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THE OCNELE MARI SALT MINE COLLAPSING SINKHOLE – A NATECH BREAKDOWN IN THE ROMANIAN SUB-CARPATHIANS

Adrian Andrei MESESCU
Authority for Emergency Situations, Valcea County adrianmesescu@yahoo.com

Abstract: A peculiarity of the mining industry in Romania consists of numerous salt mines, fact that generated numerous collapses. A special situation (a NATECH event) is represented by the Ocnele Mari collapse mine (the subsidence phenomenon) in Valcea County. Salt exploitation by kinetic dissolution through wells in Ocnele Mari began in 1961. The dissolution process caused collapses over an area of 10 hectares, with economic and social consequences, affecting 113 households and 209 persons. As a consequence, after the collapse, the authorities ant the specialists perfected their activities regarding the exploitation strategies, management of emergency situations and controlled collapse of the cavity's roof (when it is necessary).

Keywords: Salt Mining Industry, salt exploitation, kinetic dissolution, Natech, subsidence, collapse cavity

1. INTRODUCTION

A peculiarity of the mining industry in Romania consists of numerous salt mines, wherein lake pits occur as a result of collapsed salt exploitation. It is to be mentioned that Romania contains the largest salt resources/reserves of Europe, a potential of about three billion tons that could supply salt for the whole world population for over four hundred years (Fig 1).

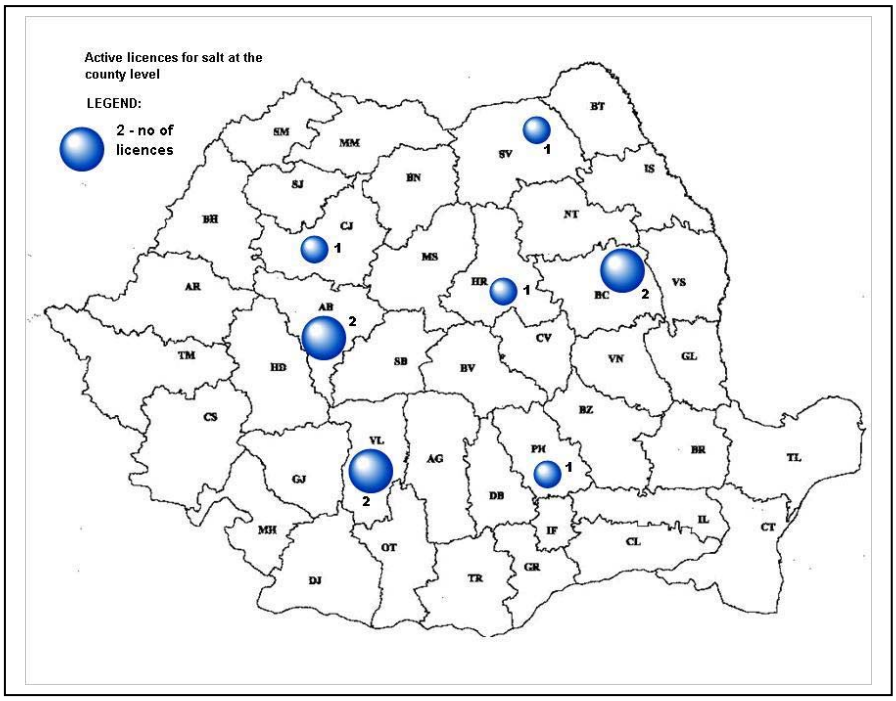

Figure 1 Active salt mining areas by counties in Romania

Sinkholes related to subsidence in salt massifs are filled with meteoric water or groundwater and extensively used for balneology. They are considered of anthropo-genetic origin, or more specific, anthropo-salted in association with diapire structures within two major settings, i.e.the Transylvanian Basin (e.g. Sovata, Ocna Sibiului, Ocna Muresului, Cojocna, Turda, Ocna Dejului), and the Sub-Carpathians (e.g. Ocnele Mari, Sacele-Gorj, Gura Ocnitei, Telega, Slanic).

