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IMPROVING TECHNICAL-ECONOMICAL PERFORMANCE AT PRAID SALINE WAY OF ROCK SALT ROADHEADER MECHANIZED MINING

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Abstract: *Increasing the mining depth at Praid Saline and implicitly the state of stresses and strains determines an increase in the dimensions of resistance structures (pillars and ceilings). Furthermore, the seismic effect generated by the detonation of explosives contributes to the degradation of resistance structures. In order to reduce the destructive effect of drilling-blasting technology a proposal is made for the implementation of mechanized salt cutting technology which makes use of a roadheader. This article emphasizes the technical-economical implementation advantages of exploitation from the lower horizons of the New Sector, those of mechanized mining with a roadheader as opposed to the classical technology of drilling-blasting.*

Keywords: *rock salt, rooms and pillars, drilling-blasting, roadheader, production capacity, production cost.*

1. General background

The Praid Basin is situated on the eastern rim of the Transylvanian Basin, at the foot of the Gurghiu Mountains and forms a well-defined micro-region known as the ''Land of salt mines'' [1].

The Praid rock salt massif is part of an anticlinal diapir structure which develops alongside an area approximately 25 km in length, from Săcădat (north of Sovata) to Corund. Inside this anticlinal the rock salt pierces the medio-pliocene mantle in the form of the two diapir pillars: Sovata and Praid (fig.1) [2].

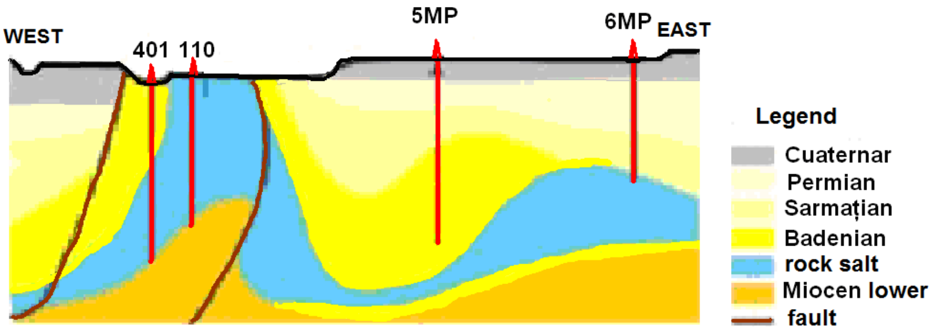

Figure 1. Vertical geologic section of Praid rock salt massif [1]

The rock salt in the Praid diapir pillar has penetrated the meadow and the terraces of the Târnava Mică and Corund valleys on a surface of approximately 1,5 km^2, creating a dome morphologic shape with a maximum height of 100 m [1].

The rock salt body, from a horizontal plane, has a quasi-circular shape, mildly ellipsoidal, its diameters being 1.2 and 1.4 km. Based on structural drills, its burying depth is estimated at 2.7-3.0 km, it therefore being the most developed and robust diapir-genic body in the whole country.

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The rock salt from Praid has a macro or micro-crystalline aspect, it being impurified with synergetic mechanical dispersions consisting of clays, shales, sandstones, crystalline limestones, etc. which take the form of disseminations, impregnations, stratiform inclusions or enclaves of varying dimensions [2].

Rock salt mining at Praid began in 1762 in bell-shaped chambers, by 1864 exploitation continued in large, trapezoid-rectangular chambers in the Parallel mine and, subsequently, in the Gheorghe Dozsa mine. Presently, rock salt is being exploited beneath the old mines, under which a 40 m thick safety pillar was created, in small chambers with long, rectangular pillars (the New Sector) and in small chambers with square pillars, in the Telegdy mining sector [2].

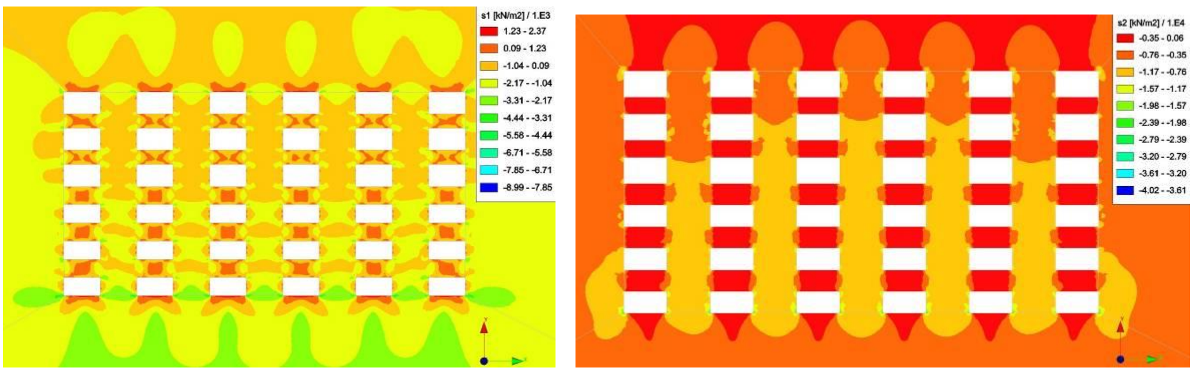
Increasing the mining depth beyond 300 metres at the Praid Saline evidently determines an amplification of the stresses and strains state, accentuated around the underground mining excavations. In this context, there exists excessive pressure on the resistance structures (pillars and ceilings) which exceeds the resistance limits of the rock salt massif. In areas with a geometry susceptible to stress concentrators in the perimeter of the chambers, the effects of the destruction of the salt massif's continuity appear by way of cracks and fissures which lead to a reduction in the bearing capacity of these structures and, sometimes, even localised failures of rock salt off the outlines of underground excavations.

