S T U D I A G E O M O R P H O L O G I C A C A R P A T H O - B A L C A N I C A

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L A N D F O R M E V O L U T I O N I N M O U N T A I N A R E A S

Recent geomorphological hazards in Carpatho-Balcan-Dinaric region

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A LARGE SCALE COLLAPSE IN THE OCNELE MARI SALT MINE FIELD, GETIC SUBCARPATHIANS, ROMANIA

Abstract. The molasse of the Ocnele Mari cryptodiapir anticline, having a weak mechanical resistance as a consequence of the Moldavian and Walachian tectogenesis, contains salt cores. Starting with 1960, about 2 million tons of salt have been exploited on the Teica Mare field, through the process of dissolution in wells.

An uncontrolled exploitation using the process of dissolution in 25 wells has led to the degradation of the inner-chamber salt towers and to the expansion of a ground cave of 10,500 m^3. The support capacity of the roof brokes in 2001, when 3 million m^3 of rock fell and a lake of 7,000 m^2 formed. The brine flooding ran into the Olt River, in the supply area of the groundwater, beard in Romanian-Quaternary rocks. By the infiltration of chlorines into the water of the above-mentioned hydrostructure (a regional aquifer), exploited through 150 wells, at Dragasani and Slatina towns, was polluted.

Keywords: salt dissolution exploitation, mining-induced collapse, Getic Subcarpathians

INTRODUCTION

The region is located in the Getic Subcarpathians which are affected by uplift neotectonic movements at a rate of 2–4 mm/year (Zugravescu et al. 1998). The Ocnele Mari salt-bearing deposit lies in the Valcea Subcarpathians, on the left side of the Sărata Brook, a right handside tributary of the Olt River (Fig. 1). The surrounding hillsides are 275–400 m high, the climate is temperate-continental, average precipitation 700 mm/year, up to 1,225 mm and 1,295 mm registered in rainy years at Govora and Râmnicu Valcea stations, respectively. Heavy rainfalls and their torrential regime favour soil erosion and gullying, also supplying the groundwater.

The sinking hole is formed on a structural plateau, with an altitude of 375 m on salt breccia being dominated by a cuesta of 20–30 m high. The plateau is located on the northern flank of the Ocnele Mari–Ocnita depression which forms an anticline (boutonière anticlinal) along the Sarata Valley, a tributary of the Olt River,

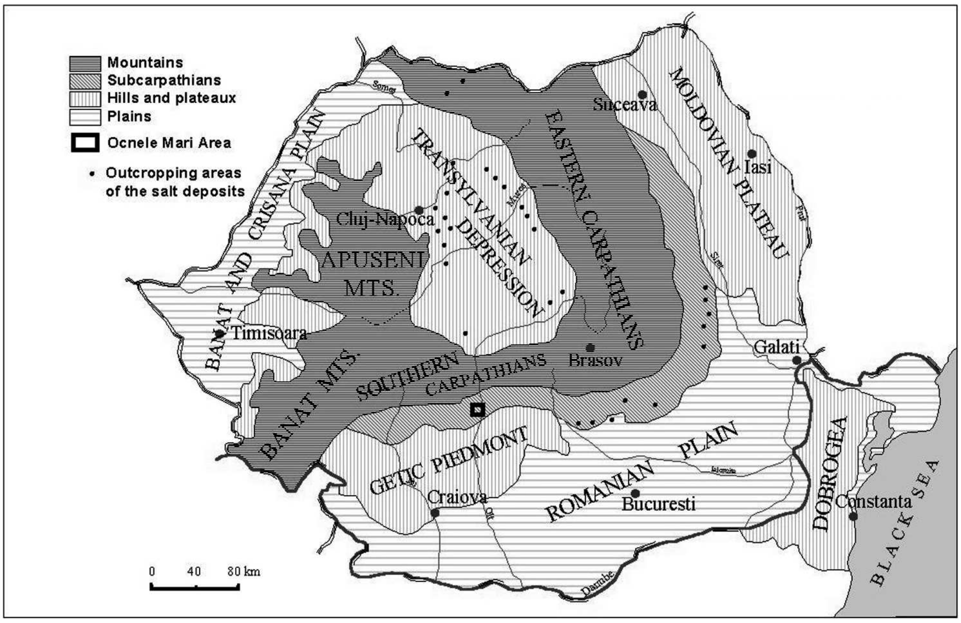

Fig. 1. Location map with outcroping areas of the salt deposits

on its right side. The plateau slopes are 15–20° steep and are affected by landslides and sheet erosion processes. The junction is marked by a fan on the 8–10 m, terrace of the Olt River.

