Classification of the Ocnele Mari saline from the point of view of gas emissions (CH_4 and CO_2)

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Abstract. Currently in Romania there are six salt mines which exploit the salt through underground mine workings: Dej salt mine, Tg. Ocna salt mine, Slanic Prahova salt mine, Ocnele Mari salt mine, Cacica salt mine, and Praid salt mine. The purpose of the present paper work is to establish the methane release (explosive gas) and the carbon dioxide release regime in mine workings from Praid salt mine in order to classification. This verification of the Ocnele Mari salt mine classification has been carried out during September 2021 and there have been taken into account the following elements: - Geological and technical-mining conditions of the salt deposit related to Dej mining perimeter; - Results of the quantitative and qualitative measurements from the underground mine workings regarding: a) Circulated air flows; b) Measured methane and carbon dioxide concentrations; c) Absolute flows registered; d) Accumulation capacity of gas in the deposit; e) Gas concentrations and pressure in the massif. - Existing evidences and documentations regarding the previous gas occurrences and their manner of manifestation; - Establishing the way in which the gas is released into the underground atmosphere of the mine workings. Based on the observations and on the carried out measurements, on the analysis of the studied geological and mining elements, there has been made the classification proposal of the Ocnele Mari salt mine from the point of view of gas emissions (methane and carbon dioxide)

1 Introduction

The purpose of this paper is to establish the regime of methane emissions (explosive gas) and carbon dioxide emissions (asphyxiating gas) in underground mining works within the Ocnele Mari Salt Mine / mine parts, in order to classify it.
The need for a new classification arose with the loss of the validity of the "Labor Protection Norms for Salt" and the "Labor Protection Law No. 90/1996" and the appearance of the "Law on Safety and Health at Work No. 319/2006 ''
The following elements have been taken into account for the preparation of this paper:
-the geological and technical-mining conditions of the salt deposit from the Ocnele Mari mining perimeter;

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-existing records and documentation on previous gas occurrences and their manifestation;
-the results of quantitative and qualitative measurements of underground mining works, concerning:
a) circulated flows;
b) concentrations of methane and carbon dioxide;
c) the absolute flows recorded;
d) gas storage capacity;
e) mass concentration and gas pressure.
According to the new classification methodology, the salt pans and underground works or areas of them where the presence of methane in the underground atmosphere was not found but where the presence of methane is found in the test holes drilled in the rock mass is considered to be mine / areas of mine or grizzly underground works.
This new classification allows the preservation in grizzly regime only of the proper exploitation areas (work fronts), the rest of the salt mine being considered as blackish.

2 General considerations regarding the location and geology of the deposit

From a geological point of view, the Ocnele Mari region belongs to the Getic Depression, which is the outermost unit of the Southern Carpathians. The sedimentary formations of the Ocnele Mari region correspond to the Paleogene - Neogene - Quaternary interval. The sedimentation process that began in the Paleogene was not continuous, with numerous discontinuities.
The Paleogene is represented by Eocene and Oligocene deposits that are relatively uncomplicated from a tectonic point of view. They form a monocline with falls of approx. 20 - 350 to the south.
The Neogene has a pronounced kneaded character, characterized by numerous plicative and ruptural deformations being represented by Aquitanian, Burdigalian, Badenian and Sarmatian.
Its most important subdivision is the salt and gypsum formation.
The salt massif appears in the axial lifting area from Ocnița - Ocnele Mari.
The elements of the Govora - Ocnele Mari anticline have undergone various tectonic influences marked by the presence of secondary plicative deformations or in the form of transverse or directional fractures.
The main rupture deformations affecting the region are:
• Teiuş fault, located west of the Ocnele Mari deposit with north-south orientation;
• Stoeneşti fault, located north of the deposit, with east - west orientation;
• The fault of the Church, which develops in the direction of Govora - Ocnele Mari.