Unfortunately, many areas with helio-thermal potential face difficulties due to the over-exploitation of the salt resources instead of a sustainable use of the combined spa and curative features (variation of temperature is from 40-50°C at the surface to 5°C at the bottom).

The paper presents a case study of a type of subsidence – large sinkhole filled with salted water as a result of a NATECH event (technical accident occurred due to a natural hazard) at Ocnele Mari salt mine (Valcea County) during over-exploitation/salt-solution by water injection from the surface, the resulting damages and collateral events with final comments on sustainable use of salt resources in order to prevent similar disasters.

2. COLLAPS FORMATIONS RELATED TO SALT MASSIFS

The subsidence of the mining areas represents a major issue in assurance of the safe exploitation activity by maintaining the land stability of the mining works. Sudden and unexpected collapse of the land surface into subsurface cavities is arguably the most hazardous type of subsidence. Such catastrophic subsidence is commonly triggered by ground-water-level declines caused by pumping, or by diversion of surface runoff or ground-water flow or injection through susceptible rocks. Though the collapse features tend to be highly localized, they can introduce contaminants to the aquifer system and, thereby, have lasting regional impacts. Collapse features tend to be associated with specific rock types having hydrogeologic properties that render them susceptible to the formation of cavities. Human activities such as salt-solution exploitation can facilitate the formation of subsurface cavities in these susceptible formations as well as the collapse of subsurface cavities.

An illustrative example is the salt mining subsidence in Retsof, New York (Kappel et al, 1996) produced by the surface water intrusion into an active salt mine, weakening the resistance column pillar between the formerly exploited salt domes. The collapse of the land surface occurred on 12 March 1994 as a sudden fall of the roof over an over-exploited salt domes, caused by the ground water infiltration within the mine, yielding dissolution and the structural weakening of the resistance pillars within the salt domes. Even the area affected was twice smaller than the one occurred in Romania, the effects of the subsidence were significant, comprising: the loss of the water resources and damages of the water and soil quality within the affected area, land deformation and instability on short and long term, causing irreversible damages of the natural recourses and disrupting the public infrastructure.

In order to forecast and avoid the sudden collapse of the salt mining works, conceptual and numerical ground water flow models have to be implemented in order to better assess the stability evolution of the salt mine stability.

3. OCNELE MARI NATECH BREAKDOWN

3.1. Location

Ocnele Mari, a important historical salt mining area of Romania, located in Sub-Carpathians, Valcea county, is nowadays at risk of extensive collapsing. This ongoing process was initiated in 2001 by the human-induced collaps and sinkhole formation within the operation sector Field II Teica as a result of over-exploitation by water injection since 1960, underground accumulations of brine, and utilisation for caustic soda manufacturing and other processes at nearby chemical plants. The area is a part of a Natural Park, under protection of salt natural formations, forests and salt springs and lakes of spa type, with 21 sites on a list of historical monuments, including churches which are endangered of collapsing due to the land instability, a subsequent effect of the uncontrolled industrial dissolution of the underground salt deposits.

The salt deposit is located by a important water course, the Olt river, impounded and transformed since the ’70s in a chain of accumulation reservoirs, down to the confluence with the Danube River (Fig. 2).

3.2. Local geology

The regional setting is represented by the Ocnele Mari-Govora anticline, a structure assigned to the Dacian Basin (Huica, 1998).The Ocnele Mari natural salt deposit occur in Miocene sedimentary deposits of E-W striking Badenian age surrounded by Sarmatian rocks. The length of the salt deposit is about 2,500 m, and the width of 1,650m. The thickness of the deposit is ranging from 24m up to 327 m.

