HOW TO PREVENT THE RISK OF SURFACE WATER INTRUSION IN THE OLD PRAID SALT MINES (ROMANIA)

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Abstract
In Romania, surface waters nearby the underground salt mine sites have a significant negative impact on the stability of mining works (trapezoidal rooms, rooms and pillars, adits, etc.). Such kind of problems occurs in many salt exploiting facilities i.e. Slanic Prahova, Tg. Ocna, Praid. In this paper, the authors intend to present a proposal to face this issue at Praid salt mine. The target of this research is to avoid the hazard represented by intrusion of surface waters into old mining works. Here monitoring activities are proposed to prevent damages due to the seepage of Corund creek water into the subsurface salt body, fact which could compromise and even produce collapses in salt mine sanatorium and in both old and new mines.

Introduction
Praid Salt Mine is located in the Praid Sub Carpathian Depression, between the volcanic plateau which is bordering Gurghiu Mountains and Becheci Hills (1080 m) at East and Şiclod Hills (1028 m) at West. The plateau is drained by the Corund creek which is a tributary of Târnava Mică stream (Fig. 1) (Deák et al., 2006b).

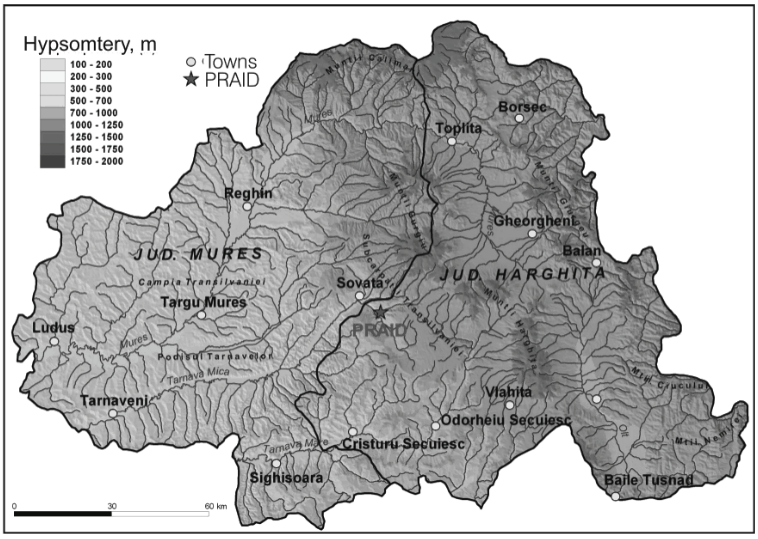

Figure 1. Site location in a regional map.

From north to south, Praid Depression is characterized by two main relief levels: a peripheral one, at 600-700 m, which gives the depression a corridor like shape 30 km long and 5-6 km wide and a lower level situated at 500 m, characterized by small erosion basins in which Corund, Ocna de Sus, Ocna de Jos and Praid settlements grew, the last one having the biggest expansion. Praid salt structure is very well shown within Dealul Sării, which is one of the biggest diapir folds in Europe.

The salt mine of Salina Praid exploits one of the largest salt rock deposits, nicknamed "Europe salt cellar" and placed in Dealul Sării at the height of +567 m, in Praid, Harghita county. The geological reserves are assessed at about 3 thousand millions tons of salt rock. Rock salt is exploited in the area since the Roman Age. The systematic exploitation was for the first time officially testified in 1787, when Mina Jozsef was opened; from this mine the underground exploitations Karoly and Ferdinand were developed at depth of 66 m from the surface. In 1864 Mina Paralelă was opened at the depth of 96 m from the surface, and on 1898 Mina Erzsebet was opened. Until 1945, the exploitation technology was exclusively based on manual digging. Since 1947 the blasting technology replaced the old one, when Mina Gheorghe Doja (Dozsa Gyorgy) was opened with large trapezoidal chambers. In 1978 Minele Noi mine was opened, employing an exploitation technique based on multilevel rectangular long pillars and a safety floor 40 m thick in Mina Doja. The spatial distribution layout of the salt mines from Praid is shown in Figure 2 (Deák et al., 2006a).