The salt deposit from Ocnele Mari has the shape of an elongated lens in the E-V direction, measuring in this sense approx. 7.5 km, and to the NW approx. 3.5 km, showing an axial elevation in the Ocnita area, with slopes to the north.
In the roof of the deposit there are deposits formed by yellowish clays, predominantly fine sandy, compact marls, sometimes with friction mirrors, and near the contact with salt and anhydrite nests.
The thickness of the deposits in the roof varies between 20 and 50 m in the south and up to 700 - 800 m in the north, with the sinking of the deposit. The thicknesses of the salt deposit are variable, reaching laminations in the north and south, the maximum thickness reaching 450 m in the central part of the lens.
Due to the alternative changes of sedimentation conditions, the salt from the Ocnele Mari deposit is presented in the form of alternating centimeter banks of white rock salt and dark gray salt, sometimes even blackish, being polluted with subcentimeter and centimeter films

and nests of blackish marls with the smell of hydrocarbons, or nests of bluish-white anhydrite. These intercalations usually appear in the lower part of the deposit, but sometimes they also appear in the upper part of the salt lens, but they have less development.
The deposits in the bed of the deposit are made of compact, layered gray marls, with sand films on stratification planes, sometimes gray-green.
In the lower part of the deposit in general, are interstratified a series of tailings lenses that have thicknesses of 0.10 - 20 m formed of black marls usually micafera, sometimes with the smell of hydrocarbons, fine sandy, compact, representing 8 - 9% from the thickness of the salt.
Inside the massif, the presence of microtectonics phenomena can be noticed, which demonstrates the existence of small tectonic movements, which produced disturbances inside the deposit

.3 Opening, preparation and operation of the mining field

The Ocnele Mari salt mine fig. No. 1 was opened and put into operation during 1991-1996. The operation is performed with the dimensions of the rooms of 12/8 m and pillars of 10/8.

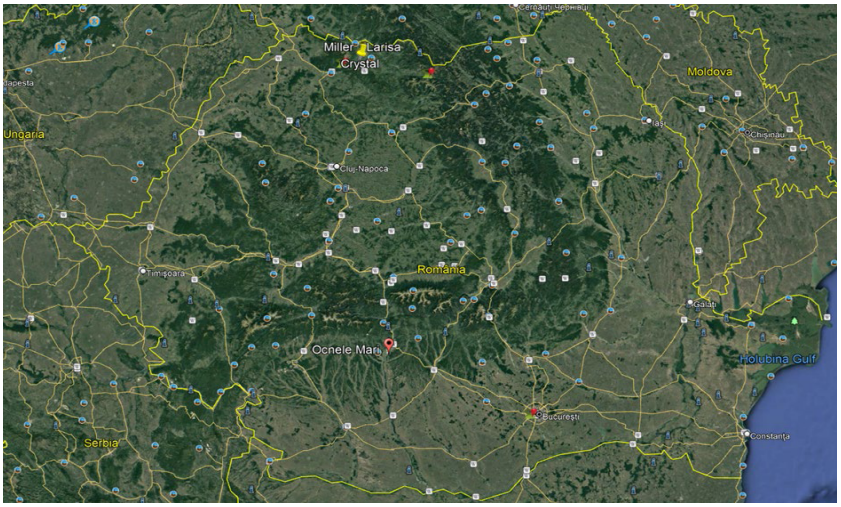

Fig. 1. Location Ocnele Mari.

In 1996, in order to ensure the stability of the mine for a longer period of operation, it was planned to change the method of operation with small rooms (width 14 - 17 m) and abandoned square pillars with vaulted ceiling (14 x 14, 14 x 15 or 15 x 15 m).

The floor between the horizons is designed at 8 m thick. For the safety of the lower horizons there are areas in the western part of the mine where the thickness of the floor is greater.

This measure was taken in view of the following:

• during the execution of the opening and preparation works of the western wing of the horizon (which was exploited without the excavation of the hearth front, and an exact elevation could not be maintained) the shooting works affected the floor by approximately 1 m thickness.

• in the western wing of the mine on the horizon that was exploited there are a series of water infiltration points in the mining works, which even if they do not have high flows, are difficult to stop completely;

• the presence of an old mining work in the west wing of the mine. From the research works with executed drillings it was found that this work has a hearth below the elevation of +227 m;

In order to make the ventilation connection between the two horizons, several ventilation suites are made. Their execution is done when the opening gallery from the horizon. +210 m, reaches the rooms where the location of the suitors is provided.

The suitors run at about 80-90 m from each other, from niches whose hearth is 1 m higher than the hearth of the gallery.

From the opening gallery, 16 × 8 or 15 × 8 m profile chambers are made, oriented perpendicularly to it, leaving between 14 m and 15 m wide pillars, respectively.