By performing stability analyses with finite elements (Fig. 2) for the New Sector support structures with an integral mining of the chambers between +286 m and +188 m horizons the following significant conclusions were reached [3]:

a) At the +188 m horizon, which is to enter roadheader exploitation in the near future, the ceiling and the floor of the chambers will have very good stability, albeit off-the-wall salt breakoff phenomena may appear (especially due to the stress caused by shear) – which are more prominent at the limit between the pillars and the ceiling;

b) By reference to the limit stability of the support structures at the +188 m horizon, using roadheaders in the technological process of rock salt extraction allows support structures favourable conditions of increased stability when compared with explosive mining. Furthermore, extracting the chambers in two 5m slices ensures, at least for the duration of exploiting the first slice, additional stability conditions;

c) As regards mining depth, below the +188 m horizon rock salt deposit at Praid, an in-depth study is considered to be necessary to reconsider the dimensions of chambers and pillars. We appreciate that exploitation below the +188 m horizon by using the present dimensions of support structures will implicitly lead to a more than 20-30% decrease in the safety coefficient, at least at the exterior level of the surface of pillars and ceilings, thereby worsening the stability conditions of the support structures.



a) b)

Figure 2. Scalar representation of the principal stresses [3]: a) maximal, in kN/m^2; b) minimal , în kN/m^2

Based on the conclusions above it is mandatory to increase the size of pillars and ceilings between the sublevels by reference to the reduction on safety coefficients as the mining depth increases.

These phenomena are amplified by the repeated effects of seismic waves generated by systematic detonation (at an interval of 1-3 days) of more than 200 kg of explosives, an induced seismic phenomenon which is equivalent to a natured earthquake of 4-5 on the Richter Scale. As a singular effect, these phenomena generated by seismic waves could appear to be minor in importance, however their cumulative effect, along year and even decades, is very important indeed, damaging the integrity of resistance structures on a depth appreciated to be more than 0.75-1.00 meters.

As such, the only solution for continuing the exploitation of rock salt at a greater depth by using the drilling-blasting technique is to increase the dimensions of pillars and ceilings above those which are necessary, exactly by a measure which would be impacted by the detonation of explosives. This measure has,

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as a negative side effect, an impact by reducing the degree to which exploited deposit is recovered, which is already quite minute in amount. Even so, in the long term, the stability of mining excavations is irretrievably affected. More plainly, if a different method to explosive exploitation was used since the inception of rock salt exploitation, the stability of support structures of the mining excavations at the Praid rock salt mine would be much better. Furthermore, we evidence the fact that, notwithstanding the rock salt reserves which are obtained by mining, underground excavations have an inherent future ”reutilization” value (for tourism, health reasons, underground storage areas, emergency refuge areas, etc.).

The only efficient solution that exists to solve the aforementioned stability issues is to give up the use of explosives for extracting rock salt out of the massif in favor of mechanical cutting with the use of roadheaders, both due to the technical advantages resulting from implementing roadheader cutting technologies but also due to the technical-economical and economical-financial advantages present, when compared to the drilling-blasting cutting technology.

We mention that, worldwide there exists a rich experience in successfully using roadheader cutting technology in rock salt deposits mining or other halides or evaporites generally (such as a series of deposits in Spain, Poland, the USA, etc.) which represents an important argument for adopting roadheader rock salt extracting technology at the Praid salt mine [4,5].

2. Choosing the roadheader based on the technical and geo-mining conditions present at Praid Saline

The main technical and geo-mining conditions imposed on the roadheader to be adequate for the geo-mining conditions present at the Praid rock salt mine, respectively those around the +188m horizon, the New Sector, are as follows [6]:

1) It must be capable of excavating an exploitation room profile with a maximum section of 200 m^2, a maximum height of 10 m and a width of 20 m, in two slices of 5 meters each, divided in 3 stripes 6.66 m wide (respectively, able to cut a profile 5 m tall and 6.66 m wide from a single roadheader position);
2) It must be capable of diffing (descending on an incline) an inclined plan with a rectangular profile, with a maximum incline of 10-12^o, a 55 m^2 section, a height of 5 m and a width of 11 m, from two roadheader positions;
3) The roadheader’s tracks should not penetrate the floor of excavated mining workings;
4) It must be capable of realizing an annual average production capacity of rock salt from the Praid salt mine of a minimum of 100,000 tonnes/years;
5) The specific use of cutting picks to be as reduced as possible;
6) It must be capable of being electrically powered by use of the electrical system currently in place at Praid Saline without further substantial investment;
7) It must be a combine in successful use worldwide in rock salt or other evaporite formations mining;
8) It must be very reliable, easily maintainable and operational and must ensure maximum underground health and safety conditions;
9) It must realise the above mentioned structures in the geo-mechanical conditions specific to the rock salt deposits at the Praid Saline.

By reference to the above mentioned conditions, a number of 30 roadheaders were proposed capable of punctiform attack (axial and transversal), with a mass of around 100 tonnes, and in line with the following selection criteria [6,7]:

A) Coverage of the transversal section and mining excavations dimensions;
B) Correlation of the directional and transversal inclines of the mining workings with the technical possibilities of the roadheaders;
C) Track penetration through the floor of the mining workings;
D) The principal performance of the combine (instantaneous cutting rate and specific cutting picks consumption) [7,8,9,10,11];
E) Successful experimentation of the roadheader in similar geo-mining conditions [4,5].

The following 30 forward roadheaders were suggested: MH 620; MT 720; ATM 105 IC; AM 105-Ex; MR 520; AM 105 ICUTROC; ET 120; ET 170; ET 180; ET 210; ET 250; ET 380; ET 250; ET 380; ET 410; ET 410Q; ET 450; ET 450L; ET 480; Mk-3; Mk-4; AQM-200; T 1.14; T 1.24; T 2.24; T 3.20; T 3.20S; EBZ 318H; EBZ 260H; EBZ 200H.

By successively applying the aforementioned selection criteria, 27 roadheaders were gradually eliminated, the following three having remained in the competition after the fourth criterion was considered: ET 250; MR 520; AQM-200. At the end of the analyses, by considering the successful experimentation of the roadheaders

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in similar geo-mining conditions to those found at the Praid Salina, the Sandvik MR-520 (Alpine Miner AM 85-P) [6] roadheader was selected.

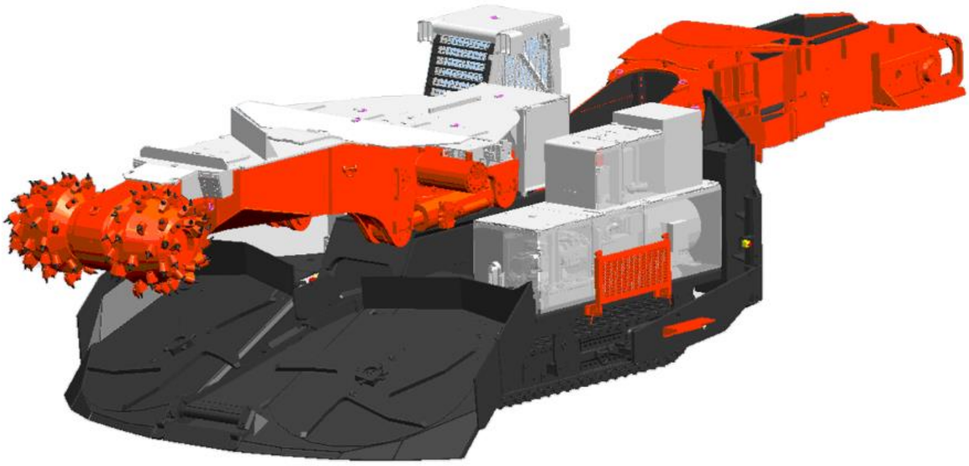

Figure 3. The roadheader Sandvik MR-520

The Sandvik MR-520 roadheader with punctual attack is a cutting machine equipped with transversal cutter heads, with a weight of 102 tonnes and an installed power of 547 kW.