Similar sinking holes, but smaller, with the formation of salt lakes (Fig. 2), were formed close to Ocnita locality during 1968–1977 period by the falling of the roof of some former salt mines and of the galleries among them (Popescu et. al. 1981).

GEOLOGICAL AND GEOMORPHOLOGICAL SETTING

The Ocnele Mari area corresponds to the epirogenetic flank of the Southern Carpathians Foredeep, formed some 65 million years ago in response to the uplift of the Carpathian Montains during the Laramie orogenesis phase. The Ocnele Mari salt-bearing geological formations occupy the Badenian–Sarmatian structural level, accumulated between the Stirian and the Attic (Moldavian) tectogenetic phases.

The salt deposit found in the Teica field has been exploited since Roman Times. The salt inside the northern slope of the Ocnele Mari cryptodiapir anticline was deposited 13.6–13.4 million years ago; it is intercalated between tuffaceous marls with globigerine (the equivalent of the Dej tuff) in the bed layer and schists with radiolarians of Kosovian age in the ceilings.

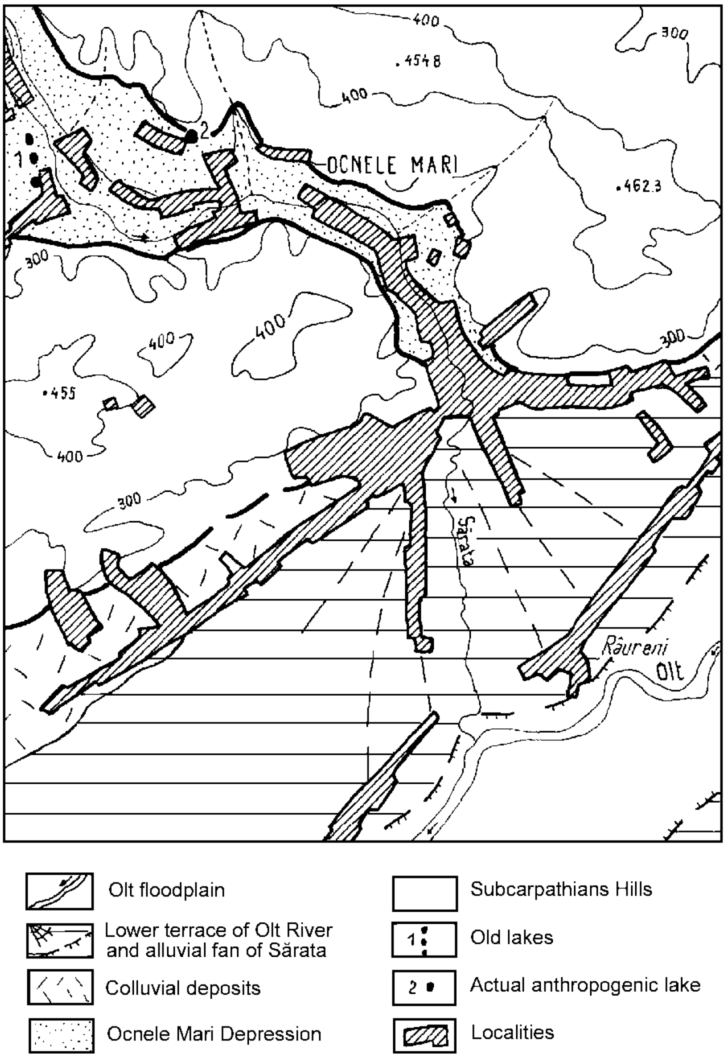

Fig. 2. Geomorphological sketch

Salt appears as a cushion about 7,500 m long and some 2,500 m wide, extending west-eastwards and dipping 25° northwards. The cushion is thinner towards the surface (124 m in well 379) and thicker deeper down (237 m in well 369). Drilling performed above the cushion crossed the Cap-Rock Formation (Salt Breccia), bordered by the Stoenesti and the Biserica Faults in the north and south, respectively (Fig. 3).