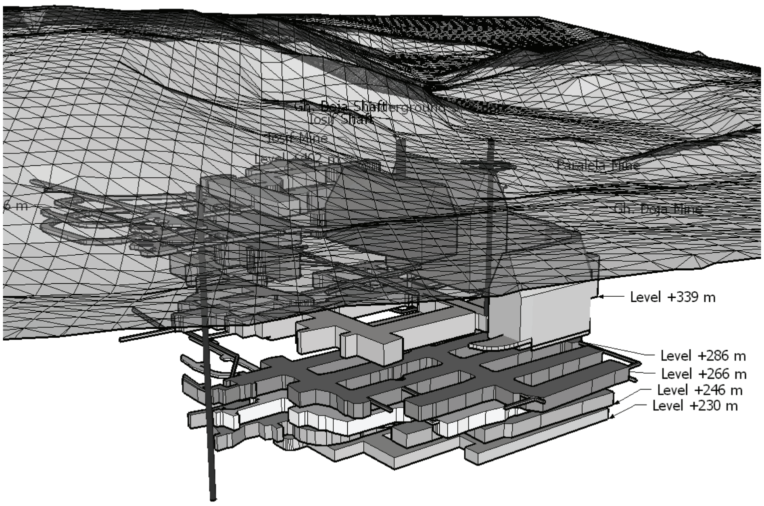

Figure 2. General view of the salt mines in Praid, Romania.

Figure 2 shows Minele Vechi (Old Salt Mines), which are now out of activity (+460 m to +360 m), Salt Sanatorium Mines (+339 m to +354 m) and Mina Nouă (New Mine) (+286 m to +230 m), which is currently working; we have also represented two main shafts (with high flooding risk) and one blind shaft whose risk is subordinated to the reliability of the tow main shafts.
The general map of the investigated zone is shown in Figure 3 together with the mining perimeters, Corund stream, salt springs line, suffosional depressions and topographical levels.

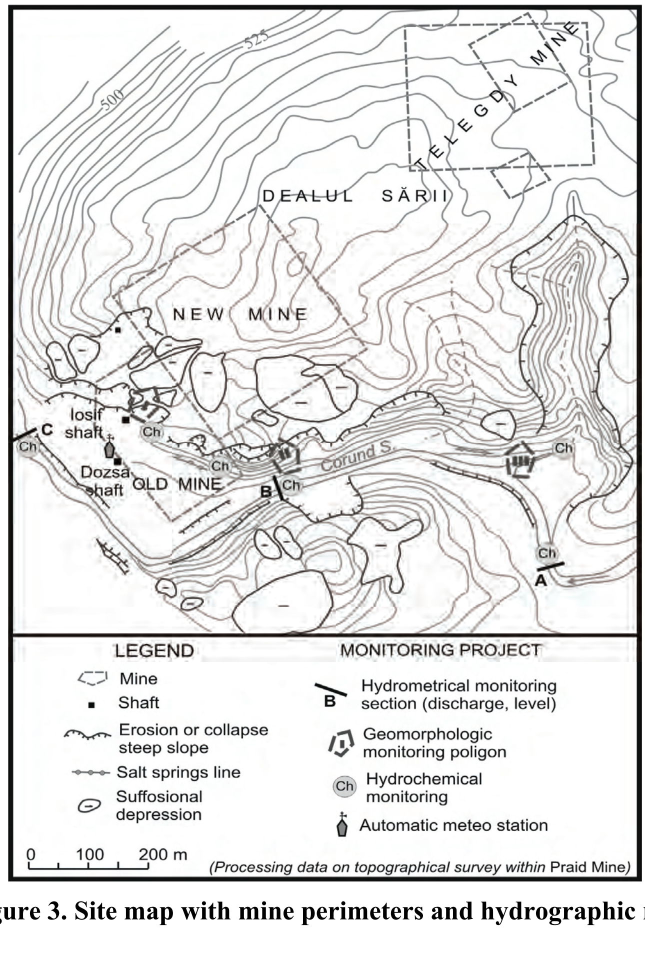

Figure 3. Site map with mine perimeters and hydrographic net.

In the following section the authors propose an investigation methodology to remove or reduce the hazard concerning the possible flooding of Praid salt mine through old salt mine chambers.

Methods

The research was developed in three steps:
Step 1 – Identification of sampling points along the Corund stream to assess water quality in the potentially impact area.
The salt spring was also identified and the Corund stream water, at and downstream of mining works, was analyzed (Fig. 4 and 5).
Step 2 – Investigation of the potential high impact zone by geoelectrical tomography. The goal was to identify the hydrogeological actual situation on the salt breccia rock.
Step 3 – A decisional analysis concerning the Praid salt mine flooding to identify the engineering solutions for risk elimination/mitigation through the DKRControl method (Deák and Deák, 1998, 2005).

Figure 4. Water sampling from middle river section.

Figure 5. Water sampling at the spring.

Results and Discussion

In order to determine water quality and dissolution capacity water samples acquired from four sampling points were analyzed. The water samples were collected as follows: 1- source of salt spring; 2 – inflow of spring water to Corund stream; 3 – Corund stream 10 m downstream of the second point; 4 – downstream sampling point, 100 m upstream from the entrance bridge to Doja shaft.
Anions and cations concentrations were introduced in software to create Piper diagrams, which were used to assess the dissolution capacity of surface waters to the salt rock. Data are presented in Table 1 while the Piper graph in shown in Figure 6 (Mihai et al., 2006).
In the investigated stream section between point 3 and 4, the salt concentration increases from 0.21 g/L NaCl to 0.44 g/L NaCl. This could show the high dissolution potential for Corund surface water in the impact zone. At the same time samples 1 and 2 exhibit a very high salt concentration, close to that of saturated brine.