At the horizon of +210 m, in the western wing of the mine the chambers with a width of 16 m are executed, and in the eastern wing of the mine the chambers with a width of 15 m are executed.

The cutting is performed after the front is baked and consists of cutting a horizontal track at the base of the front, on the whole width of the chamber, with a thickness of 1400 - 1600 mm, and a depth of up to 3 m. 33.

The drilling of the mine holes is performed with the help of the SECOMA type drilling rig.

Loading and firing of mine holes is done manually from the platform.

Astralite and millisecond electrical staples are used as explosive materials.

The fronts are ventilated under the general depression of the mine.

The loading and transport of salt from the front is done mechanically with the front loader type Wola in dump trucks. Depending on the needs, the salt from the front is transported to the underground preclassification plant or directly to the surface, to the preparation plant.

The belt transport gallery together with the production silo from the horizon of +226 m and +210 m and the inclined connection plane, is the set of works necessary to replace the current car transport of salt, from underground to surface.

At present, the strip plan from the surface to the horizon is executed. +210 and is equipped with the salt belt conveyor system.

At the same time, a new ventilation shaft was built, in the eastern area that connects with the surface.

4 The mine's ventilation system

The general aeration of the mine (fig. No. 2) is made of suction-discharge, diagonally, by means of the main aeration station which is located underground at the base of the aeration well.

Under the action of the depression created by the main fan, located at the base of the horizontal ventilation shaft. +226 m W, part of the fresh air is introduced on the gallery and the conveyor belt plan elevation +253.7 ÷ 210.0 m, and part on the inclined car plane, elevation +255.33 ÷ 227.0 m. The fresh air that is introduced on the car inclined plane will ventilate the tourist point, and the fresh air that is introduced on the gallery and the belt transport plan, will circulate on the aeration suite S2 (the aeration suite between the gallery and the inclined plane with belt and the directional gallery horiz. + 226E), directional gallery horiz. + 226E, operating chambers, front of the horizon directional gallery. + 226E, will descend on the SA 6 suite in the directional gallery the horizon + 210E, (the ventilation doors in the directional gallery horizontal + 226E closed and the ventilation doors positioned in the upper ramp of the inclined plane of car access to the horizon +210, closed), cameras operated from horizon + 210E, barley directional gallery. + 210W,

cameras operated from the horizon. + 210W, SA 10 suite, directional gallery horizon. + 226W and the ventilation shaft, forming the following ventilation circuits:

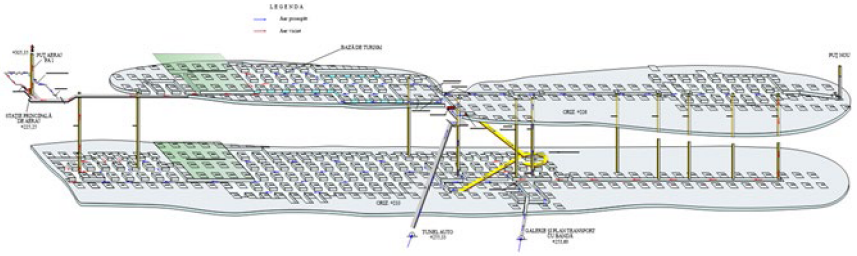

Fig. 2. Indicative scheme of the Ocnele Mari Salt Mine.

4.1 Ventilation circuit no. 1

Ensures the ventilation of the rooms operated from the + 226E horizon and the tourist point, then it will circulate on the horizon directional gallery. + 226E, and the vitiated air will then be taken up by the fans from the main ventilation station and evacuated on the PA2 ventilation shaft to the surface.
Under the action of the depression created by the fans of the main ventilation station from PA2 located at the base of the ventilation shaft PA2, rice. +226 E, the fresh air is introduced on the gallery and the conveyor belt, on the aeration suite SA1, and together with the fresh air passing through the ventilation doors in the horizon directional gallery + 226E, it will circulate on the horizon directional gallery. + 226E.
The fresh air will ventilate the exploited rooms from the horizon + 226E, then the tourist point will circulate on the directional training gallery + 226E, and then it will be taken over by the fans from the main ventilation station from the aeration well no. 2 and discharged, on aeration shaft PA2, to the surface.

