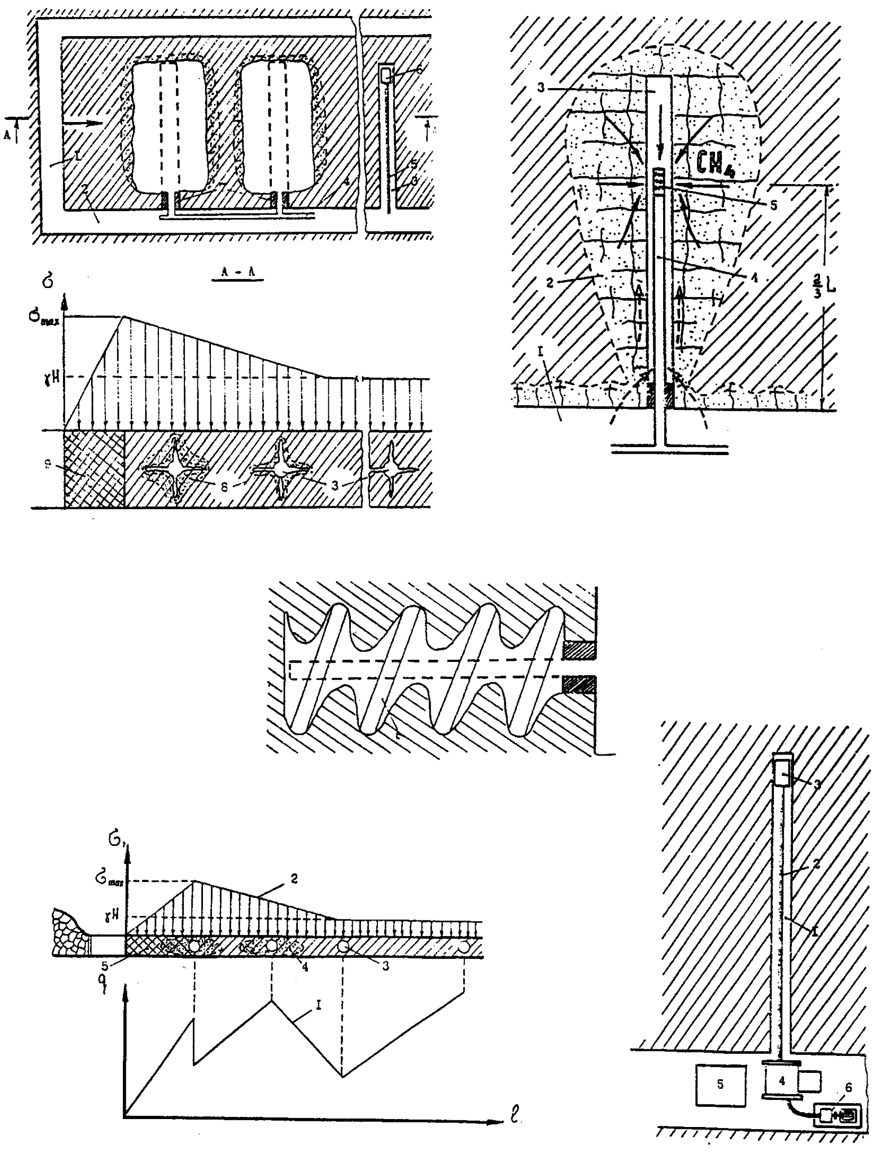


*Figure 1*

Rock opening conditions cannot be simulated by laboratory experiments. Similarly, results of field experiments depend upon experimental methodology, e.g. technical means. Therefore, both the conventional and alternative approaches are formulated as hypotheses. We believe that there are two counteracting mechanisms of coal methane emission. The first (conventional) predominates at small depth above the gas erosion level. The second (alternative) mechanism [1-5] starts to lay the major role at great depth, i.e. below the gas erosion zone, where coal seam edge self-destruction may occur. Arising of a slip area in the coal seam edge is interpreted as generation of dissipative structures (Figures 2, 3).

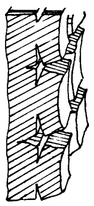
Figure 2

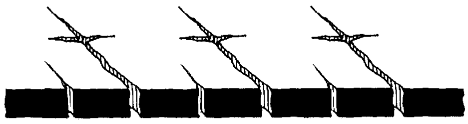
Figure 3

The self-destruction proceeds from the surface to the rock mass depth and lasts until mechanical equilibrium is restored due to generation of a post-failure coal zone. If this zone is reduced critically or eliminated, another self-destruction cycle starts and proceeds at a sound rate until mechanical equilibrium is re-established. If the increase in mechanical energy flow density is caused by another event, it results in stepwise growth of the post-failure zone following a period of elastic resistance of the rock mass. The step of post-failure development has at least two critical points. At the first critical point, a new substance (methane) is generated at the tip of the growing crack. At the second point, the methane amount is so large that all of it cannot filter into the opening and induces crack growth.

There are several experimental studies in different areas of knowledge in which a new substance is generated when extremely dense mechanical energy passes through the initial substance. For instance, metal salt ($CuSO_4$) explodes to generate pure metal (Cu) [14]. During 1975-81 the author carried out numerous mine experiments to measure initial gas emission rates during hole boring at certain intervals (MakNII methodology [15]) and discovered the following. Gas emission sources may appear and change intensity in a random manner at the end of the rock mass under processing. (That is why these emission sources are not taken into account by conventional approaches.) The measurements were made at the same place as the stope progressed. The holes or short wells both uncovered the appearing face and created new sources of gas emission. It was practically impossible to have at least two similar measurements under the conditions described above no matter how many experiments were performed.

**Based on these considerations we propose the following:**

**First**. A new geotechnology is proposed that is based on the previously described [11-13] methods of coal seam degassing for underground openings. The technology is characterised by hole boring from the earth surface. Generation of a cavity is an intermediate step aimed at inducing generation of a maximally large crack area around the cavity. The induced crack area is needed to produce gaseous methane and to make channels for gas self-transport to the well and to the earth surface. There are several methods to create the cavity, as follows.

1. Mechanical coal destruction with slime removal by airlift.
2. Hydraulic coal destruction using high-pressure jets with slime removal by airlift.
3. Combined mechanical and hydraulic (1+2) technique.
4. One of the previous techniques plus intensification of slime removal by a rotating auger. The auger body is a tube to be used to deliver water to the stope cavity.

5. Induction of coal and gas outburst in the well with removal of the outburst products as in 2.

After a cavity is made, the auger (if applicable) is removed, water is withdrawn, the well mouth is sealed, and industrial methane extraction is carried out.

**Second.** We propose that coal methane extraction should be performed together with minced coal using the Vulcan technology [17]. This is a safe and practically people-less technology of coal and gas extraction and transport to the earth surface exclusively by means of controllable gas dynamic events (GDE). Coal seams are opened by well boring from the earth surface under conditions preventing crack generation. Then coal and gas outburst into the well is induced, and conditions to transport the outburst products (only by means of natural energy) to the earth surface are provided. Outburst control (arrest and reinitiation) is effected by restoration of mechanical equilibrium of the "coal seam-cavity" system. The GDE reactor plant at the surface should be isolated from the air to preserve 100% of extracted methane. The solid component of the GDE products (minced coal) is used as water-coal suspension (WCS). Methane and WCS are transported to the surface by separate pipelines. The WCS is enriched and burnt in a heat power station instead of conventional liquid fuel. When extraction of minced coal is finished, the well may be used for a long time for gas extraction.

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