ANALYSIS OF THE INFLUENCE OF THE MINING ACTIVITIES IN ROVINARI MINING BASIN UPON THE FUNCTIONING OF ROVINARI THERMAL POWER PLANT IN FULLY SAFETY

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Abstract: *The paper analysed geology, hydrogeology, geomorphology, climate and exploitation activities in the Rovinari mining basin, inside which is located the Rovinari thermal power plant, which the safely function can be affected by these activities.*

Key words*: Rovinari mining basin, Rovinari thermo power plant, lands features, safety*.

1. Introduction

Upper mining activities cause, due to their specificity, multiple and varied negative environmental effects, exemplified by:

- *Changes in relief* manifested by landscape degradation and displacements of households and industrial sites in the exploitation areas;
- *The occupation of large areas of land for exploitation*, dumping, storage of useful mineral substances, industrial installations, access roads etc, which are thus totally unusable for other purposes, for a long time, with effects on the local communities (conflicts over land use, displacements, recreation areas, etc.);
- *Land degradation*, vertical and horizontal displacement of the surface and slipping of tailings ponds and tailing ponds, causing serious accidents;
- *Pollution of surface water* and groundwater;
- *Hydrodynamic imbalance* of groundwater;
- *Negative influences on the atmosphere, flora and fauna in the* area;
- *Chemical soil pollution*, which may affect for many years its fertile properties;
- *Noises, vibrations and radiation* spread to the environment, with a strong unfavourable action.

Of these, for the safe operation of a thermal power plant in the area of influence of the activities of open pits, two negative effects are significant, namely an imbalance of hydrodynamic groundwater as a result of the stripping of sterile and extraction of useful coal by the operation area and surface degradation by horizontal and vertical displacements of the surface as a result of dewatering works, displacements that will affect the stability of the buildings inside the power plant and thus endanger completely or partially the technological flux of it.

Today, in Gorj County, the activity of extracting the lignite on the surface is carried out in the open pits: Tismana I, Tismana II, Rovinari East, Gârla, Pinoasa, Roşia de Jiu, North Peșteana, Lupoaia, Roşiuţa I, Jilţ Nord and Jilţ Sud.

In the proximity of the above open pits there are two major consumers of extracted lignite i.e. Rovinari and Turceni thermal power plants.

In the case of Rovinari thermal power plant, at a production level of approx. 8.6TWh/year, lignite consumption at an average calorific value of 1800 kcal/kg (7.6GJ/kg) would be approx. 9.7 million tons, which can be obtained from Pinoasa, Tismana I, Tismana II and Rosia de Jiu open pits (with a total of approximately 500 million tons) for a period of more than 50 years.

For Turceni thermal power plant, taking into account the same levels of electricity production, i.e. 8.6TWh / year, the Jilţ Nord and Jilţ Sud open pits with a total reserve of approx. 270 million tons, can consume consumption for over 30 years.

Exploitation at Gorj County open pits generates the degradation of the aquifer systems intercepted by their site. The aquifer formations by roof and lair of seams of lignite cause difficulties in their exploitation through the danger of inundation of work fronts and mining works, of grounding of the equipment from technological fluxes, or by slipping and dropping the steps and the work and definitive slopes of the open pits. To remove these shortcomings it is necessary to dewater the aquifer formations. Dewatering works in Rovinari open pits, for example, lead to annual discharges of approx. 90 million cubic meters of water from the dewatering bores and pumping stations existing in surface exploitation. Their influence, respectively the dewatering actions on the aquifer system, can be clearly seen on very large distances in the adjacent areas to the open pits. Intense dewatering and evacuation of groundwater can lead to severe and even subdued phenomena, with sudden breaks and landslide of argil-marl formations at the roof of seams coal and horizons of aquifers.

The crushing caused by dewatering and consolidation of the fine-grained aquifer layers produced in the Rovinari thermal power plant area, located in the centre of the Rovinari mining basin, did not exceed 10-15 cm, which did not have any significant negative consequences on this industrial objective.