The spiralled way in which the cutting picks are placed on the cutting heads ensures successful cutting of sterile intercalations.

The high performance of the loading equipment is provided by the fact that the machine is equipped with loader stars which replace the old loading arms system, which gather the material along the loading plough.

The special accessories, such as the pivoting conveyor and the rapid movement speed make the roadheader usable in mining with the chambers and pillars method.

The loading mechanism has the capacity to store a large volume of salt, thereby making it possible for the work front to be cut during the operation of changing the transport machinery (trucks) therefore reducing unproductive time.

The roadheader moves along tracks which are powered by hydraulic engines. A slope of up to 20^o can be scaled without auxiliary equipment.

The principle of punctiform attack, with an arm that can pivot in any direction, makes it possible to cut in any desired profile with only one go, the maximum cutting profile being approximately 44 m^2 and 5.2 m high.

The Sandvik MR-520 roadheader is recommended for cutting rocks with a compression resistance of up to 100 MPa.

3. Rock salt mining using the roadheader in the New Sector at Praid Saline

Implementing the technology of mining with a roadheader refers to extracting the rock salt deposits in the New Sector, starting from the +188 m horizon, at a production capacity of 100,000 tonnes/year, road salt of the 0-8mm sort, whilst simultaneously mining via drilling-blasting in the Telegdy Sector starting from the +432 m horizon at a production capacity of 10,000 tonnes/year, boulder salt (Fig. 4) [6,12].

Implementing the roadheader's insertion programme will start as soon as the roadheader and adjoining machinery are set into motion (deduster system, transformer, electric switch boxes, the power line, etc.) in the mounting chamber at the +432 m horizon, Telegdy. The roadheader, deduster and adjoining equipment will be transported on subassemblies from the surface, through the adit entrance all the way to the assembly room. The length of the mining workings (the adit and inclined planes) necessary to move the roadheader and adjoining machinery (on subassemblies), between the gallery entrance and the mounting chamber situated at +432 m is over 1.2 km.

In order to start mining the rooms at the +188 m horizon it is necessary to connect this horizon with the mounting chamber situated at the +432 m horizon, via the +286 m horizon. Firstly, in order to join the +432 m horizon (Telegdy Sector) with the +286 m (New Sector) workings will be performed integrally an inclined with roadheader, with a section of 55 m^2 (L=11 m, h=5 m) with a length of approximately 1.2 km. The usable section of the inclined plane was calculated to allow the circulation on two ways of 35 tonne Renault Kerax DXI 11 430 trucks, having the following overall dimensions: length=9 m, width=2.55 m, height=3.1 m.

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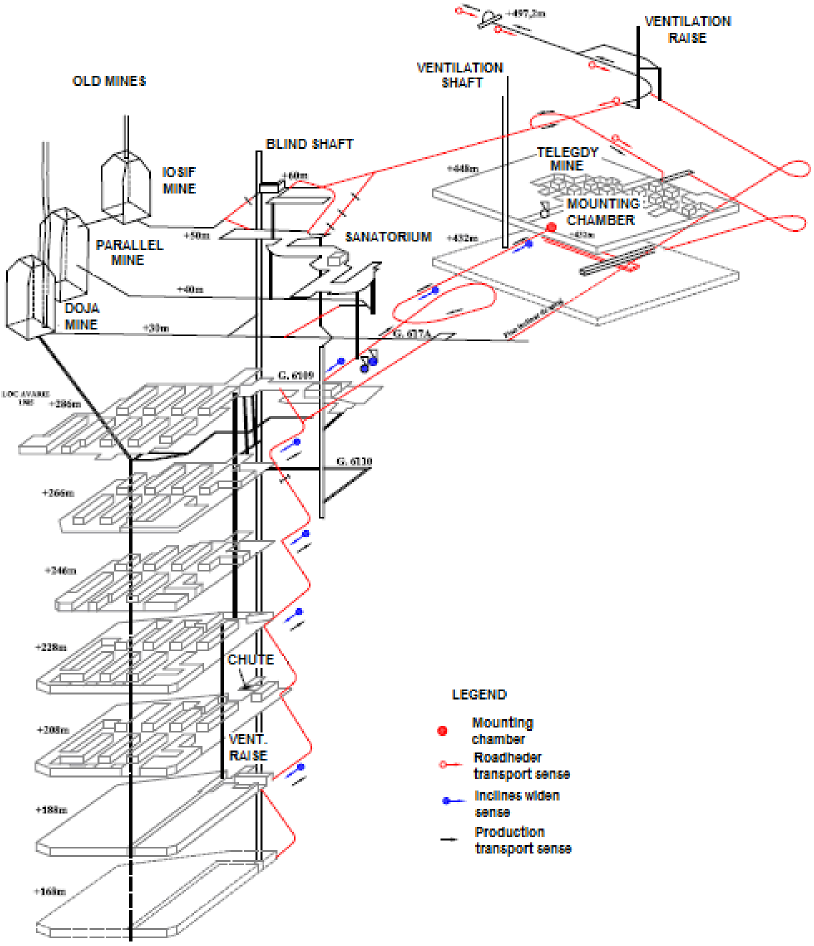

Figure 4. The general opening scheme of Praid Saline, marking the insertion pathway of the roadheader via the +188m horizon, in the New Sector [12]

Secondly, the conjunction between the +286 m horizon and the +188 m horizon in the New Sector will be realised by using the roadheader to widen the already excavated inclined planes, from an existing section measuring 19.3 m^2 to the planned 55 m^2 section (excavating 35.7 m2) on a length of above 1.5 km. The final profile of the inclined plan will be 11 m in width, 5 m in height and a maximum incline of 6-8º. These values are imposed by the possibilities of fitting the roadhedear in the relatively tight corners of the inclined planes and the need to have two transport accessways.