The Cap-Rock Formation becomes thicker from south (43.6 m in well 379 and about 44 m in the adjoining wells 366 and 378) to north (242 m in well 369) in the direction of salt tilting.

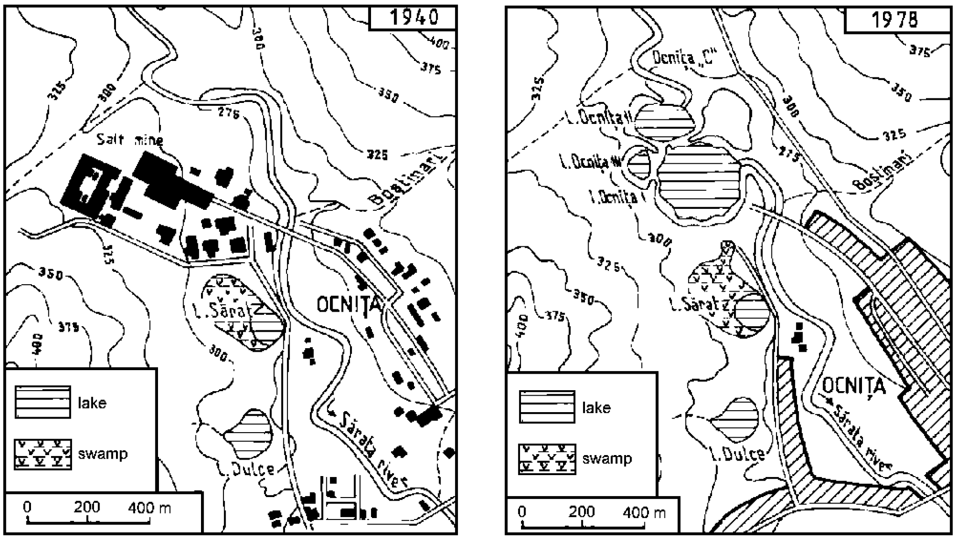

Fig. 3. Old lakes in the salt exploitation area Ocnita (Popescu et al. 1981)

ENVIRONMENTAL VULNERABILITY AND ANTHROPIC IMPACT

The rocks forming the left-hand side of the Sarata Brook, especially between the Stoenesti and the Biserica Faults situated above the salt cushion, have very low mechanical resistance and high intergranular fissured permeability. In such conditions, the slopes are affected by landslides, which are reactivated periodically.

Salt layers accumulated in a large sheet during the Badenian time, but folded and pushed up along the lines of minimum structural strength during Attic (Bessarabian) and Wallachian (Upper Romanian–Lower Pleistocene) tectonogenetic phases.

Between 1960 and 1973, a quantity of 3.4 million tons of salt was extracted from several wells of Teica Mare field I. Exploitation chambers, 50 m in diameter, and cylindrical in shape were designed with 20 m inter-chamber support pillars and a 70 m ceiling.

In the course of the dissolution process, the inter-chamber pillars were dissolved enabling the brine to flow in 9 of the 10 chambers as follows: 5 in 1962; 6 in 1966; 7 in 1967 and 9 in 1968. In view of it, the field ceased to be exploited in 1970. The same year, a second exploitation was opened in Teica Mare field II. This field, with 15 wells in all laid on the same side of the Sarata Brook, a little farther east; the chambers are 50 m in diameter and inter-chamber pillars stand at distances of 50 m outside the dissolution pillars (Fig. 4).