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The inconveniences generated by the crushing and subsidence phenomena can be avoided if industrial activity is preceded by hydro-geological studies carried out very carefully at a regional level and, on the basis of the results obtained, suitable measures of planning and management of activities are taken.

In this paper we will analyse only the grounds and the exploitation activity of Rovinari thermal power plant that was, is and will be affected by them, based on a geotechnical study of the terrain corresponding to the site of the thermal power plant, to assess their condition in relation to the loads acting on them and to establish the level of safety of its functioning over a long period. Depending on the outcome of the evaluation, solutions for improvement and stabilization will also be proposed.

2. Overview of the Rovinari thermal power plant

The thermal power plant is located near Rovinari, about 25 km S-V from the Municipality of Tg-Jiu, near the mining exploitation of Rovinari coal basin /2/ (Fig. 1).

Fig. 1. **Overview of the Rovinari thermal power plant**

According to its location, the plant is placed at the "mouth of the mine", unique in Romania, which offers the possibility of direct energy recovery of large quantities of lignite from the corresponding quarries, ensuring also a minimum transportation distance on coal strips from the open pits in Tismana I, Tismana II, Rovinari East, Garla, Pinoasa and Rosia de Jiu. This also involves minimal transport costs of coal, S.E. Rovinari being the only power plant which has no rail transport costs, the transport of coal being provided on the conveyor belt systems.

If the site of this thermal power plant has the advantages mentioned above, it should not be forgotten a major disadvantage, namely the influence of the activities in open pits that serve it upon the stability of the terrain on which the buildings are located, as well as on the deposits of coal (figures 2 and 3), slag and ash (fig.4).

Fig. 2. **Crushing coal deposit**

Fig.3. **Coal deposit Central-Pinoasa**

Fig.4. **The slag and ash deposit Cicani-Beterega**

3. Geology of the area of the Rovinari Thermal Power Plant

From a geological point of view, the region falls into the Pre-Carpathian Depression where, at the end of the Cretaceous, there was an immersion of the crystalline foundation, creating a tectonic depression called the Getic Depression, which was crossed by the rivers Olt and Jiu /3/.

The formation of lands of Rovinari occurred in the last part of the Pliocene, from Pontian to Levantin, when slow lifting movements of the marine mixture were recorded, thus determining the development of a marshy region.

These lands impregnated with the abundant vegetation associated with this area led to the creation of the ten coal beds (in the riverside area), over which were deposited marls, fossil clays, sandy clays, sands and gravels entrained by rivers, and above it was laid fertile soil. From a seismic point of view, the administrative area of Rovinari falls within the seismicity zone E (a.g. = 0.12g, T.c. = 1) with a seismic degree 7.

Rovinari Mining Basin is located in the Jiu River meadow, with a hilly relief to the hillside in the west; the lignite deposit is located near the surface and has presented conditions for its exploitation through open pits.

The main mineral and surface mineral resources are: lignite, oil, natural gas, anthracite, graphite, dolomite, granite and chalk.

In the area where the lignite seams of Oltenia are situated, young geological formations are formed, consisting of soft, cohesive and friable rocks (marls, clays, sands, etc.).

The coal layer is caught in clays, marls and sands easy to remove, the exploitation being facilitated by the thickness of the tailings layer not exceeding 2-3 m, the inclination of the lignite layers varying between 50 and 100. A drawback is that the coal has relatively small thicknesses, involving large discovery volumes and the retention of a relatively large proportion of tailings in the excavated coal, impacting on its calorific capacity.

Rovinari subsoil had an immense mass of lignite coal, about 200 million tons with an average calorific value of 1945 kcal/kg.

From this total amount, up to the present, 182 million tons (net carbon) were extracted, the difference remaining in the safety pavilions and in the areas occupied by roads, constructions, enclosures, deposits, etc.

