The main causes of a geomechanical accident of brine caverns at field II of Ocnele Mari - Romania

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Abstract: The salt exploitation by dissolution associated with an inadequate monitoring program resulted in the formation of a large cavern in a highly populated area of the Field II in the Ocnele Mari region. Geomechanical coupled processes, as related to the presence of such cavern, induced the September 2001 collapse, with a major environmental impact.

Key words: salt exploitation through dissolution, cavern with solution under pressure, subsidence, monitoring systems, geomechanical coupled processes.

Introduction

The Ocnele Mari salt deposit is located in the Getic Depression of the Lower Carpathians' Hills. It occupies the both flanks of an asymmetrical anticline. The deposits are stratiform, presenting also numerous lenses and are situated in formation of Badeniann Age. The upper limit of the salt deposits, which is in contact with a sequence made up of marls, sands and stratified sandstone, is undergoing an incipient dyapiric process.

The Field II – Ocnele Mari, with a surface of about 25 ha, comprises 12 boreholes exploited during the 1971-1991 period. It was produced from these boreholes by the dissolution of about 12 million tones of salt. The production ceased on 5.03.1991, after an accident, when soil vibrations were recorded, similar to those of a small magnitude earthquake.

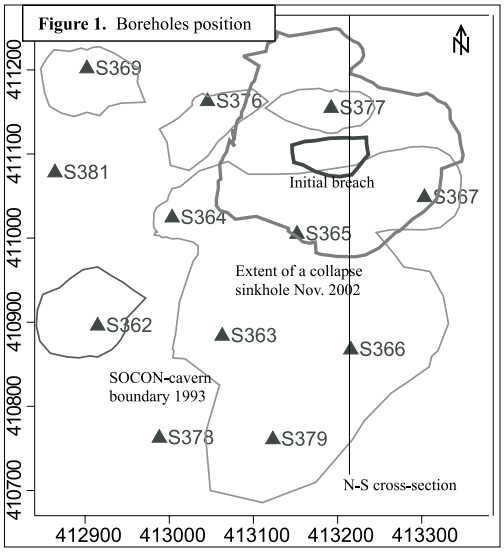
On 12 September 2001, at 7.00 hr p.m., without any earlier signs, some brine from the wells 365 and 367 (Fig. 1) started to be spilt out. Southward from the 377 well, a collapse cone appeared having a diameter of about 10 m, filled with brine level and having beneath the topographic surface. The crater dimensions have continuously increased. The southwards advancement of the collapse toward a zone with a lower relief made the brine be spilt out, over the hill slope. The maximum expelled flow of about 17 m^3/sec was reached around 3.00 hr a.m.. During six hours values greater than 10 m^3/sec were recorded. Afterwards the flow has continuously decreased at 4-5 m^3/sec after 12 hours and at only 0.4-0.5 m^3/sec, after 24 hours.

The damage brought about very important material losses, having a major environmental impact as well. In the morning of 13.09.2001, the presence of a failure crater was recorded, with a surface of about 2.4 ha, which contained a brine lake of 2.0 ha at the level of 310.5 m. The angle of the failure surfaces was about 70-75°. The northern part the failure surface coincided with the plane of a fault. As early as the first day it has been developed concentric fractures, situated until at 60 m from the collapse cone, especially eastwards and westwards.

Scientific paper

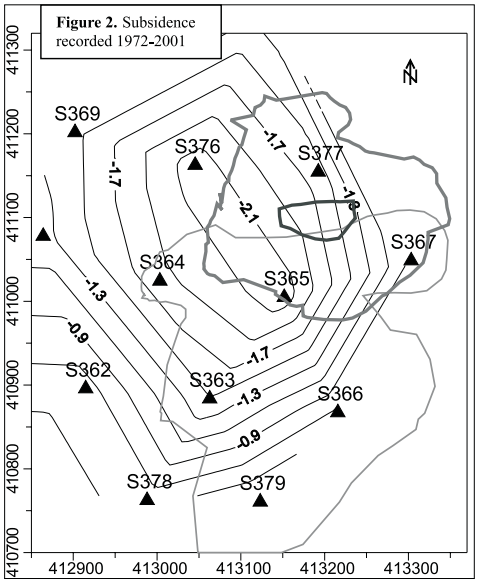
The shape and dimensions of the dissolution caverns

After the cavernometric measurements, performed in 1993 by SOCON Company, it resulted that upper parts of the individual voids of the boreholes 363, 364, 365, 366, 367 and 379 were in fact connected by a common cavern (the SOCON–cavern). This cavern is located in the upper half of the deposits, it has a height of 40-60 m, a horizontal surface of 10.5 ha and a volume of about 4.500.000 m^3.



Based on the production technology, it can be concluded that the main cavern is extended to the north and northwest by a dissolution void, whose dip exceeds 30°. This void has a tabular shape and it comprises the dissolution voids of the wells 369, 376 and 377 as well as their connection voids with the SOCON-cavern. Its volume is of about 1.300.000 m^3. In 1993, this tabular void was already filled up and it was not recorded by the cavernometric measurements. After 1978, when the tubular void has been established, it begins to be subject to a closing process. The fault detected after the collapse occurred in September 2001 played an important role if one considers the important values of the effective stress. As a consequence of the closing process, a large subsidence valley has been developed at the surface. During the 1993-2001 period, the roof of the SOCON-cavern was continuously moving up, reaching 20-35 m at the central-northern boundary. At the same time, in the northern part of the cavern fall down material was stored. The thickens of this dispatched material was about 20-50 m, with its total volume was 770.000 m^3 (530.000 m^3 of salt fallen from the roof and 240.000 m^3 sterile gangue, which has pervaded from the north).

