ANALYSIS OF THE SELF-ORGANIZING HYDRODYNAMIC STRUCTURES AND THE TOPOLOGY OF THE ROCK SALT DISSOLUTION RELIEF

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The knowledge of the surface relief, which develops through mass transfer during the dissolution of rock salt, allows for drawing conclusions on the steering physical mechanisms.

Until recent time not much attention has been paid to the study of self-organization phenomena within fluid systems. Principles of interrelation of structurization of a solution and self-organization of the whole system remain vague.

Visual inspection proves that during dissolution on the surface of natural samples (natural area of mass transfer of rock salt), regular sequence of craters is developed – an area with three-dimensional concavities system. Vortices on the rock salt surface with natural mass transfer form three-dimensional craters with smooth contours and concave surface; however in some cases craters developing on core samples are also characterized by different depths and sharp edges.

Fig.1 illustrates the general view of the crater with characteristic geometrical parameters (h_c – height of the crater; b_c – geometric cross length of the crater; R_o – radius of rounding up the edges; R_c – radius of cross-section of the crater). Very important from hydrodynamics and mass exchange point of view is the h_c / b_c ratio which equals approximately 0.23 for natural mass transfer area of the rock salt. Correspondingly, the craters formed are considered to be relatively deep with regard to this parameter.

Craters are natural intensifiers of mass transfer process in rock salt dissolution. The emerging vortex structures intensify the mass exchange between the mass transfer area and the main mass of fluid. It is evident that the characteristics of the craters depend on the roughness, which in turn influences the indicators of mass transfer. There is an interrelation between the roughness and the vortices, which strengthens their interaction.

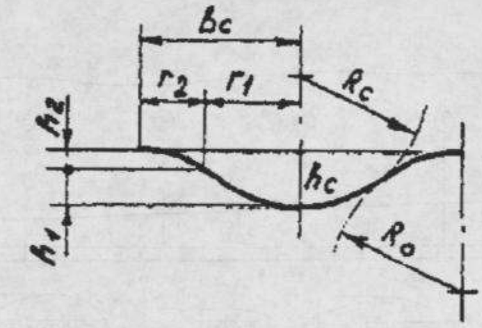


Fig.1. Characteristic geometrical parameters of the craters:
h_c - height of the crater; b_c - geometric cross length of the crater;
R_o – radius of rounding up the edges; R_c – radius of cross-section of the crater.

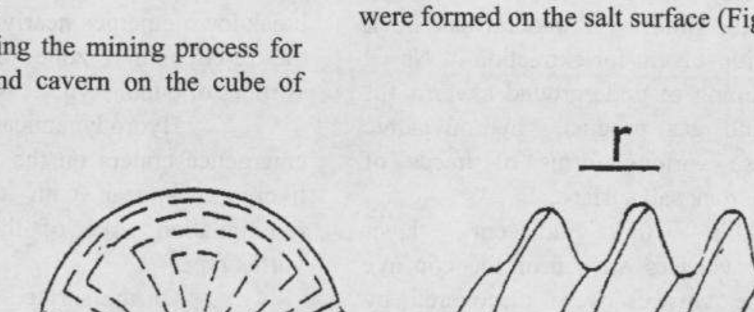
The process of spontaneous formation of regular structures occurs during the interaction of a great number of elementary subsystems, which are characterized by self-organizing evidences.

Self-organizing (or synergetic from Greek Synergetikos - i.e. acting in concord) hydrodynamic structures are formed near the rock salt surface. Interaction of self-organizing hydrodynamic structures and salt surface on the contour of the underground target cavern produces area relief structures (traces of self-organizing hydrodynamic structures). Self-organizing hydrodynamic structures form regular structures on the surface of salt rock.

During a laboratory examination, after dissolution of vertical surface of the salt rock core (cylinder) under natural convection, semi-spherical craters appeared on the convex surface of the sample.

By modeling the mining process for a vertical underground cavern on the cube of rock salt, after uncovering the model, semi-spherical craters were found on the upper surface of the void, which included the vault concave roof and the side surface.