The conditions for the exploitation of deposits in the quarries of Oltenia are largely influenced by the physic-mechanical properties of the whole section of the deposit. The values of these characteristics are the basis of the geotechnical calculations for the dimensioning of the open pit geometric elements: step heights, slope angles, width of the beams.

In the conditions of increasing the height of the open pits, the problems of optimization of the basic technological processes (excavation, transport, storage) and of the stability of the slopes become more complex.

The determination of the physical and mechanical characteristics of the deposit cover, the foundations of the waste dumps and the rock mixes to be deposited, is done within each technical documentation, taking into account that under the influence of some factors (water, lithostatic charges, etc.) physical-mechanical rocks change essentially, influencing directly the construction parameters of the heaps.

The rocks in which are located the lignite seams belong to the young formations, Dacian and Quaternary ages. (fig. 5).

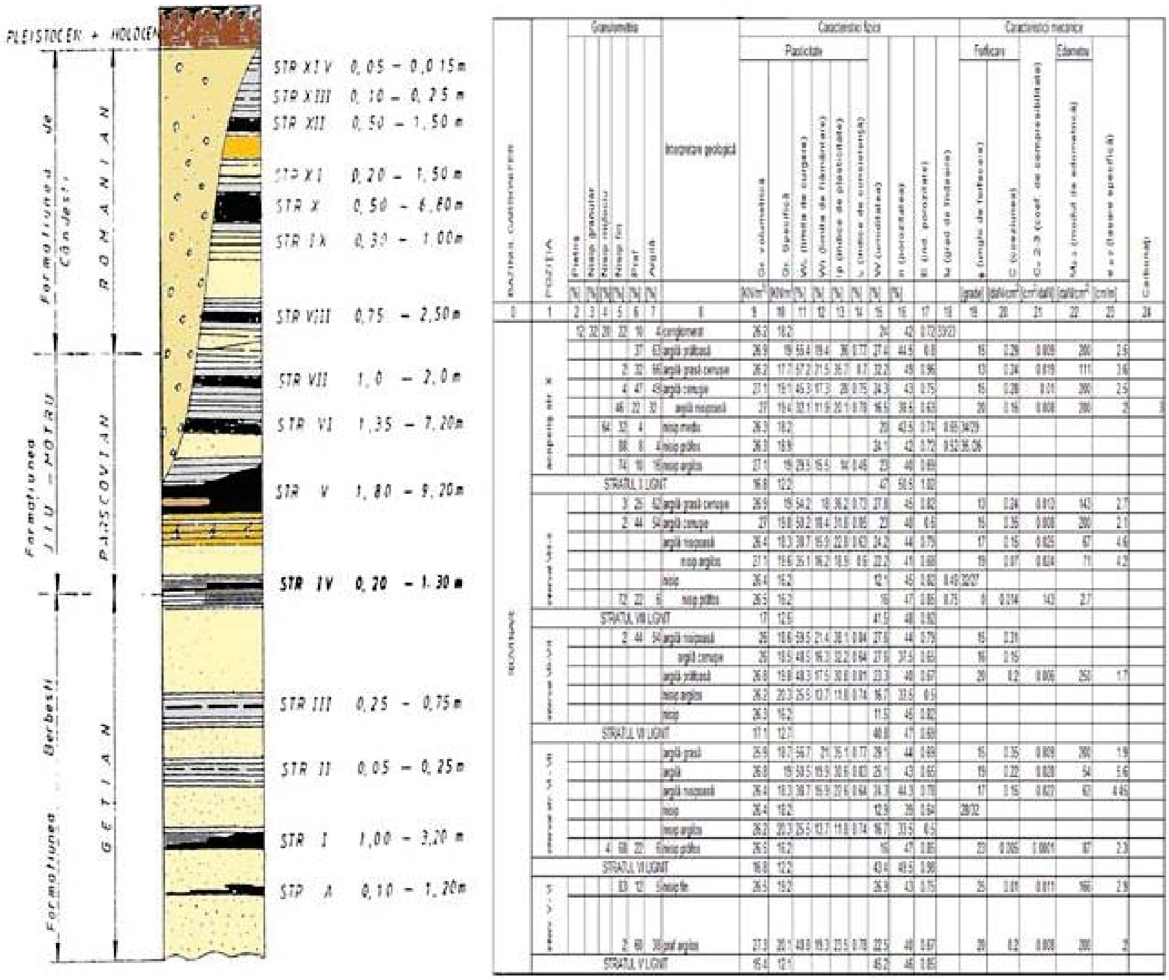

Fig. 5. **Stratigraphy of the Rovinari coal basin and the physico-mechanical characteristics of the rocks**