The absence of the necessary control devices to check on dissolution cavities facilitated uncontrolled exploitation also in this field. The presence of three molasse layers interlayered in the salt and laid out conformable with the general

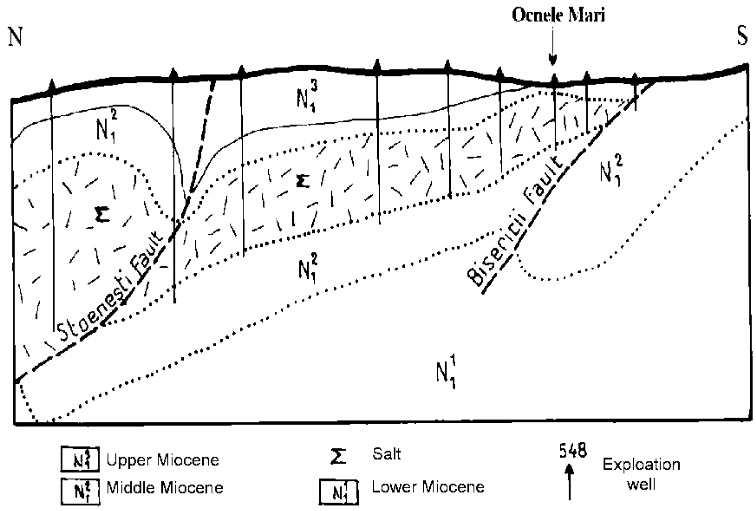

Fig. 4. Geological sketch through Ocnele Mari salt deposit (Deak 2003)

structure, led to the anisotropic dissolution of salt mainly along strata dip. In this way, much of the support pillar salt was dissolved, favouring communication between different wells.

However, the first deterioration of the ceiling had taken place much earlier, in 1970, when fissures in the slope and Diesel oil outflows were seen near well 378 adjoining the Sarata Brook. The oil was injected into the upper side of the chambers in order to limit the dissolution of the 50 m-thick salt left as ceiling support pillars. The sterile in the ceiling is only 44 m-thick.

Since cavity measurement devices over the 1970–1979 period were missing and the salt had to be supplied to the chemical plants of Râmnicu Valcea and Govora, exploitation went on uncontrolled and the underground cavity kept enlarging. Well 363 suffered some damages (uncompleted cementining), while the ceiling of well 379, with only a 43.6 m-thick Cap-Rock Formation (Salt Breccia), partially collapsed. Over the 1970–1993 interval, the extraction 16 million tons of salt from field II dislodged some 9 million m^3, corresponding to a horizontal cavity section of 105,000 m^2 (Goga et al. 2002).

As from 1970, the exploitation system lost its permeability by Diesel outflows in five points. At the same time, the dissolution of two field pillars and the deterioration of another three pillars in proportion of 40–60% led to the development of underground voids along a distance of 50–60 m in the upper side of six wells. As a result, the ceiling remained the main equilibrium support element. In 1993, ceiling thickness varied between 46 m (well 365) and 81 m (well 363) with spans of 200–300 m (Goga et al. 2002).

Cavity measurements made in 1993, 1995 and 1997 suggested that, in time, the ceiling would lose its carrying capacity.

In September 2001, in the area of the Teica Mare sink funnel marginal pillar, the ceiling, well 377 and 3 houses collapsed (Fig. 5). The total volume dislodged was of 3 million m^3, about 1.1 million m^3 of brine was discharged and approximately 1.9 million remained in the funnel. On the first day, up to 560,000 m^3, of brine were discharged at a flow rate of 6.5 m$^3 \cdot$ s^{-1}, flooding some houses and the proximate agricultural land on the 10 m terrace of the Sarata Valley.