After the rock salt reserve measuring approximately 0.2 million tonnes at the +188 m horizon is exploited (which would be left unexploited at the time the roadhedear enters this horizon), work will start on executing the inclined plane to connect the +168 m horizon, having a useful section of 55 m^2, with a total length of 165 m and a rock salt volume requiring excavation of 9,000 m^3. Thereafter the exploitation of an industrial rock salt reserve measuring over 0.5 million tonnes will begin in the +168 m level, until 10 years would have lapsed from the date of the insertion of the roadhedear.

Alongside the works to open up and mining the New Sector, work to mining the rock salt deposits in the Telegdy Sector will continue, with a production capacity of 10,000 tonnes/year of rock salt boulders, by use of the drilling-blasting technique.

The Praid salt mine, in the inferior horizons sector (+286 m, +266 m, +246 m, +228 m, +208 m and +188 m) or the New Sector is defined by the following parameters:

-The ceiling (crown pillar) has a minimum thickness of 30 m;

-The floor pillar has a minimum thickness of 25 m;

-Marginal pillars at the New Sector will be a minimum of 30 m thick;

-The ceilings between horizons are at least 8 m thick;

-Inter-cameral pillars are straight prisms with a width of 20 m, a length of 40-100 m and a height of 8-12 m;

-Mining rooms have a straight roof, a width of 20 m, a height of 8-12 m and a length of 20-300 m.

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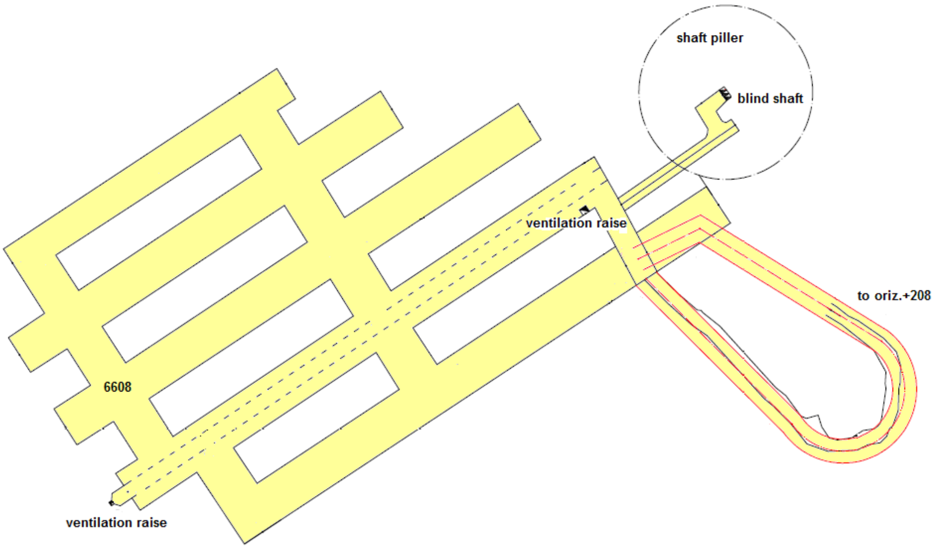

Figure 5. The location plan of the +188 m horizon

With regards to the dimensions of the transversal profile of the 20 m wide and 10m height mining rooms and the cutting possibilities of the Sandvik MR-520 roadheadear, a mining room is divided vertically in two exploitation slices (measuring 100 m^2/slice) with a height of 5 m each, extracted in 3 strips of 6.66 m width (33.33 m^2/strip) starting with the central strip (Fig. 6 and 7).

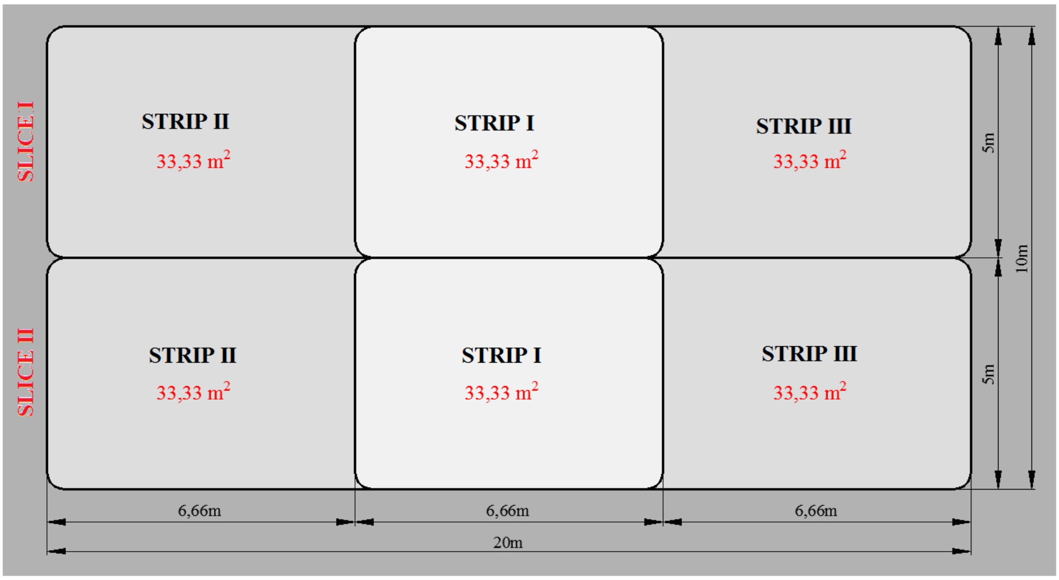

Figure 6. Mining rooms in slices and slices in strips – transversal section [6, 12]