The stratigraphy of the deposit is composed by argillaceous rocks of Dacian age over which alluvial quaternary deposits are settled.

Dacian deposits are mostly formed of argillaceous rocks and powdery clays. Intersections of powdery sands and sandy powder of the marl-argil complex located in the roof of lignite V layer, contain underground water under pressure.

Alluvial quaternary deposits consist of:

- Pelitic rocks (vegetal soil, sandy clays, argillaceous sands, argillaceous powders);
- Psamito-psephitized rocks (gravel and boulders).

The quaternary pelitic rocks are settled in the upper part of the flat, having a height of 0-2 m, rarely reaching 4 m.

From the particle size point of view, quaternary pelitic rocks are very varied:

- sandy clays pass easily into argillaceous sands.
- argillaceous sands pass easily into argillaceous sandy powders.

The quaternary psamito-psephitic rocks are settled in the lower part of the floor, with their height of 5-7 m and 10 m in certain areas.

Although almost entirely saturated with water, due to the high values of the filtering coefficients and the yield capacity, these rocks do not pose any particular problems with the dewatering.

Based on the analysis of particle size, plasticity index and cohesion, it highlights the following categories of rocks:

- non-cohesive: sands and gravel;
- poorly cohesive: sandy or dusty clays and argillaceous or sandy powders;
- cohesive: clays and marl.

4. The energy resource of the Rovinari coal basin

With all the factors favouring the formation of lignite deposits, during the clogging of the Getic Basin, a charcoal complex consisting of 21 lignite seams was settled, alternating with pelitic and psamatic deposits.

Lenticular lenses and low height *lignite seams I-III* are inexhaustible.

Coal seam IV, arranged in the roof of the horizon of artesian aquifer, consists of 1-3 coal benches with average height of 0.3 - 1.9 m. The interval between layers III and IV consists of medium grain sand.

Coal seam V reaches height of over 7 m and branches into two benches across the entire surface of the basin. In Pesteana Sud, North Pestera, Urdari and Rosia Jiu open pits the coal seam V is located under heavy hydrogeological conditions.

Coal seam VI has a uniform development with height of 0.7 - 4.5 m in the perimeters where it appears singular (Pinoasa, Roşia de Jiu, Tismana) and 4.0 - 6.5m in the areas where it appears united with the layer VII.

Coal seam VII consists of 1-5 coal benches with height of 0.5 - 5.6 m (at Roşia de Jiu), 0.8-3.8 m (in the Gârla open pit), 1.8-4.3 m (at the Rovinari Est open pit) and 0.4 - 3.6 m (at Peşteana Nord).

Coal seam VIII develops unitary or fasciculate in several benches, two of which have exploitable height, separated by a layer of argil not exceeding 1 - 5 m. The height of the upper layer VIII is 2.0 - 3.5 m and the lower layer of 0.5 - 1.2 m.

Coal seam IX has extensive erosion or non-sedimentation areas. It consists of 1-5 coal benches with a total average height of between 0.5 - 2.7 m.

Coal seam X is one of the most important exploitable layers, but has extensive erosion areas. It is a fasciculate layer, developing on two levels: the lower layer X, with height of 0.5 - 2.4 m; the top layer X, with a height of 4.0 m, the maximum height being 7 m.

Coal seam XI consists of 1-4 junctions with height between 0.2 - 2.0 m. This coal seam has erosion surfaces in the high areas of the interfluves valleys.