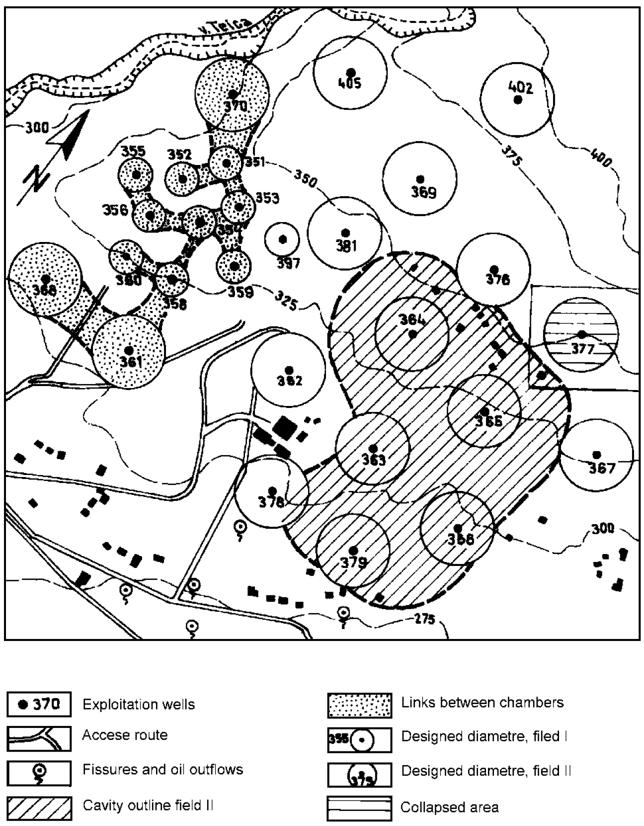

Fig. 5. Scheme of well fields I and II — Ocnele Mari

HYDROGEOLOGICAL AND GEOMORPHOLOGICAL PROCESSES

Owing to the medium-high permeability of ceiling rocks, slightly brecciated, as well as to the continuous uprising of the salt and uncompleted cementing of the conductor pipe of some wells (well 363), rain water from the slope began seeping into the salt massif favouring the dissolution of soluble minerals and weakening the internal cohesion of the rock (Fig. 6).

As a result, in the wake of local sagging, gentle depressions formed on slope, with gullies later developing around them.

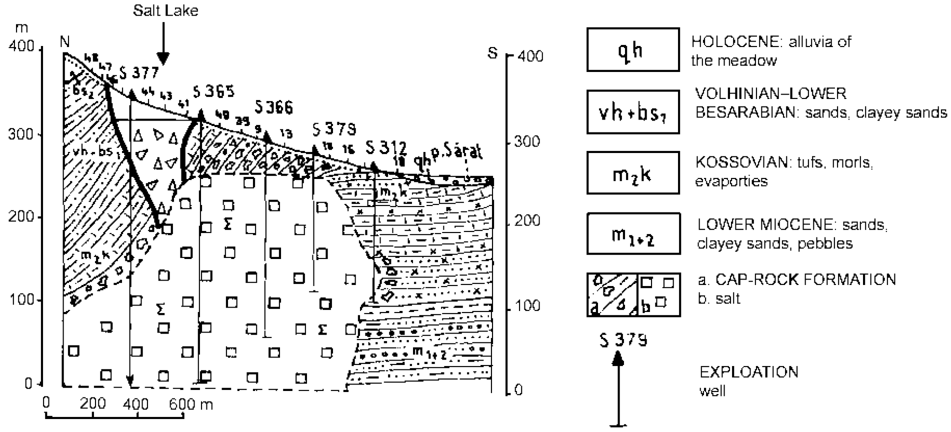

Fig. 6. Geological cross-section in exploitation field II — Ocnele Mari with the collapse area

The uncontrolled exploitation of salt made underground voids enlarge, facilitating mining-induced subsidence on the surface. The sinking process, observed throughout the period of exploitation, was seen to grow in intensity. For example, in well 377, the sinking depth increased from around 1 cm in 1976 to 14 cm in 1984 (Deak and Deak 1999). Forecasts for 2001 estimated a 3.2 m cumulated vertical subsidence at well 377. As a matter of fact, the year 2001 witnessed the collapse of 3 million m^3 of rock and the formation of a lake over an area of nearly 7,000 m^2.

Because of the collapsed terrain, the brine flood eroded the sides of the gully between the funnel and the Sarata Brook, ran into the Olt River and polluted its waters (Balteanu et al. 2003).