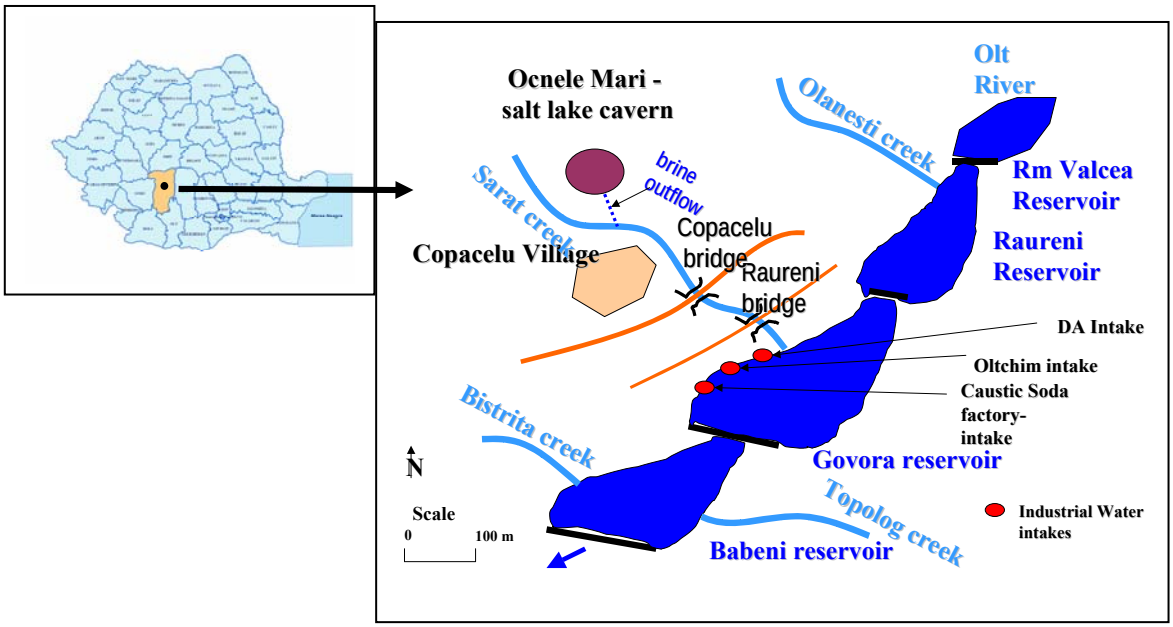

Figure 2. Location of the Ocnele Mari salt mining subsidence lake, upstream of the main industrial intakes from Ramnicu Valcea (capital town - Valcea County)

The cover of the salt deposit comprises tuffitic marls and slightly permeable clays. The alluvia located at the top of the main valleys in the area, especially the Salt creek, having different width, allow the water surface percolation in the upper part of the salt deposit and intense salt dissolution with effects on the soil surface.

The geological conditions affects the technological process of salt dissolution due to heterogeneity of the salt deposit and because of the barren intercalations varying between 0,5-20 m. The barren intercalations and the qualitative variation of the salt composition modify the sinking speed of the solvent used to remove the salt from the deposit, blocking the normal direction of the solvent, and activates the dissolution along the contact surface salt/barren, facilitating the random connection of the dissolution cavities. In addition, barren intercalations found between the dissolution cavities, as a part of the resistance pillars, could induce a negative structural effect on the resistance structure and exploitation technology. Commonly barren intercalations are found especially in the footwall of the salt deposit.