Coal seam XII is developed in the hilly area of the basin with a height of 1.6 - 1.7 m.

Coal seams XIII, XIV and XV have low heights and extensions, appearing only in hilly areas.

5. Climate conditions of the area

Rovinari mining area, it is included in the climate of hills and plateaus, with a continental climate, as a result of the transition from alpine climate of the Carpathians Mountains and the plain of Oltenia. The temperature of the air, as a multiannual average, is around 10ºC. Summers are moderate and winters are mild with sufficient precipitations, but unevenly distributed: abundant in spring, autumn and winter and summer deficient. Between November and March, the activity of the open pits work in difficult or heavy conditions.

Due to the relief configuration, the climate is differentiated according to the relief steps. Annual average temperatures rise from north to south. The dominant winds are the Nordic. The prevailing wind direction is northwest, its average speed being 3.2 m / s (fig.6).

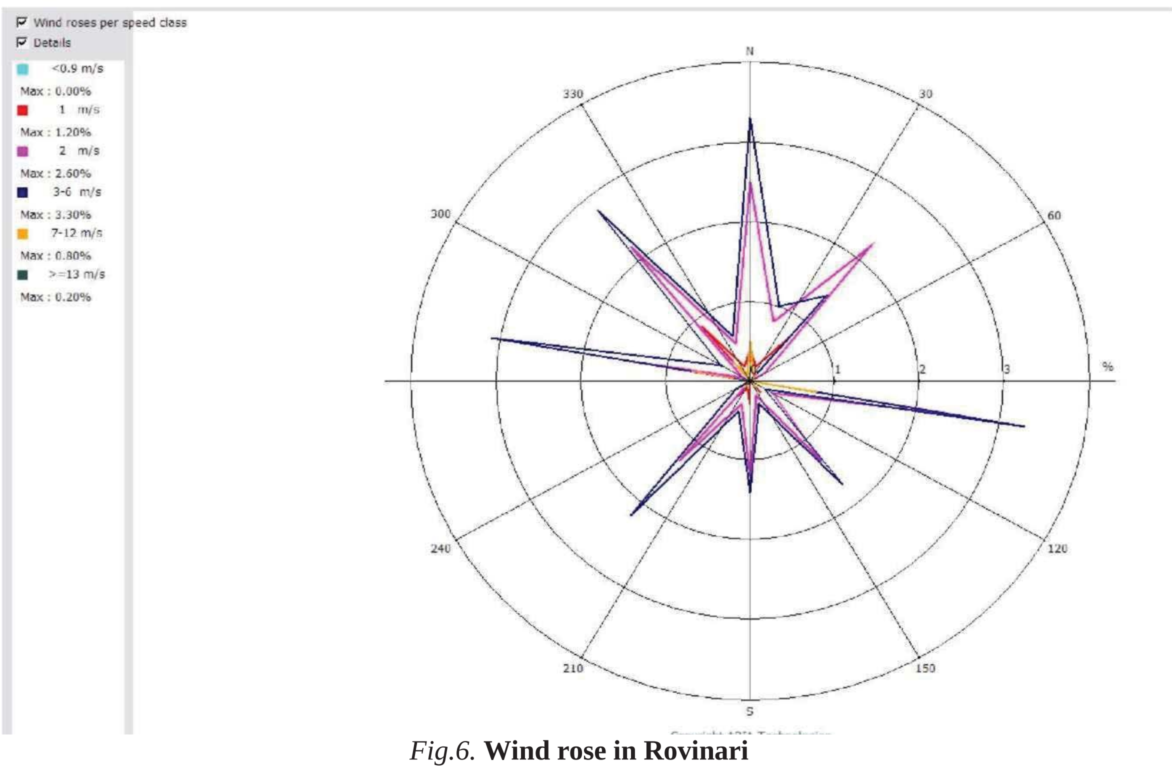

Fig.6. **Wind rose in Rovinari**

Due to the shelter in the depressions, the average thermal values rise to 9-10°C. The precipitation decreases with the altitude, from 1400 mm on the mountain peaks to 600-700 mm in the Oltenia Sub-Carpathians and 600-500 mm in the Getic Plateau.