In a large scale step-by-step modeling of the mining process of an extensive horizontal underground cavern with vault (arched) roof and isometric cross sections along the length (through vertical-horizontal and horizontal drills), on the concave upper part of the cavern, comprising ~2/3 of the total contact area, an area relief structure – a lattice of semi-spherical craters – emerged due to the influence of self-organizing hydrodynamic structures. With mass transfer near salt surface, a convective lattice of self-organizing hydrodynamic structures emerges with natural formation of a lattice of craters on the salt surface. In the lower part of the cavern, ribs were formed on the salt surface (Fig.2).



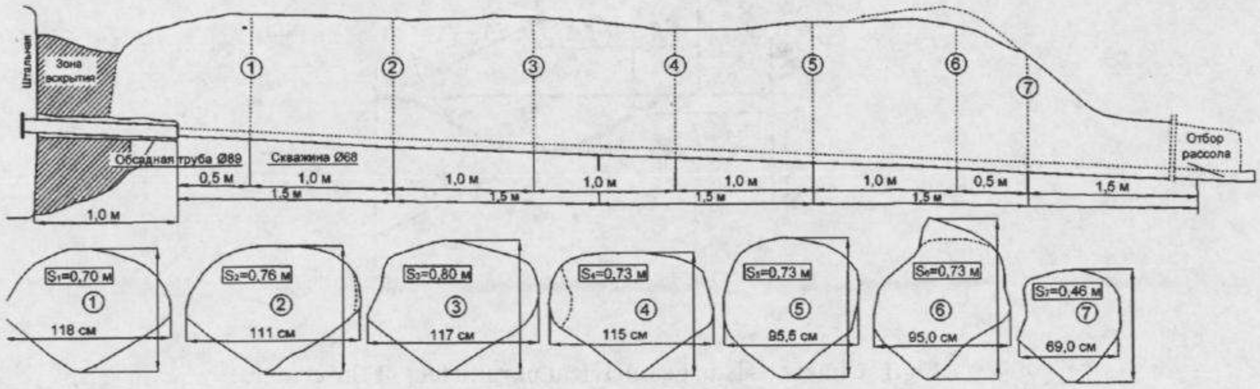


Fig.2. The form of a horizontal cavern model and its cross-cuts (r – round-rib surface)

Mass transfer during underground salt mining is accompanied by interaction of the self-organizing systems.

The analysis of the fundamental flow characteristics within the turbulent adjacent layer provides new interpretations of the process mechanisms within the adjacent layer. In the zone of viscous sublayer, insignificant emissions of decelerated fluid from the flowed around side surface into the outer part of the adjacent layer were observed as well as the influx of accelerated fluid from the outer part into the adjacent layer near the side surface. These evidences related to the renovation of the flow within the sublayer have a direct impact on the emergence of turbulences within the adjacent layer and occur strictly periodically from the statistical point of view.

In the process of underground rock salt mining with solvent for extraction of Na Cl brine or in mining of underground caverns for storing oil and gas products, hydrodynamic effects cause various forms of traces of vortices on the rock salt surface.

Within the adjacent layer Taylor-Gertler vortices arise near the concave surface. These vortices were discovered by Gertler. He determined that in the laminar flow regime the vortices emerge, when Gertler's number equaled 16. When calculating Gertler's number during experimental dissolution of rock salt core sample according to the equation: $G\ddot{o}_{cr} = u_\infty \delta / \nu (\delta / R_w)^{0,5}$; where u_∞ - the speed on the outer interface of the adjacent layer, δ - thickness of the adjacent layer, ν - kinematic viscosity, R_w - radius of the surface curvature, the obtained value of Gertler's number approximated 16.

The experiments showed that the vortex can undergo rapid changes, so that the character of the flow changes significantly. This phenomenon is known as vortex breakdown or bursting, as the vortex tends to burst from inside, locally increasing in size. During the breakdown, on the vortex' axis symmetrical bubble appears or neosymmetrical spiral structures are observed.

Numerous types of vortices breakdown are known; however bubble and spiral types prevail. As a rule, a spiral breakdown emerges nearly immediately beyond the re-circulation zone of the breakdown of vortices of bubble type.