4.2 Ventilation circuit no. 2

The fresh air necessary for the ventilation of the operating rooms, of the exploited rooms and inactive works from the + 210E horizon is introduced on the inclined car plane, on the inclined car access plane to the + 210E horizon, through the exploited rooms, on the + 210E directional gallery, will ventilate the gallery transverse (idle work) from the horizon chamber. + 210E (44G to 44D camera), operating cameras, will then run on the horizon directional gallery. + 210E, on the SA7 suite, on the horizontal direction gallery. + 226E, then it will be taken over by the fans from the main ventilation station from the ventilation shaft no.2 and evacuated, on the ventilation shaft PA2, to the surface.

4.3 Ventilation circuit no. 3

The fresh air needed to ventilate the inactive works in the west wing of the salt mine, from the horizon. + 226W and oriz. + 210W is entered on the car plane at the horizon level. +226, part on the transversal gallery no.1, through the access door to the former tourist point, on the directional gallery oriz. + 226W and part on the inclined plane of car access up to the horizon +210, will ventilate the inactive works from the horizon + 210 W and under the depression created by the fan from the main ventilation station from the ventilation shaft no.1, PA1, will climb the SA10 suite and along with the air from the horizon. + 226W will run on the horizon directional gallery. + 226W, will ventilate the explosives depot and then it will be taken over by the main ventilation installation, from the

aeration well no. 1 and discharged onto the surface well PA1. Because on the car inclined plane, the transport of tourists to the tourist point, the transport of salt lumps, etc. is done. the air flow required for the circuit will also be checked according to the criterion of the required air flow for diluting the gases resulting from the transmission operation.

4.4 Secondary circuit no. 1 - explosives depot

This circuit ensures the air flow required to ventilate the explosives depot from the + 226 horizon.
The aeration of the explosives depot is carried out with the help of a partial aeration installation, which takes over the necessary air flow from the horizon gallery. + 226W.
The air that washes the explosives depot is taken over and evacuated to the surface, on the PA1 aeration well, under the depression created by the main aeration installation.
The main aeration installation works in suction - discharge regime, being located underground, at the base of the aeration well. Thus, the network of mining works comprised from the entrance to the access gallery to the fan is under its depression, and from the fan to the surface, it is under the influence of the pressure created by it.
The fan is of centrifugal type, having the following nominal parameters:
flow: 220,000 m3 / h;
depression: 160 mm H2O;
speed: 590 rpm.
The fan is driven by a 160 kW motor at a voltage of 6000 V.
At the new ventilation installation mounted at the base of the New Horiz Well. + 226m, 3 axial fans of type P-N8L5 / 0/1400 / GD / 8 are used, mounted in parallel, having the following characteristics:
- QV = 116,666 m3 / h = 1,944 m3 / min; (QV = 3 x 1,944 m3 / min = 5,833 m3 / min)
- H = 153 mm H2O (1533 Pa);
- Pn = 75 kW;
- U = 400 V;
- NM = 1,532 rot / min.

Partial aeration systems in the discharge system are used to ventilate the preparation works. At present, the Ocnele Mari Salt Mine has no preparation and opening works, nor does it include any in the annual exploitation project.

5 Results of measurements performed

The results obtained following the measurements and determinations performed in the underground atmosphere and in the salt massif, presented centrally in tables no. 1-2, highlighted the following:
- absence of methane in the underground atmosphere;
- the air flows venting the mining works at the time of the measurements were below the planned level due to the shutdown of the centrifugal fan which was in the repair and refurbishment phase;
- the absence of methane in the salt massif around the works;
- the presence of carbon dioxide in the atmosphere of mining works in concentrations up to 0.1% vol .;
- the presence of carbon monoxide in the atmosphere of mining operations opening horizon III in concentrations up to 0.0001% vol. (aeration stopped 24 hours).

At the same time, qualitative measurements of the air were performed at the new ventilation shaft.

The oxygen concentration at the base of the well was 20.8% vol, 0.09% vol. carbon dioxide and 0.00001% vol. carbon monoxide.
No methane was reported. The new ventilation station is located at the base of the New Well, at the level of the horizon +226 east wing and was put into operation during 2016.

Table 1. Gas concentration in the salt massive.