The S-V position of the territory includes it in the area of manifestation of the sub-Mediterranean influences, especially felt in the western depressions (Turnu Severin, Tismana, Baia de Aramă). Also in V-N-V there are phenomena of weaker intensity.

It is a slight mood of climatic desertification in the west-east and north-south directions, the south-eastern corner of the region having the most prominent rigor /1/.

The main features of the climate are:

- Average annual temperature + 11°C
- Maximum temperature + 45°C (summer)
- Minimum temperature - 30°C (winter)
- Days with precipitation - about 90 days/year

The temperature at the surface of the soil is differentiated, with annual averages decreasing with the increase in altitude.

From one place to another, depending on the structure of the active surface, soil temperature values may have substantial changes. They can grow at 1-20°C on sunny and sheltered surfaces, but may fall in forested areas, wetted areas of valleys, or in heavily ventilated areas (meadows and open pits).

The winter thermal regime is characterized by negative thermal values, which are a necessary condition for the production of specific phenomena. The multi-annual average of frost-days is 110-120 days/year, with an average of 28.7 days in January, with a frost.

The average date of the first frost is from 15 to 20 October, and the average frost is 15-25 April.

The relative humidity of the air in the analysed area averages 68-70% per year, increasing to forested areas on the sides of the hills and to the riverside of river Jiu at over 75%. Relative maximum moisture is recorded in December and January, 82-85%, and the lowest in July and August by 62-63%.

As a result of the multiannual general trend of multiannual average temperature increase, there has been a certain tendency of decreasing moisture lately.

Due to the scale of the anthropogenic activities in the analysed area (mining and electricity production in thermal power plants), the nebulosity is higher compared to the neighboring regions, the multiannual average in the area being about 5.5-5.8 tens and the annual amplitude of about 3.3 tenths.

The highest values of nebulosity are recorded from November to March, exceeding 6.8 - 6.9 tenths, and the lowest from July to September, with values below 3.5 tenths.

From the analysis of observations regarding the atmospheric precipitation in the last ten years, at the hydrometric station in Rovinari, the following monthly averages (Table 1) are observed:

- the average multiannual of precipitations is 644.6 mm.
- the maximum of precipitations in one year is recorded in July and September by 81-90 mm; the minimum is recorded in March by 18 mm;
- the maximum of precipitations in 24 hours was 89 - 95 mm;
- the average number of snow days is 25-40 days / year the snow cover period is 40-70 days/year.

The average annual evaporation-transpiration for the studied area is approximately 669 mm, and the average annual evaporation of 571 mm, the maxims being recorded in July, by more than 122 mm.

The surplus of water in the soil, compared to the evaporation potential, reaches 182 mm, the maximum being recorded in January, by 53 mm. The water deficit in the soil relative to the evaporation potential is 98 mm, the maximum being recorded in August by 69 mm.

Tabel 1. **Average precipitations recorded at the Rovinari hydrometric station**

Hydrometric station	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
Average precipitation (mm)	39,9	21,9	17,7	68,4	66,2	66,0	81,2	55,2	90,4	52,3	27,8	57,6

6. Vegetation and fauna of the area

The flora and fauna of the area are varied. The flora consists of over 2000 species of sub-Mediterranean, Pontic, Balkan and Balkan-Dacic plants /1/.

The perimeter analysed is floral in the vegetation area of the deciduous forests. The bio-geographical potential is arranged in close correlation with the morphological factors. Its most expressive element, vegetation, describe its associations without symmetry, starting with the thermophilic oak forests in the low hills of the Getic Plateau and continuing with the hills of 450-600 m, with the holm-beech forests of a transition placed at 600-700 m, and beech developed floor-up to 1100 m.