The additional material laid down later on the bottom must also be mentioned: 800.000 m^3 (March – November 2001) and 400.000 m^3 (November 2001 – February 2002).



Evolution of the recorded setllements

The shape of time-settlement curve as recorded reflects the main changes of the salt production system The subsidence generated by the development of the tabular void was a continuous pro-

cess throughout the 1978-2002 period and is still active. Before the1991 damage, the most active zone was situated between the boreholes 364 and 376. After 1991, over this general background the effects of a very active subsidence zone situated in the north of the 365 well were superimposed. Before the collapse of September 2001, the maximum values of subsidence recorded along the subsidence valley were about 2.2 m. (Fig. 2). A strong increase of the subsidence gradient was recorded again at the northern boreholes after the collapse of September 2001. Until now, the highest values of 50-55 cm/year were recorded at the 365 and 367 wells.

The causes of the 12 september 2001 colapse

The SOCON cavern separates the dissolution void of the borehole 367 by the remaining parts of a pillar. The partially saturated water coming from the 367 well was able to attend the southern and western boreholes only by going around the "salt barrier" which separated the 367 and 365 wells. As a consequence, the dissolution void was developed predominantly towards the north, reaching the salt – sterile gangue boundary. It was during the production period, before 1991, the breach was in connection with the tabular void.
The 1991 damage led to the failure of the remaining part of the pillar situated between the boreholes 365 and 367, accompanied by the stress redistribution in the northern pillar of the SOCON-cavern.
Consequently, the instability of the collapse arch increased and the sterile gangue material coming from this collapse arch filled up the tabular void (Fig. 3). Also the subsidence of the northern part of the cavern was reactivated and the most active zone was around the 365 well. The resulted displacements superimposed over the preexisting subsidence valley while the salt roof of the cavern in now northward.

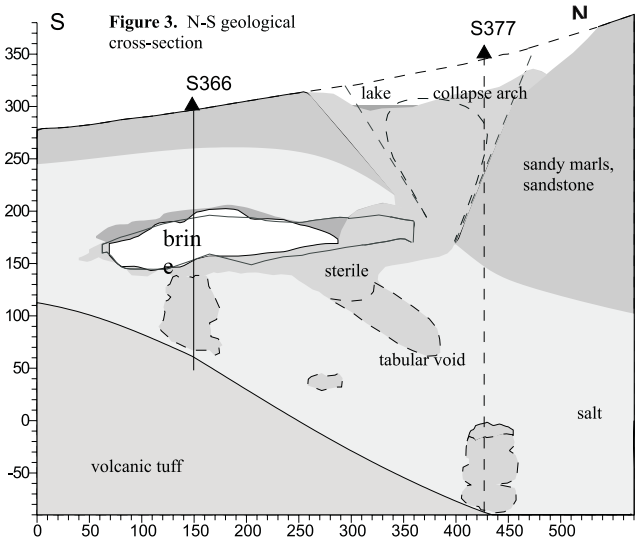


Figure 3. N-S geological cross-section

The 12-13 September damage was due to the collapse of an old void. The immediate consequences were: the decrease of the cavern pressure by 1.4 bars, the penetration of an important volume of sterile gangue material into the cavern and the setting up of a collapse crater at the surface. It results from the balance of materials that in March 2001 and September 1993 were dislocated from the collapse arch 930.000 m^3 and 820.000 m^3 respectively. At the same time, the arch levels were 310 m and 300 m respectively.

The behaviour of the lake-cavern system

After the crater was formed, a period of very intense reshaping process of the hill slopes followed. The spilled brine volume has the same value as that of the sterile gangue, which penetrated into the lake. The downward mobility of the weathering deposits is due to the both geological effective stress at the basis of the collapse cone and the resistance at the penetration into the cavern. In order to maintain a constant level of the lake, when an important volume of brine was spilt out an upward movement of brine equivalent with the downward movement of sterile gangue was necessary.
The reshaping process of the hill slope around the lake decreased during the period November/December 2001. Also the downward movement of the sterile gangue becomes less intensive, as well as the upward movement of the brine. A plug with a very low conductivity was set up in sinking case, working as a piston. The material stored over the plug led to an increase of pressure in the cavern: on 03.01.2002 a value of 2.7 bars was reached, while the bottom of the lake has a constant level of 295 m.
In June 2002, the lowering pressure in the cavern released the material stored in the sinking case. Consequently, the pressure in the cavern increased suddenly to 3.3 bars. The excess of the cavern pressure was discharged in to the lake generating waves and turbulently phenomena. The working of the cavern – the lake system causes that the pressure in the cavern be equal or higher than hydrostatic pressure of the sinking cone. Because the weathering material brings up about 280 l/m^3 of fresh water, the specific weight of the brine diminishes from 12 kN/m^3 to 11,6 – 11,9 kN/m^3. Consequently, the lake level is over the piezometric head of the brine. In order to increase the taching over of large volumes of sinking material without brine expelling, some volume of water was siphoned out from the lake.

CONCLUSIONS

The main coupling phenomena, still active at present, which can generate the future evolution of situation in the Field II area, are: accelerated continuation of subsidence process along the existing subsidence valley; expanding outline of subsidence cone and outrunning limit equilibrium condition in northern pillar and one third roof of SOCON-cavern. Lowering the bottom lake under 280 m level can generate sloping of the northern hills. On the other hand, energetic deformation of the roof in breach zone can generate the collapse of northern half SOCON-cavern (in the same time with the upsetting of a large quantity of brine); the deposits of crumbling cone remobilization and sloping hills from north to future depression.
There are many possibilities that natural coupled processes start with disastrous consequences. These processes once started, it will be impossible to control them.
It is obvious that “ecologic bomb” from the Field II in the Ocnele Mari area, is still active.