The effect of salt burst scaling in solution-mining

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The effects of scaling (scouring) salt plates along with breaking intercrystalline bonds during solution-mining were discovered for the first time:

- Scaling from the surface of salt crystals, formed at low temperature, with local inner stress caused by external factors;
- Scaling from the surface of salt under gas pressure within the void inside the salt crystals – under local inner stress resulting from the internal factors.

The mass transfer coefficient of the rock salt is the main indicator of solution-mining process, which predetermines technological parameters of the underground cavern mining under the hydrodynamic impact of the adsorption-active environment on the rock salt, as well as the speed of mining and shaping the cavern under defined mine-geological conditions and actual temperature.

During the solution-mining of the rock salt sample, characterized by higher inner stress, (from the Talakan oil-and-gas field), the salt plates scaling (scouring) from the surface was observed.

The core samples of rock salt, obtained at a small distance from each other (the Talakan oil-gas field), reveal significantly different characteristics of the mass transfer during solution-mining. In particular, the core samples taken nearby from one and the same field showed different values of the mass transfer coefficient.

In the solution-mining process of one sample thin rock salt plates up to ~1-2 mm and 2-3 mm in diameter (the ellipsoid plates, sometimes as thick as ~ 5 mm) were scaling.

Scaling of salt plates from crystals, caused by hydrodynamic impact of the solvent, appears due to the change of the tense state of the near-surface layer of the rock salt. During the total time span of solution-mining of this sample (20 min) salt plates were scaling from the core surface for the distance of 5 cm. Per100 g of the mass transfer the number of the plates scaled amounted 23.2 g (i.e. 23.2%).

The mass transfer coefficient of the first sample was 29% higher as compared to the second sample.

A similar scaling effect was observed during solution-mining of salt samples with inclusions of gas in crystals (the Tyuz-Gelyu field, Turkey).

Scaling (rock burst scaling – sound scaling of lens-like plates of a rock with sharp edges; scouring – breaking of a rock into separate plates along the contour of a cavern) – is a breaking effect of the near-surface layer of the rock salt due to a separation of rock plates from the surface caused by the change in the tense state of the rock due to impact of a solvent, accompanied by a sound.

If a solid body is affected by external tensile stress (or it has areas of significant inner tensile stresses), grain-frontier fracturing at fluid phase presence can occur.

Breakage during solution-mining of the near-surface layer of the rock salt, formed at low temperature and locally increased pressure, is characterized by fracturing and scaling (scouring) of salt plates and is

comparable to the thermal breakage of rocks by high temperature gas spurts: fragile scouring prevails, i.e. thin plates are being separated from the rock surface.

Breakage of salt rock during solution-mining was discovered for the first time not in form of fracturing, but scaling (micro-outburst) of salt plates in solution-mining of rock salt with crystals containing gas (the Tyuz-Gelyu field).

While determining the coefficient of mass transfer of the vertical rock salt core surface under natural convection, an even, nearly of the same value, distribution of gas within the crystals in the rock salt from the Tyuz-Gelyu field was observed. This distribution of gas provides locally changing pressure in the salt rock (i.e. increase of pressure within crystal voids filled with gas).

Mass transfer in solution-mining of the rock salt with increased gas content within the crystals is characterized by a transition of a mass of rock salt into the solution, mass of rock salt scaling in form of plates and escape of gas.

Such a process of mass transfer can be viewed as a combined gas-dynamic phenomenon – i.e. escape of gas accompanied by salt plates scaling (gas release with salt crystals breakage).

During solution-mining of rock salt from the Tyuz-Gelyu field, when thinning the rock partition in the salt crystal, which contains gas under pressure, rock salt plates scale and gas escapes.

Scoured particles are characterized by a flat ellipsoid shape. Formation of thin plates, of approximately similar size, is peculiar for various types of destruction of salt rocks, including salt plates scaling (flakes) when gas escapes from the rock salt crystal during solution-mining (micro-outburst). This corresponds to the theses by S.A.Christianovitch stating a layer-by-layer "tearing off" of outburst endangered rocks. The micro outburst of gas from the salt crystal, accompanied by plates scaling during dissolution, is a continuous process of "tearing off" of salt particles (breakage of the near-contact zone of the rock).

The average coefficient of mass transfer from the vertical surface of the salt rock under natural convection at 20° C for the core from the Tyuz-Gelyu field (with increased gas content inside salt crystals) was in the drillhole 1 0,063 m/h; in the drillhole 2 – 0,0582 m/h. The maximum coefficient of mass transfer (0,0761 m/h) was observed for the sample 52P (see tables 1,2).