Since the Sarata–Olt Rivers confluence is situated on the epirogenetic flank of the Southern Carpathian Foredeep, these courses, together with the underground waters of the lower Olt terrace, supply in the outcropping sector the aquifer confined in the Upper Romanian–Lower Pleistocene Formation. The waters spilled from the collapsed area polluted this aquifer with chlorides. The effects of the Teica Mare brine flooding into the lakes of the Olt River will in time affect the catchment lines of wells lying in the south (main source of drinking water for of Dragasani and Slatina towns). Near these two localities, there are 3–4 north-south-oriented alignments with over 100 pumping wells having a depth of 100–125 m to meet population and industrial demand which will be heavily polluted. Dragasani is situated in the axis of the Southern Carpathian Foredeep, and Slatina lies on the southern flank (epiplatformic) within the underground transit area of the aquifer of Upper Romanian Formation (Enciu et al. 1998). Subsequently, during the 2004 and 2005 years, the new areas pertaining to northern side of the funnel collapsed.

In conclusion, the terrain degradation in the Ocnele Mari exploitation field will continue as the cavity ceiling is subsiding and eventually collapsing when new surfaces on slope keep retreating. The diameter of the sinking funnel becoming ever larger, the risk for a major landslide to occur in the upper part of the slope at altitudes of 350–400 m is increasing, too. Starting with 2006, the controlled collapse of the ceiling associated with brine evacuation Project was promoted.

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REFERENCES

Balteanu D., Enciu P., Deak G., 2003. *Riscuri geologice şi geomorfologice în arealul exploatării de sare Ocnele Mari, judeţul Vâlcea, Mediul-Cercetare, Protecţie şi Gestiune*, edit. Presa Universitară Clujeană, Cluj-Napoca, 39–43 pp.

Deak G., 2003. *Elaborarea unui sistem de monitorizare si control in vedera imbunatatirii conditiilor de stabilitate la exploatari de sare gema pe cale uscata.* Ph. D. Thesis, abstract, Univ. Pertosani, 47 pp.

Deak G., Deak S., 1999. *Evaluarea situatiei de posibil colaps a Campului II de sonde Ocnele Mari prin metoda DKR control*. Rev. Minelor 7, 23 pp.

Enciu P., Popescu Gh., Hadnagy A., Ciuvalu M., Enciu M., 1998. *Hydrostratigraphy of the of the Neogene Deposits from the Central Dacic Basin*, An. Inst. Geol. Rom. 70, 15–20.

Goga T., Sarachie I., Prida T., Miklos G., Giurgiu N., 2002. *Surparile de la Ocnele Mari (Rm. Valcea) si ce trebuie sa învatam din efectele lor dramatice*, Rev. Minelor 3, 3–11.

Popescu N., Ciumpileac Gh., Ielenicz M. 1982. *Valea Sarata şi complexul lacustru Ocnita. Consideratii morfohidrografice*. SCGGG-Geogr. 29, 34–41.

Zugravescu D., Polonic G., Demetrescu C., 1998. *Recent crustal movements map of Romania.* Rev. Roum. Geoph. 10, 21–27.

STRESZCZENIE

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WIELKOSKALOWE ZAPADLISKO KOPALNI SOLI OCNELE MARI W SUBKARPATACH GETYCKICH W RUMUNII

Molasowa antyklina Ocnele Mari jest kryptodiapirem o małej odporności uformowanym 13,6–13,4 mln lat temu podczas morfogenezy mołdawskiej i walachijskiej. Podnoszące ruch neotektoniczne odbywają się do dnia dzisiejszego z szybkością 2–4 mm/rok. W jądrze tej struktury występują sole, które są intensywnie eksploatowane od czasów rzymskich. Od roku 1960 około 2 mln ton soli zostało wydobyte w procesie wypłukiwania w systemach studni. Niekontrolowana eksploatacja 25 studzien spowodowała degradację komór i jaskiń oraz osiadanie 3 mln m^3 skał i uformowanie jeziora o powierzchni około 7000 m^2. Potok Sarata odwadniający obszar górniczy spowodował zanieczyszczenie wód rzeki Aluty (Olt). Procesom osiadania towarzyszy osuwanie zboczy.