Table 1. Input data from surface water sample analysis.

Sample	*TDS 105°C g/L	Na^+ g/L	Cl^- g/L	SO_4^{2-} g/L	K^+ mg/L	Mg^{2+} mg/L	Ca^{2+} mg/L	Fe mg/L
1	319.23	123.22	192.9	1.882	282.4	198	1063.4	-
2	269.176	103.58	159.3	2.315	150.3	173.1	854.2	-
3	0.312	0.0735	0.135	0.069	1.47	3.04	12.77	0.03
4	0.568	0.168	0.276	0.076	2.2	3.47	13.93	0.06

*Total Dissolved Salt, determined at 105 °C

On the platform from Gheorghe Doja shaft geoelectrical investigations were carried out through 15 profiles, using mapping technique for the first six profiles and vertical electrical sounding (VES) for the next nine.
The geoelectrical data, transformed in apparent electrical resistivity values, were processed in order to obtain a map of the electrical resistivity in the investigation area, the platform between the two air shafts. It was assumed

that the maximum investigation depth of the Schlumberger device used is equal to AB/4, considering the geological situation in the area, presented in Figure 7, and information from the VES diagrams.

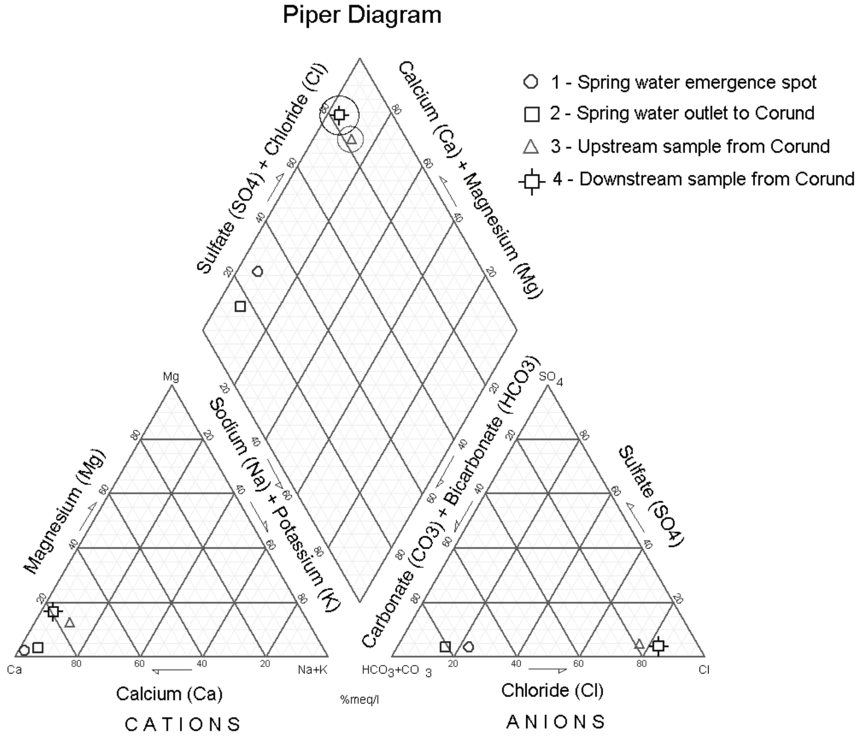

Figure 6. Piper diagram.