A characteristic of the vegetation of the region is the intercalation, in the lower floors, of sub-Mediterranean species such as the flowering ash, hornbeams, the lilac, and hawthorn.

While the spontaneous vegetation is represented by the bull thistle (*Cyrsium arvense*), the shepherd's purse (*Capsella bursa pastoris*), wheat grass (*Agropyrum repens*), the crop species are represented by wheat, corn, potatoes, fruit trees, vine.

A similar arrangement is displayed by the fauna elements, in the woods which are the favourite biotope for the wild boar, wolf, fox, wild cat, beetle, finches, and in the coniferous bears, deer, laughter, jar, eagles. Hotter climate elements such as corn viper (on the sunny limestone of Motru to Mehedinti) also appear.

The soil cover preserves in its typology the influences of the lithological substrate, climate or vegetation. On the limestone of sub-Carpathians, of Getic Plateau, there were rendzine and pseudorendzins, under the beech forests reddish, brown reddish or brown soils, under the coniferous intensely acidified podzola. Hydro-morphic, alluvial, or regosolar soils are not missing.

The mining works carried out in the area led to the clearance of hundreds of hectares, which resulted the destruction of the natural flora and the strong influence of the neighbouring areas. The consequence of this situation is the marked reduction of the floral diversity in the analyzed territory. The restoration of the vegetation is observed on the fields on the heaps where, from the first year after deposition, the spontaneous flora appears. A feature of planting vegetation on tailings dumps is the mass appearance of the *Phytollacca americana* species. In the process of restoration of the vegetation, *Salsola ruthenica* (cocklebur), a species known especially in the Romanian Plain, appears quite frequently on the heaps. On the slopes of the steep slopes, caused by the mining works, *Cirsium candelabrum*, another interesting species for this area, is planted.

7. The operating perimeters adjacent to the Rovinari Thermal Power Plant (fig. 7)

The deposit conditions in the exploitation perimeters are specific to the structure of the geological formations in the region, being defined by the way of presentation of the lignite layers, their thickness, the lithological nature of the rocks, the structural configuration, and the hydro-geological conditions. These factors must be carefully studied in the technical documentation drawn up at the level of the mining units, the results underlying the calculations of the stability of the pit pitches and the determination of the production capacities /4/.

Fig.7. **Mining basin Rovinari - perimeters adjacent to the Thermal Power Plant**

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In all cases where the geomorphology of the perimeter (the transition from the meadow to the hill area) has changed, there have been changes in the conditions of the deposit regarding:
- geotechnical characteristics;
- position, thickness and tilt of the strata;
- hydrogeological conditions;
- the lithological structure of the steps, etc.

In the Jiu hydrographic basin siliceous rocks predominate, the limestone being on small surfaces at the upper part of the mountainous area as well as in the northern part of the sub-basins Bahna and Topolnita.

The ratio to be found in the meadow area is 5.2 m^3/t, and in the hilly area of 6.05 m^3/t. At the beginning of 1970, the basin was outlined with approved technical and economical studies and the open pits Beterega, Gârla, Tismana, Cicani were in operation or opened and since 1973, Roşia de Jiu.

In order to cover the coal demand for the thermal power stations in the area (Rovinari and Turceni), four further perimeters were in operation for open pits: Rovinari Est, Peşteana-Urdari and Pinoasa.

Tismana open pit. In order to increase production capacity in this quarry and to eliminate the deficiency of excavation and dump capacity at the level of 1975, the study elaborated for the period 1976-1980 foresaw the introduction of a new technological line consisting of a wheel excavator and an abzeter with the help of to which the production capacity of the open pit could be increased to 4000 thousand tons since 1978.

Rovinari Est open pit. The reserve is cantonated in this perimeter in the V, VI, VII, and VIII levels. Although it has the opening trench in the meadow area (from the opening trench, the Beterega open pit in the counter front), it will enter the hill area between 180 and 350 m.