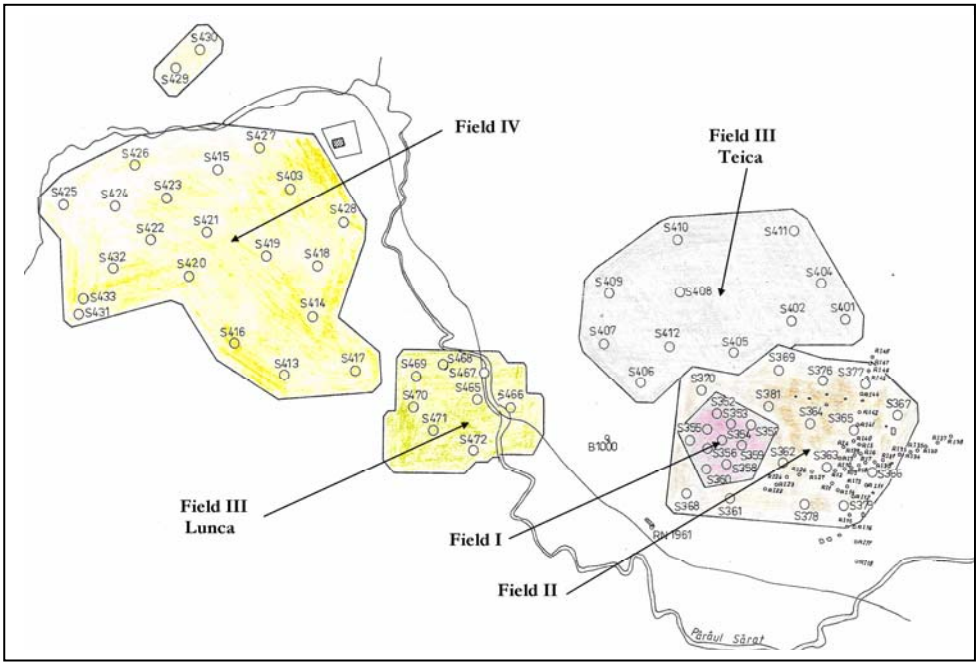

Figure 3. Layout of Field II at Ocnele Mari salt mine

The dissolution wells could allow the exchange of technological water with the groundwater from the surface inside the salt deposit due to the well steel column defects, allowing the contamination of the surface water with brine (Mesescu et al 2008, 2009).

3.3. Human-induced collaps cavity at Field II Teica, impact and measures

A cavity appeared suddenly in the area of Ocnele Mari salt deposit, Field II Teica (Fig. 3) on 12 September 2001 following a period with heavy rains which weakened the structure around the over-exploited underground salt deposit (Fig 4).

When the hanging roof of the cavity collapsed, the excess of the shallow salted water flowed down to a nearby creek, and afterwards reached the Olt River. The outflow of brine water from the new formed cavity severely polluted the downstream water reservoirs of the Olt River, which is the main water resource of the industrial area of Ramnicu Valcea, capital Town of Valcea County. Several chemical plants, among them the major producer of caustic soda from Romania, Govora SA, and another two plants, had to reduce the output by 30% because of the improper quality of the water intakes from the Olt River. Until the uncontrolled brine evacuation diminished, due to temporary collapse stabilization and dilution measures from upstream reservoirs, the water salt content from Olt River exceeded 30 times the maximum admissible values. Following this, urgent measures for diluting the excess salt content were taken by the national water authorities, i.e. releasing supplementary discharges from upstream artificial lakes.