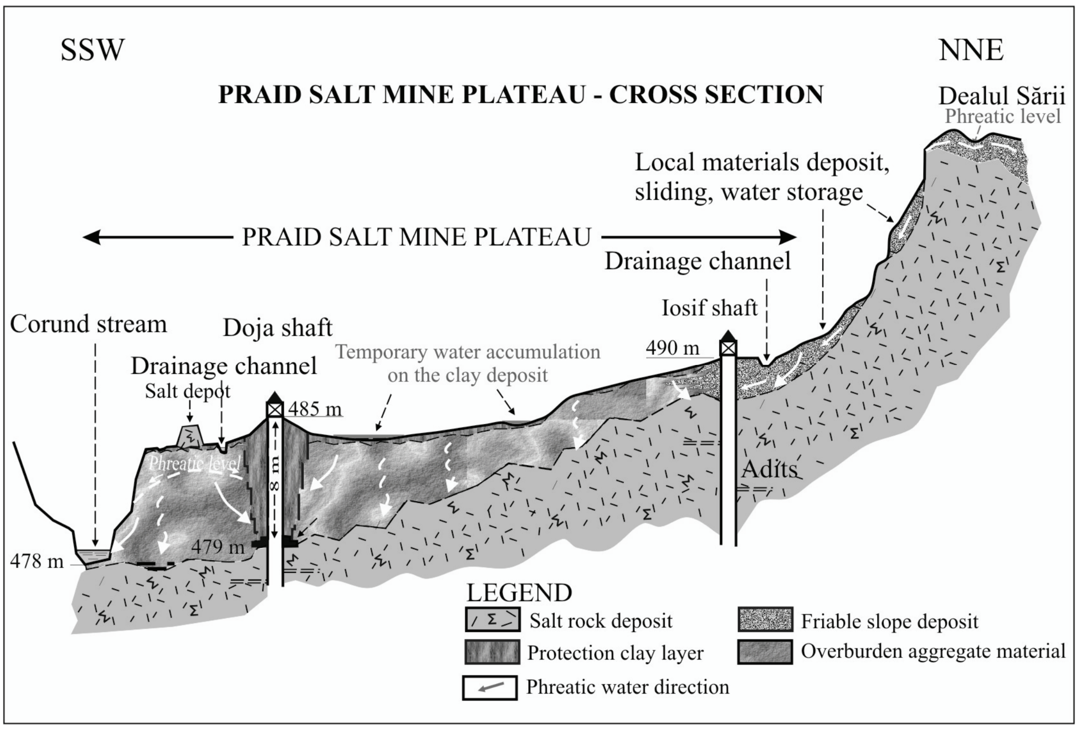

Figure 7. Geological structure of the investigated zone.

Two areas with resistivities less than 1.5 ohms at W, NW and E of Doja (Dozsa) shaft were recognized. These areas are clearly shown in Figure 8 on the sections from heights +480 m and +475 m, and are fading/superposing in depth. The geological interpretation of the geoelectrical data is based on the knowledge that minimum values of resistivity are associated to geological formations with high humidity.

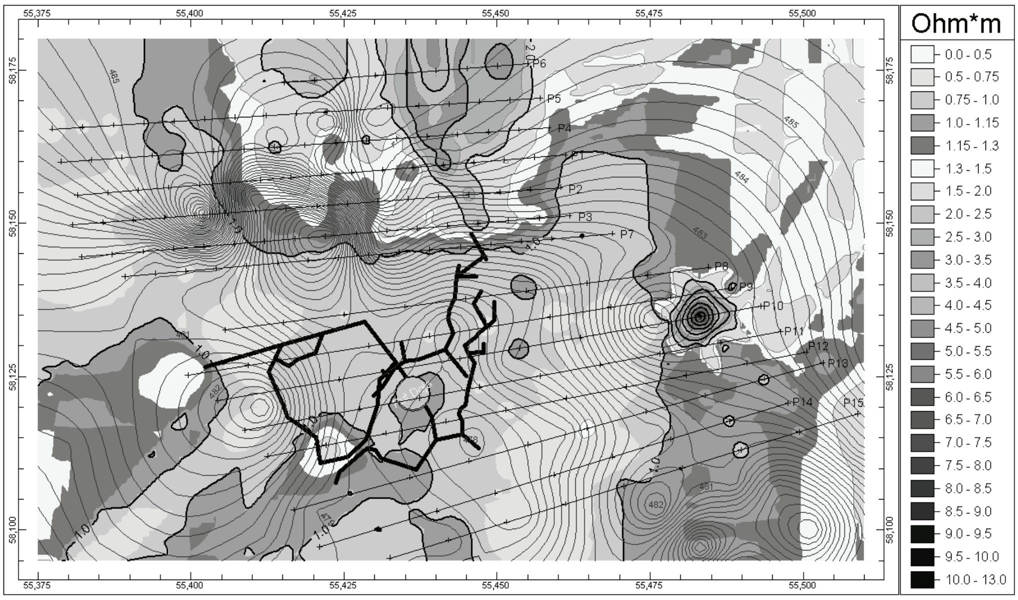

Figure 8. The horizontal distribution of apparent resistivity at altitude about +480 m.

According to the DKRControl method, there is a risk between 20 and 23 % of information, which lacks while it should be necessary to describe completely the system having a significant influence on the studied problem. The authors consider that in the case of the Dozsa shaft (the zone most exposed to the flooding risk in the investigated area) a knowledge degree of 80% can be accepted.

Conclusions

From the geochemical analysis, the dissolution capacity of Corund surface water may increase the potential risk of generating hydrogeological "windows" with direct impact on underground mining works flooding. For elevations close to salt breccia stratum the electrical tomography showed resistivity anomalies with minimum values for a quite large surface. This points out a high humidity zone (presented in Fig. 8). Prevention solutions against flooding depend on the execution of three hydrological and geomorphological monitoring stations on Corund stream (presented in Fig. 3). In case of increasing risk with serious damages the river diversion could be imposed.

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