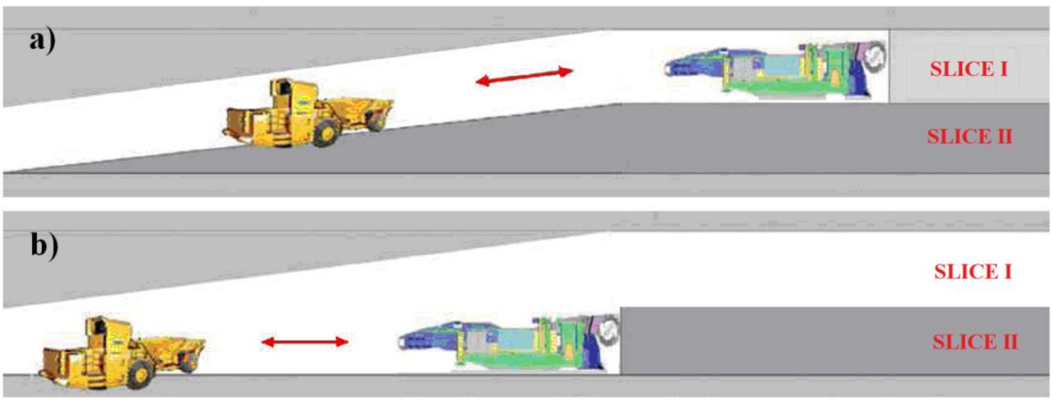

Figure 7. Mining rooms in slices – longitudinal section: a) Extracting the first slice; b) extracting the second slice; (adapted by Sandvik)

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In order to ventilate under the general depression of the mine in the exploitation horizon, the first, superior slice is extracted using the roadheadear. This is situated at the level of the room (with a length of approximately 255 m) which connects with the ventilation raise at the end of the mining panel. In order to do this, accessing the first slice is done by starting at the level of the exploitation horizon by executing an inclined plane with a slope of 6-8° and a length of approximately 48-36 m (Fig. 6).

From the first slice's inclined access plane the extraction of the first slice continues, in accordance with the usual roadheadear cutting process, summarised in Fig. 8, on a length of approximately 200 m until a connection is made with the air duct. This method of getting the roadheadear to the level of the superior slice, by digging a short access plane to the same, is somewhat complicated and is only to be recommended where the inclined access plane to the horizon under exploitation is already executed by use of the drilling-blasting technique, as is the case at the +188 m horizon.

If the access plane is executed with the roadheadear, it is recommended that its floor connects directly with the superior slice (for example, at +173 m for the +168 m horizon, or at +153 m for the +138 m horizon) consequently the floor being excavated with the roadheadear when the second slice is exploited, to reach the floor of this slice.

In the first case, due to the fact that it is impossible to exploit the wedge of rock salt at the top of the inclined access plane of the first slice by using a roadheadear (Fig 7.b) a residual reserve of approximately 1,600 tonnes will remain abandoned above the inclined access plane.

Extracting the superior slice is continued by enlarging the room by subsequent extraction of the lateral strips, 2 and 3. Following this, the remaining rooms situated at first slice level are extracted in a similar, planned fashion, in the order applied when extracting the superior horizons in the New Sector by drilling-blasting.

After the superior slice is entirely exploited, the roadheadear is lowered at the depth of the inferior slice, which is exploited in a similar fashion, by extracting the rock salt in the same order of rooms and strips.

Exploiting the inferior horizons in the New Sector (+188 m, +168 m and +148 m) takes place in two successive slices (slices 1 and 2) with a height of 5 m, along the whole horizon, in a well-devised order of rooms, as was presented previously.

Each slice with a height of 5 m, from each room (with a total height of 10 m and a width of 20 m) is extracted in 3 strips which are 6.66 m wide (as presented previously).

From the technical characteristics of the Sandvik MR-520 roadheadear one can conclude that the maximum dimensions of the transversal profile which can be extracted with this roadheadear, situated in only one position, are: maximum height of 5.2m and maximum width of 8.32 m (values which cover a slice 5 m tall and 6.66 m wide).

The roadheadear extracts the work face from a single position in a circular shape with a length of 7.1 m, and the rotation angle from left to right of the cutting crown, in horizontal plane, is 35.4° (Fig. 8).

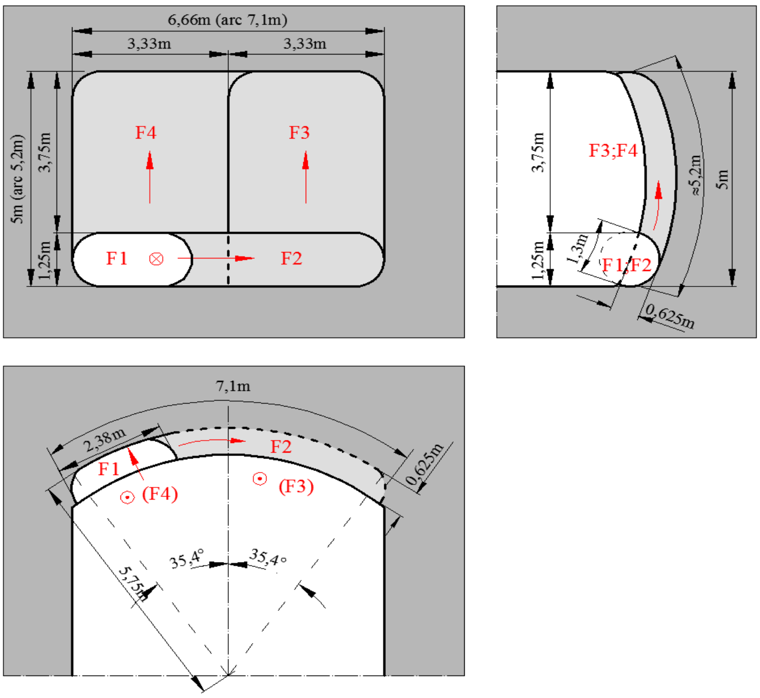

Figure 8. A representation of the main phases of cutting an extraction strip with the roadheader (F1-F4) [6, 7, 12]

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4. Staggering the production capacities obtained by exploiting rock salt with a roadheadear

Realising an industrial production of 105,000 tonnes/year, which is 176 tonnes/shift (required by the project) from the exploitation rooms where rock salt reserves are exploited with a roadheadear in the inferior horizons (+188 m, +168 m, +148 m) in the New Sector at the Praid Saline requires cutting, loading, transporting and storing 29.33 tonnes an hour, which is realising 1.3 transports an hour, with trucks with a 22-tonne capacity [6, 12].

With reference to the distance that must be travelled for transport, it is necessary to ascertain the number of means of transport required for this task, as well as organising the transport, respectively establishing the means of transport movement schedule by correlation to the working mining faces dynamics.