Hydrodynamically influenced emergence craters on the rock salt surface are likely to appear with the formation of a re-circulation zone of the bubble-breakdown vortex type.

On the surface of the crater (formed by a "big" vortex), a trace emerges caused by a "smaller" vortex.

Visual observation shows that the shape of the trace on the crater surface (the shape of the secondary trace) reminds the “calla” flower, similar to the conic breakdown of the vortex (of spiral-type shape), with only the conic part of the trace “penetrating” the broken part on the rock salt surface (in other words, the “calla’ shape has the form of a spiral with the conic rounding).

Experiments show that the conic breakdown is a structure, consisting of two or more interlaced spirals with conic rounding (rotating n-spiral).

Fig.3 illustrates longitudinal vortices in convection in water beneath the heated surface, at 35° angle to the vertical line. The flow underneath the sloped heated plate corresponds, for instance, with the winds, lowering down the cold side of a hill, as well as with the muddy sea water streams at the bottom of the slope. Analysis of the formation of the longitudinal vortices and, correspondingly, longitudinal ribs on the rock salt surface resulting from their influence during m ass transfer (Fig.2).

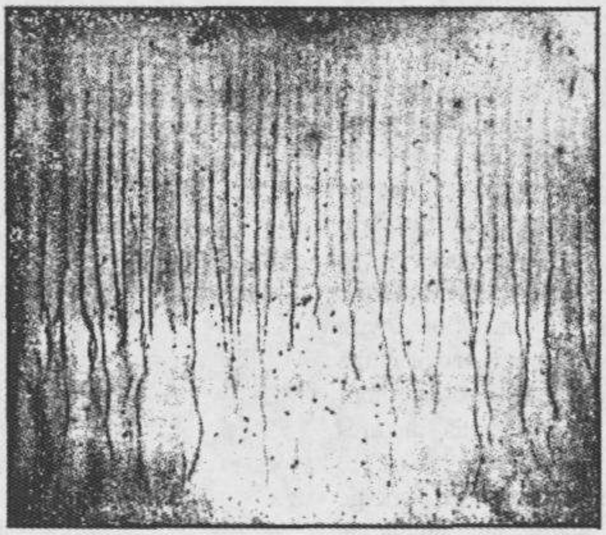


Fig.3. Longitudinal vortices when convection in water underneath the heated surface at 35° angle to the vertical line.

Paint is distributed evenly (by electrochemical method) on the surface of the plate.

During mass transfer process near the rock salt surface, various vortices are formed, which leave traces on the rock salt surface. Table 1 shows some examples of such traces on the rock salt surface resulting from the vortex effect (Table 1).

Hydrodynamic influence of a solvent on the rock salt surface leads to the emergence of the adjacent vortex layer.

Seven phenomena with corresponding traces on the rock salt surface under concentrated vortices impact were discovered.

Phenomenon No.	Description of the phenomenon
1	Craters – roughnesses of semi-spherical shape
2	Combination of the form of a crater and "calla". Spiral-like shaping with conical rounding on the surface of semi-spherical shape (on the surface of the crater)
3	Longitudinal ribs on the sloped (inclined) and vertical surfaces
4	Combination of the form of a crater and longitudinal ribs
5	Combination of the form of a crater, spiral-like shape and longitudinal ribs
6	Twisted spiral ribs
7	A shape with rough surface similar to the fluid funnel, flowing out from a vessel through its bottom mouth (the shape of a pressed-in funnel with rough surface). Emerges on the surface of the rock salt core sample with dissolution of the sample under pressure at the laboratory plant.

Table 1. Examples of traces on the rock salt surface after concentrated vortices impact.

A general evidence of the hydrodynamic effect on the rock salt is the co-existence of vortex structures of different shapes and sizes.

As a result of hydrodynamic influence, characterized by the flow with chemical reaction on the frontier between the phases, a wavy roughed surface on the contour of the underground cavern emerges as fractures of mass transfer. Near the surface self-organizing hydrodynamic structures emerge. Interaction of self-organizing hydrodynamic structures with the salt surface on the contour of the underground cavern result in formation of the surface relief structures (the traces of interaction of the self-organizing hydrodynamic structures).