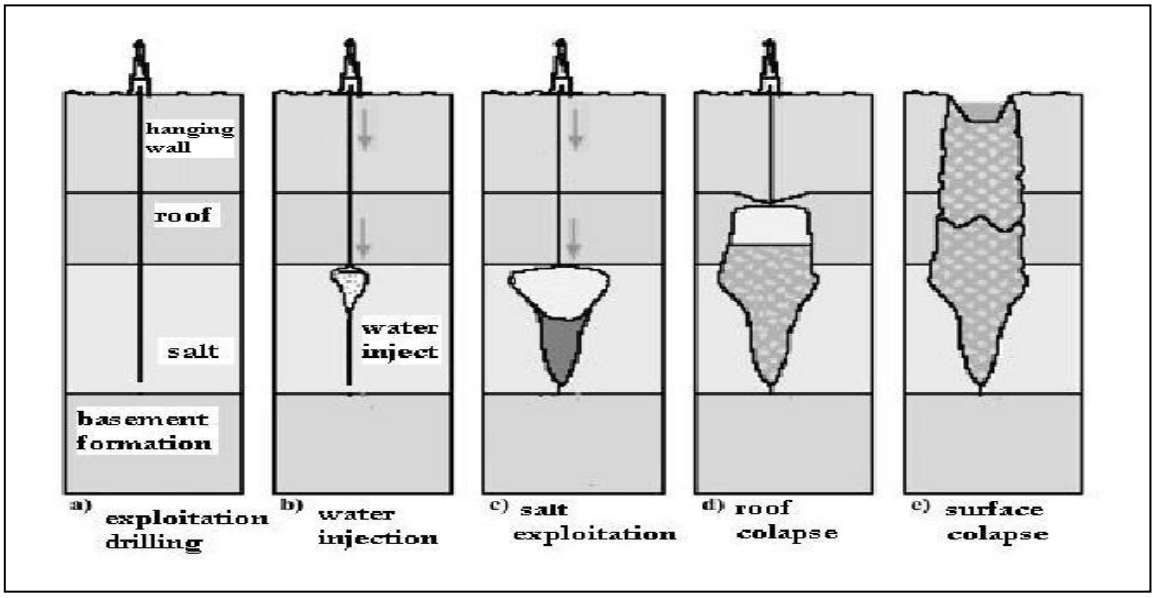

Figure 4. Evolution stages of a subsidence area: a) drilling in the salt formation b) injection of water in the salt formation and brine abstraction c) uncontrolled expansion of the dissolving area due to the lateral dissolution d) roof formation collapse inside the previous dissolved cavity, e) roof formation collapse extension through the surface.

Next year, following the early damaging event other collateral collapses, triggered by the extreme weather conditions with increased rain over the affected area, gave rise to a large crater-like area, filled with a salt lake with a total surface of 3000 sq. m, and 80 m diameter.

Each time when the meteorological conditions deteriorated large amounts of brine, hundreds o thousand of c. m. have been discharged into the Olt River, through the local tributaries. Emergency measures have been taken in order to minimize the impact on the surrounding human settlements, and to the intakes from the local chemical industry, such as (Petrescu et al 2008, Mesescu et al 2009):

- the continuous surveillance of the endangered zone; the resettlement of the affected households and peoples;
- construction of a 80,000cm retention dam (Fig.5a,b) in order to avoid direct spill into the Olt River;
- cleaning up the spill from the affected area.

3.4. Prevention of future impacts

The impact of the mining industry in Romania often constitutes an impediment to the development of any economic, recreational or rehabilitation activity, both from the landscape and environment

quality point of view. Consequently, such an impact is an important issue to be taken into consideration, in order to create sustainability in terms of mineral resource management and natural heritage preservation (Fig. 6).

The authorities, supported by the local stakeholders, with public consent, are to be involved to speed up the assurance of safety mining activities, in order to fulfil the European and worldwide standards of environmental protection. Overall mining activities should be carried out by appropriate allocation of financial founding, and by imposing the legislation for the whole range of mining operations. The most important aspect regarding the degree of innovation in the mining industry refers to the demands of harmonizing the mining operations with international main policies of the environmental protection.

Figure 5. Protective dam, a before and b. after a new collapse episode following abundant precipitation in the affected area.

Figure 6. Uncontrolled continuous flow of brine from the underground cavity increased the vulnerability of landslides in the surrounding area of the Natural Park at Ocnele Mari, affecting local heritage.

Figure 7. Field II Teica, 2009 - recent evolution of the damaged area, strongly suggesting urgent recovery measures to stop the subsidence extension to the remaining unaffected salt mining field

The key components for an environmental friendly mining industry stem from the management of wastes of the extractive industry and the decontamination of adjacent air, waters, ground and underground. Due to the actual needs of expertise in the field of ongoing mining activities, closure and conservation, including the clean up of the abandoned areas, the priority in the actual framework of academic research for environmental impact mitigation of the mining activities, is to meet the EU environmental protection requirements.

Therefore, in order to achieve a sustainable use of the natural heritage given by numerous salt pits lakes, urgent measures and allocation funds for rehabilitation and conservation should be taken in order to mitigate the impact of possible disrupting activities over the rational use of this welfare (Fig. 7).

Continuing studies, achievement of accurate modelling and refined management strategies of the exploited or abandoned salt deposits sites, and the methodological guidelines for recovering the geological environment of the contaminated sites (including rehabilitation of the mining lake pits) constitute a prevention and remediation useful tool for the risk managers involved in structural safety of the salt mining industry.

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