With regards to the aforementioned, design an organisation for transport will be made for the conditions under which the necessary production capacity is realised in a critical scenario involving the longest transport distance possible. In such a case, the total time for loading, transport (full-empty), unloading and returning of the means of transport is [6]:

$$T_t = t_p + t_d + t_g + t_{in} = \frac{L_T}{v_p} + t_d + \frac{L_T}{v_g} + t_{in=} 28{,}2 + 5 + 14{,}1 + 5 = 52{,}1 \cong 52 \text{ min} \tag{1}$$

where: L_T=4.7 km is the total transport distance; v_p = 10 km/h is the transport speed for a full load; v_g = 20 km/h is the transport speed for an empty load; t_d = 5 min is the unloading time; t_{in} = 5 min is time of maneuvers for the means of transport to approximately 20m from the mining face.

By reference to the data above, the diagram of the trucks' movement for mining room 6 608 at the +188m horizon, first slice, is represented in Fig. 9.

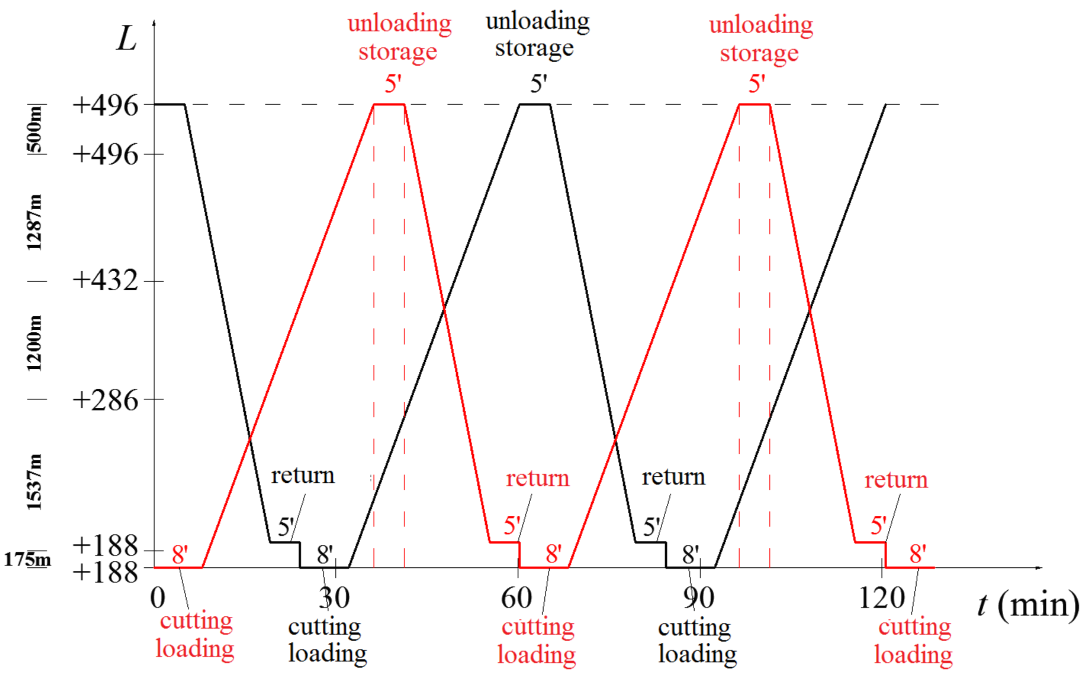

Figure 9. The movement schedule for 2 trucks of transport mining room 6 608 at horizon +188 m [6]

In the conditions explained above, if a single truck was used only 7 tours could be performed each shift, which would lead to a production of approximately 154 tonnes/shift, which is only sufficient to cover planned production of 103,000 tonnes/year, if work is done over 4 shifts over 167 working days/year. If the number of working days/year is reduced below the one mentioned above, realising the planned production capacity is only possible by using 2 Renault 22.8 t Kerax 430/43 trucks, which can allow for increased production conditions to about 308 tonnes/shift (which far exceeds the planned production capacity).

As such, in a 6-hour shift, using a single truck, exploiting a slice with a roadheadear can lead to a production of 154 tonnes/shift, which corresponds to 616 tonnes/day if 4 shifts are undertaken, with the mining face advancing by 8.56 m per day (on a transversal profile of the exploited strip of 33.33 m^2).

Therefore, a single truck can lead to an annual production of 103,000 tonnes in a maximum number of 167 working days where 4 shifts are worked daily. Furthermore, if we analyse the distribution of production by months or quarters, we shall observe that the largest production, which is approximately 13,400 tonnes (about 160 tonnes/shift) is barely covered, by distributing the 6 tonnes/shift difference to other months, so that only one truck can be used. This method can result in savings of 21,168 man·shifts/year or 6,435,075 lei/year. As such, by using this method alone, in approximately 3 years from the date when the roadheader mining technology is implemented, the whole investment can be recovered, knowing very well that presently at least two trucks are used to transport the production to the surface.

The massive influence of organising the transport, and respectively that of the number of trucks (in this case, 22-tonne trucks) in use at the same time on daily production realised with a roadheader is evident in the graphic shown in Fig 10. In this theoretic (ideal) case, which considers the most favourable organisational and exploitation conditions, with the roadheader being 100% in use, when extracting from the +188 m horizon one can obtain a maximum production of 3,960 tonnes on a day with 4 shifts. This is approximately 1 million tonnes/year in 252 working days, using seven 22-tonne trucks. This means that, in order to obtain an average daily production of 408.73 tonnes (projected at Praid Saline), the roadheader utilisation is 10.32%; and for normal exploitation conditions, for a utilisation degree of 50-60%, one can obtain a daily production of 1,980-2,376 tonnes or approximately 500,000-600,000 tonnes/year, using 4 trucks.

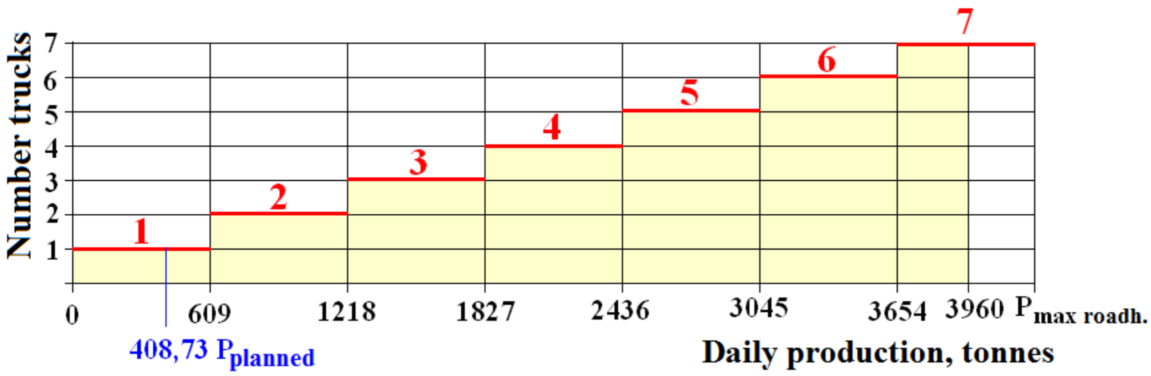

Figure 10. The influence of the number of trucks in simultaneous use on the production capacity realised at +188m horizon

Distributing physical production over months and quarters, preliminarily for 2020 and depending on market demand, is presented in Fig. 11. This is at the very basis of establishing the exploitation programme, including the one where a roadheader is used, at the Praid Saline for a 10-year period, respectively of physical and value production obtained during this period.