Sample No.	Depth, m	d, cm	h, cm	ρ, g/cm^3	G_1, g	G_2, g	K, m/h
10P	1048,0-1048,2	9,44	10,01	2,20	1541,40	1273,54	0,0596
15P	1077,0-1077,3	9,40	10,01	2,17	1510,0	1223,36	0,0643
25P	1083,6-1084,0	9,45	9,95	2,23	1558,6	1290,31	0,0598
36P	1105,4-1105,6	9,41	9,96	2,126	1472,8	1297,79	0,0387
42P	1108,0-1109,0	9,38	10,08	2,19	1524,7	1262,70	0,0583
45P	1151,0-1151,35	9,41	10,0	2,12	1471,15	1167,69	0,0685
52P	1154,2-1155,0	9,44	9,87	2,11	1458,7	1126,41	0,0761
64P	1203,0-1204,0	9,47	9,91	2,18	1520,6	1234,51	0,0644
74P	1250,0-1251,0	9,44	9,96	2,24	1559,35	1298,09	0,0584
82P	1275,5-1275,8	9,51	9,96	2,15	1524,45	1186,93	0,0759
86P	1301,0-1302,0	9,47	9,97	2,20	1524,90	1223,35	0,0682
93P	1308,0-1309,0	9,50	9,90	2,18	1533,2	1247,39	0,0640

Table 1. Coefficients of mass transfer from the vertical surface of rock salt in water under natural convection at 20°C, determined for the core samples from the UGS 1 drillhole, Tyuz-Gelyu.

Sample No.	Depth, m	d, cm	h, cm	ρ, g/cm^3	G_1, g	G_2, g	K, m/h
27P	962,6-963,0	9,46	9,99	2,17	1523,45	1249,60	0,0610
33P	956,6-966,0	9,50	9,97	2,10	1486,72	1206,60	0,0624
44P	972,0-972,7	9,52	9,98	2,24	1590,15	1362,98	0,0499
52P	978,0-929,0	10,16	10,29	2,22	1854,2	1568,78	0,0489
55P	1033,0-1034,0	9,52	9,92	2,18	1540,9	1262,71	0,0620
68P	1044,0-1045,0	10,15	9,92	2,24	1800,7	1538,84	0,0540
68P^{double}	1044,8-1045,0	10,16	10,05	2,25	1828,75	1568,7	0,0532
74P	1049,8-1050,0	10,17	9,92	2,21	1783,3	1512,98	0,0553
80P	1105,0-1105,5	10,08	11,1	2,25	1990,21	1707,2	0,528
84P	1107,4-1108,0	10,16	10,05	2,23	1816,9	1544,2	0,0558
90P	1112,0-1112,5	10,15	9,90	2,23	1782,36	1508,0	0,0572
96P	1116,0-1117,0	10,16	10,05	2,25	1837,87	1590,2	0,0502
98P	1118,0-1118,4	10,15	10,05	2,26	1838,5	1574,59	0,0537
99P	1118,4-1119,0	10,17	10,02	2,25	1831,9	1561,0	0,0551
101P	1181,0-1181,5	10,14	9,74	2,20	1731,7	1474,4	0,0533
107P	1185,5-1186,0	9,46	9,93	2,18	1519,85	1263,44	0,0574
110P	1188,0-1189,0	9,46	9,99	2,10	1530,17	1261,82	0,0586
112P	1251,0-1251,25	9,53	9,98	2,21	1573,71	1318,17	0,0563
120P	1255,0-1256,0	9,49	9,98	2,21	1564,9	1315,85	0,0550
127P	1259,0-1260,0	9,48	9,83	2,22	1539,3	1284,74	0,0573
131P	1323,0-1323,4	9,52	10,02	2,25	1607,75	1417,28	0,0413
139P	1327,0-1327,4	10,02	8,65	2,11	1436,19	1180,07	0,0612

Table 2. Coefficients of mass transfer from the vertical surface of rock salt in water under natural convection at 20° C, determined for the core samples from the UGS 2 drillhole, Tyuz-Gelyu.

During solution-mining of rock salt with the increased gas content, the destruction of near-contour zone is observed, being accompanied by local, nearly constant short-term release of gas bubbles from salt crystals (the Tyuz-Gelyu field), or by differentiated gas escape (the Leykovsky salt stock) for this period of solution-mining.

The value of the coefficient of mass transfer increases in the process of solution-mining of rock salt with higher gas content as compared to solution-mining of traditional salt; therefore despite the fact that the mechanisms of gas evidences at the Leykovsky stock and the Tyuz-Gelyu field were different, their coefficients of mass transfer were rather similar.

The increase of the coefficient of mass transfer of rock salt with higher gas content is characterized by significant role of micro-destruction of salt due to escape of gas.