The perimeter of the open pit is affected by the Bălăceşti-Cîrbeşti fault and the faults of Dâmbă, Corbului and Moi, which gives this perimeter a rather complicated tectonics, which has the effect of complicating the technological flow of exploitation in the open pit. The V-VIII coal seams totals an average exploitation depth of this 12.2 m pitcher.

Pinoasa open pit. The perimeter affected by this quarry is entirely hilly and has been designed according to previous provisions for underground exploitation (the abandoned Pinoasa mine).

The exploitable coal seams are: X with a thickness of 1.5-5 m (with two or more jambs), XI by 1.0-2.5 m, by IX by 1-1.5 m, by VII by 2-4 m , VI of 2.5-3.2 m, V of 1.5-3 m. There is also a sporadic layer XII with a thickness of 1 m.

The distance between the latitudes is between 6 and 20 m. In the roof and the bed of the coal seams there is an alternation of fine clays and sands, as well as aquifers or lenticular horizons with low pressure. In the bed of the IV layer, there is the artesian aquifer horizon. Career hearth is on coal seam V.

The industrial reserve calculated over a period of 20 years is 63,500 thousand tons with a total area of 1.059 ha, the average discovery ratio is 6.01 m^3/t. The total volume of the dump is 661 mil m^3, out of which 355 mil m^3 in the over heap Gârla and Tismana. The works of this open pit began in 1983 with classic machines in small open pits, opening Pinoasa I, II and II. Later, Pinoasa IV and V were opened. The opening transection for the Pinoasa II and V open pit separated by the Rogojel valley was designed to unite the north-eastern zone of the quarry. By joining the two opening, southern and northeast open trenches, the opening trench for the entire Pinoasa mining field will be formed.

The perimeter of the open pit being near the ponds North and South Pesteana, the surface arrangements were foreseen in common with these quarries by extending the constructions from the assembly platform, the coal deposit and the enclosure.

The opening trench was located on the eastern side of the perimeter. The outer dump, in a volume of 15 million m^3, was placed between the open pits of Pesteana Nord and Pesteana Sud. The exploitable seam is X and consists of 4-5 junctions with a thickness between 5 and 10 m. In the roof and the bed of X seam, there is an alternation of clay and sand. In the couch are aqueducts horizons with elevation.

Roşia de Jiu open pit. Its perimeter is located on the right bank of the Jiu River, south of the city of Rovinari. The entire career field includes:
• *the riverside area* located on the right bank of the Jiu river, in the vicinity of the Moi and Vlăduleni localities, on the north side and respectively on the Fărcăşeşti and Roşia-Jiu localities on the southern side;
• *the hilly area* south of the village of Roşia-Jiu, bounded between Valea Pârâului and Valea Roşie.

The riverside of Jiu is about 2 km wide and has odds of +148 m to +160 m, with inclinations east, Jiu and south. In the hilly area the hills are ENE-VSV oriented and have heights between the 1.70 m and 300 m elevations

In this area, erosion has removed coal seams XIII-XVII, and in the meadow zones the seams XI-XVII. Lower carbon strata have small tilts ($2-3^0$), while upper layers have slightly more pronounced tilts ($4-10^0$).

Within the Roşia de Jiu perimeter, in the Dacian, Romanian and Quaternary formations were highlighted sandy levels with varying thicknesses and granulometry, alternating with clay, marl and coal deposits. Within these porous-permeable formations, aquifers are individualized which, depending on the conditions of the deposit, are free or deep under pressure.

8. Conclusions

The paper has intended to be an introduction to a broader study on the influence of the mining lignite quarries in the Rovinari mining basin dealing with the stability of the buildings in the Rovinari thermal power plant and its coal and slag-ash deposits. This stability depends on the safe functioning of the thermal power plant throughout its lifetime.

Knowledge of the geology of the site, the geological and mining characteristics of the rocks, the hydrogeology, the climate and the exploitation technologies will allow for a correct analysis of the stability of the foundation grounds of the buildings inside of the energy complex and finding suitable solutions for the remediation of potential accidents.

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