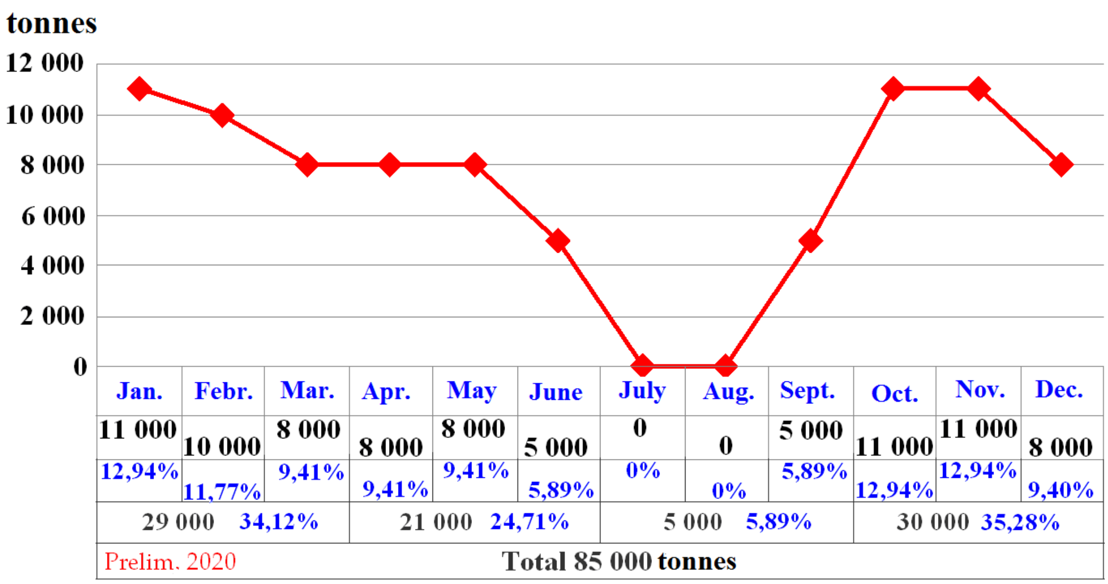

Figure 11. The distribution of net rock salt production over months and quarters, throughout 2020 – preliminarily [12]

In order to plan the production of salt via roadheader exploitation and in the New Sector and via drilling-blasting in the Telegdy Sector for a 10-year period, the following parameters were calculated:

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a) The production share from the total delivered production is as follows: 77.5% in the New Sector; 17.5% in the Telegdy sector and 5% from special furnacing works;
b) The exploitation coefficient C_e (or extraction /recuperation, in %), the coefficient of losses in exploitation pillars K_p (losses in pillars, in %), the coefficient of quality extraction K_c (quality extraction, in %), calculated in sectors and at total production level (with the assistance of which these were determined, starting from valued production in tonnes, the following indicators: industrial production, geologic reserve, losses in exploitation pillars and the share of stockpiled production);
c) The distribution of physical production in quarters is as follows: Q1: 34.12%; Q2: 24.71%; Q3: 5.89%; Q4: 35.28% (see Fig. 11).

An analysis covering a period of 10 years of roadheader exploitation was undertaken, up to the point where the reserves at the +168m horizon are depleted.

Depending on market demand, average annual production realised by using a roadheader in the New Sector (horizons +188 m and +168 m) and from opening and preparation works necessary at these horizons, for a period of 10 years are as follows: industrial production: 103,000 tonnes/year; net sold production: 94,500 tonnes/year; valued production: 25,326 lei/year. These values were taken into account in the calculations and technical-economical analyses undertaken [6, 12].

Also, depending on the production distribution coefficients at the Praid Saline, over months and quarters, the evolution of industrial productions was realised, both sold and valued, by using a roadheader, during a 10-year period. This data serves to optimise the distribution in time of financial and personnel resources, depending on seasonal demand for rock salt for road traffic use, within the time period under consideration [6, 12].

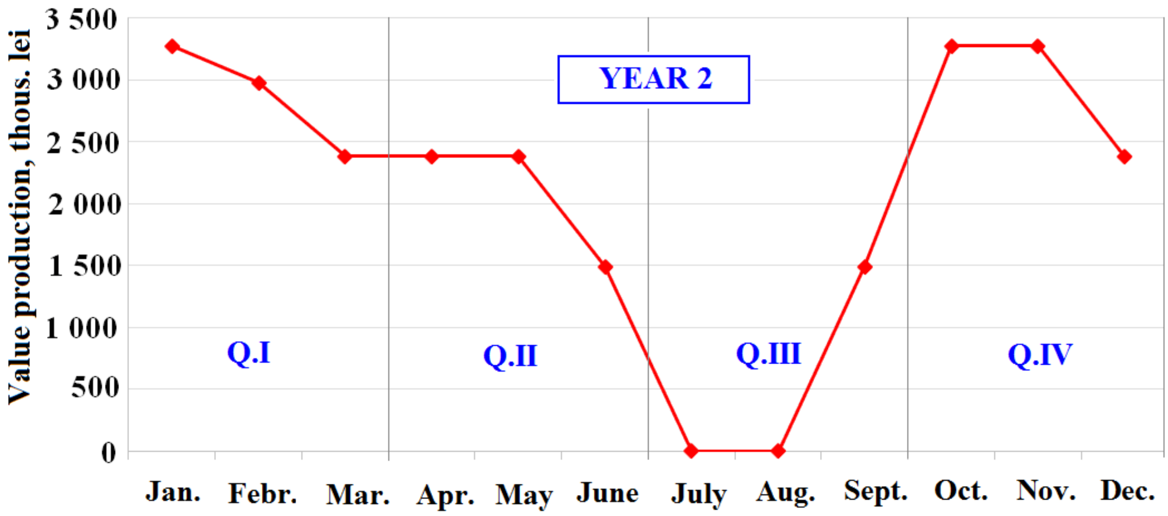

Figure 12. Distributing value production, over months and quarters, during the second year of implementing roadheader mining technology [12]

5. Comparative production costs between roadheader mining technology and drilling-blasting mining technology

The investment realised in the roadheader and adjoining installations at the Praid Saline, can be recovered from two main sources, as follows:
1) From the benefit obtained from recuperating reserves lost in pillars and ceilings, which would have to be oversized due to the destructive effects of detonating explosives if the drilling-blasting technology was used;
2) From reducing production costs by using the roadheader cutting technology, as compared to the drilling-blasting technology.