N0.	The name of the mining work	The rock in which the drilling was carried out	Test hole number	composition of gases (% vol.)					
				Before sealing			After sealing(24hours)		
				CO_2	O_2	CH_4	CO_2	O_2	CH_4
0	1	2	3	4	5	6	7	8	9
1	ROOM NO 36 G(N-S) HORIZON 190E	SALT-NISA FRONT	1	0,09	20,8	0	0,1	20,7	0
2		SALT-NISA FRONT	2	0,08	20,8	0	0,09	20,6	0
3		SALT-NISA FRONT	3	0,03	20,8	0	0,06	20,7	0
4	ROOM NO 8 H G(W-E) HORIZON 190E	SALT-NISA FRONT	1	0,02	20,8	0	0,07	20,7	0
5		SALT-NISA FRONT	2	0,04	20,8	0	0,09	20,6	0
6		SALT-NISA FRONT	3	0,05	20,8	0	0,08	20,7	0

Table 2. Gas concentrations in the underground atmosphere of the saline.

No.	The name of the mining work	Place of measurement	composition of gases (% vol.)			Remarks
			CO_2	O_2	CH_4	
0	1	2	3	4	5	6
1	Air well connection gallery	Profile	0,09	20,8	0	Defective air outlet
2	Horizon +210 west	Profile	0,05	20,9	0	Inclined plane access horizon +210

3	ROOM NO 37 G(N-S) HORIZON +190	Up	0,09	20,8	0	Measurements performed in work fronts
		Down	0,1	20,7	0	
		The hole of the coal-cutting machine	0,11	20,7	0	
4	ROOM NO 34 I(W-E) HORIZON +190	Up	0,07	20,8	0	
		Down	0,09	20,7	0	
		The hole of the coal-cutting machine	0,11	20,7	0	
5	ROOM NO 9 H (N-S) HORIZON +190	Up	0,05	20,8	0	
		Down	0,08	20,8	0	
6	ROOM NO 8 F (N-S) HORIZON +190	Up	0,07	20,9	0	
		Down	0,1	20,8	0	
7	Explosive tank	Profile	0,1	20,8	0	
8	Tourist spot	Profile	0,03	20,9	0	
9	The base of the new well	Profile	0,09	20,8	0	
10	East directional gallery (+210)	Profile	0,09	20,7	0	

6 Conclusions

The last verification of the classification of the Ocnele Mari salt mine from the point of view of gas emissions (methane and carbon dioxide) was carried out in 2021.
In order to prepare the current classification verification documentation, the geological conditions of the area and the mining perimeter were analyzed.
The observations and specialized measurements performed in the underground mining works as well as in the rock mass in front of the works mentioned in this paper, highlighted the following:
a) the absence of methane gas in the underground atmosphere of mining works;

b) the absence of methane gas in the salt massif before and after 24 hours from the sealing of the test holes;
c) the presence of carbon dioxide below 1% vol. in the atmosphere of mining works;
d) the absence of carbon dioxide in the salt massif;
e) the presence of carbon monoxide in the atmosphere of mining works opening horizon III (aeration stopped 24 hours), in concentrations up to 0.0001% vol.
Based on the specific measurements performed and the existing records on gas emissions, as well as Law 319/2006 - Health and Safety at Work, it is proposed to maintain the Ocnele Mari salt mine in a BLACK REGIME.
The lack of carbon dioxide in concentrations above 1% vol. In the underground atmosphere did not allow the categorization from this point of view.
Considering the extension of the underground mining works, it is recommended to equip the Ocnele Mari Salt Mine with high-performance equipment for qualitative and quantitative measurement of the mine air and the training of the afferent personnel.
In order to optimize the ventilation network related to the Ocnele Mari Salt Mine, it is recommended to model and solve the ventilation network with the help of the specialized 3D CANVENT program.
Formations of workers who will perform technological operations in active work fronts, such as: execution of shooting holes; the loading of the working fronts with explosives and the shooting of the working front and / or cutting with the hasza, will be equipped with a device for measuring the gas concentrations (methane and carbon dioxide). Also, during the execution of the research drillings, the workers' teams will be equipped with a device for measuring the gas concentrations (methane and carbon dioxide).
Quantitative and qualitative control of mine air (flow rates, gas content, including methane), as follows:
- quarterly for the mining works aerated by the depression / pressure of the main fans;
- monthly on all ventilated work fronts with the help of partial ventilation installations;
- whenever there are changes in the gas release regime, in the aeration regime, as well as in the structure of the mining works.

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