The industrial reserve losses, calculated only at the level of the +168 m horizon of the New Sector, by increasing the dimensions of pillars and ceilings by approximately 0.75-1.0 m are summarised in tables no. 1 and 2.

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Table 1. Reserve losses/production at the +168 m horizon, due to increasing the dimensions of ceilings and pillars by 0.75-1.00 m [12]

Affected depth, [m]	**Rooms dimensions, [m]**		**The volume of lost reserves, [m^3]**			**Industrial reserves losses, [tonnes]**	**Sold production losses, [tonnes]**
	height	**width**	**ceiling**	**pillar**	**total**		
0.75	9.25	19.25	18,974.25	17,281.31	36,255.56	78,312	65,981
1.00	9.00	19.00	25,299.00	22,419.00	47,718.00	103,071	92,764

Table 2. Value losses in supplementary abandoned reserves at the +168m horizon, due to increasing the dimensions of ceilings and pillars by 0.75-1.00m [12]

Affected thickness, [m]	**Sold production losses, [tonnes]**	**Value production losses, [lei]**	**Total costs, [lei]**	**Total benefit lost, [lei]**
0.75	65,981	17,682,908	9,443,861	8,239,047
1.00	92,764	24,860,752	13,277,311	11,583,441

If in the economical evaluation one takes into account the increase in the sizes of pillars and ceilings only from the +168 m horizon and only by 0.75 m, the estimated benefit losses due to abandoning supplementary industrial reserves rises above 8.2 million lei, and where the resistance structures are increased by 1.0 m, the benefit losses rise above 11.5 million lei. Taking into account the fact that the cumulated industrial reserves at the +168 m and +148 m horizon are approximately 1 million tonnes, over the about 10 years of exploitation, in both cases the investment is recovered in full solely by exploiting the supplementary reserves which would be lost in the resistance structures mentioned above [12].

The comparative analysis has at its basis the structure of total unitary cost, corresponding to the two technological variants under comparison and is summarised in Table no. 3.

Table 3. A comparative analysis between Variant 1 (roadheader cutting) and Variant 2 (drilling-blasting) [6, 12]

Specifications	**UM**	**Value**		
		Variant 1	**Variant 2**	**Differences (Var.1 - Var.2)**
Unitary cost generated by electricity use	lei/tonne	2.545	2.513	+0.032
Unitary cost generated by fuel use	lei/tonne	2.650	2.817	-0.165
Unitary cost generated by devaluation of machinery and means of transport	lei/tonne	22.478	22.365	+0.113
Unitary cost generated by other consumable materials	lei/tonne	0.345	4.787	-4.442
Unitary cost generated by maintenance and repair works of machinery and means of transport	lei/tonne	2.306	3.235	-0.929
Unitary cost generated by personnel costs	lei/tonne	10.578	21.277	-10.699
TOTAL UNITARY COST	**lei/tonne**	**40.902**	**56.994**	**-16.092**
Annual Production	tonne	103,000	103,000	0
Daily Production	tonne	408.73	408.73	0
Productivity	tonne/shift	29.20	18.90	+10.3

Following an analysis of the differences between the costs produced by the two technologies one can see that the roadheader cutting technology is superior to the drilling-blasting technology in the majority of respects involving costs, only being minutely inferior in energy consumption (by 0.032 lei/tonne) and devaluation (by 0.113 lei/tonne).

As regards total cost, the roadheader cutting technology is vastly superior, producing a tonne of rock salt approximately 16.1 lei cheaper than the classical technology. Also, the productivity of the roadheader cutting technology is 10 tonnes/shift greater as opposed to the drilling-blasting technology.

If we only analyse the total implementation costs of the roadheader cutting technology, generated by the mining face production costs, summarised in Table no. 4, one can observe that by applying this technology (giving up the drilling-blasting technology in the conditions present in the New Sector) the investment can be recovered integrally in a maximum of 10 years of exploitation, without affecting the value of the benefit produced hitherto by drilling-blasting.

Table 4. Centralising table with a total investment created by implementing the roadheader cutting technology at Praid Saline

Specification	**Value**	
	lei	**EUR**
Machinery and adjoining electrical equipment	14,597,712	3,041,190
Electrical networks	1,930,000	402,083
Total	**16,527,712**	**3,443,373**

6. Conclusions

Following an increase in the mining depth at the Praid Saline, the projected dimensions of the pillars and ceilings grow correspondingly. Also, the destructive effect of drilling-blasting works on these resistance structures imposes a reconsideration of these dimensions.

In the premises, the only solution is to give up the drilling-blasting technology in favour of the roadheader cutting technology using a high-capacity forward roadheader to cut the rock salt. As such, 30 forward roadheaders were taken into account, each having a weight of approximately 100 tonnes, and following the application of a number of selection criteria, corelated with the geo-mining conditions in the New Sector at the Praid salt mine, the Sandvik MR-520 roadheader was chosen.

The main advantages of implementing the rock salt mining technology by use of the Sandvik MR-520 roadheader at the Praid Saline are as follows:

-The destructive effect on resistance structures generated by the detonation of explosives is eliminated;

-The annual production capacity can be distributed over time, there existing the possibility of concentrating production over a shorter period of time, depending on seasonal demand for roc salt for road traffic use, without restrictions in terms of personnel;

-Recovering the investment is done integrally in the difference between production costs, by comparison to the drilling-blasting mining technology, without having an impact on the obtained benefit;

-A supplementary benefit is obtained by recovering the rock salt from the reserves contained in oversized pillars and ceilings (should the drilling-blasting technology continue to be used).

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