ABOUT THE MECHANIZATION OF OPEN PIT PRODUCTION

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1. Overview

When choosing the way a deposit should be exploited, considering its form, size and its placement in the layer, we have three possibilities:

I. Surface exploitation for the entire mineral reserve from the deposit;

II. Surface exploitation is advantageous for only a part of the reserves, the other will be exploited underground;

III. Due to the high depth of the deposit, it cannot be exploited on surface, the entire works should be done underground.

In order to have an entire surface exploitation, the deposit should be: a large deposit, or a large area stratiform deposit with different thickness, placed low depth from surface.

For partial exploitation through surface works, the deposit should have the form of a layer, lens or vein, big thickness and average or big tilt, which outcrops close to surface.

The deposits having the form of a lens, nest or stainings are exploited totally or partially on surface in open pits, depending on their placement and extension on the ground surface.

Considering the surface of the zone which quarters the deposit, it can be: field, slope, hill, mount or water.

For the deposit exploitation to produce value, technically and economically, apart from the favorable geologic condition, there should be met another series of conditions, the most important are:

- Favorable land surface to allow normal conditions for open pit exploitation
- Hydrologic area without surface waters or underground water canvas; the presence of underground waters impose measures for their drainage and evacuation outside the exploitation area;
- Deposit cover layers to be formed of rocks which may be taken away easily;
- Mild climate which allows work without excessive atmospheric weather.

The following type of deposits are valid to exploited in open pits, from the economic, technical and substance point of view:

- Solid mineral fuels (peat, lignite, brown coal etc.);
- Metal mineral deposits (iron, copper, zincum, gold etc.);
- Non-metal mineral deposits (kaolin, phosphates, clay, bentonite, sulfur, asbestos etc.);
- Any kind of rocks used in constructions or decorative (sand, gravel, marble, granite, chalk etc.).

When local and technical-economic conditions obviously allow the total or partial open pit exploitation for a deposit, the next step is the preparation of the deposit for being exploited and its scalping and exploitation in order to achieve the planned production.

Most of the time, the scalping and mineral exploitation requires the organization of four main operations: massif excavation, loading on transport, transport and ore storage or dump tailing.

These operations will be mechanized through the achievement of various tools which will lead to lower production costs for the excavated unit.

Sometimes, we might lack one of these operations as an independent work. For example, when we work on soft rocks and ores, the massif excavation does not take place, the operation being the same with transport loading, being carried by the same machinery. Economic wise, the most expensive production operations are transport and dump foundation. For example, for scalping the transport and dump foundation represents 70% of the total scalping costs in case of soft rocks and 60% in canse of hard rocks.

In open pit exploitation, together with the main operations of the production process, it comes the necessity of acomplishing different auxiliary works, mandatory for the main ones. Therefore, among the works related to the main operations we note: drill changes or their refurbishment or sharpening in case of hard rocks, change of cutter knives or excavator buckets in case of mechanic exploitation, railway riping along the work front or tail dumps in case of railway transport, riping of dynamic transporters from work fronts and tail dumps in case of continuous transportation with belt conveyors, work berm leveling, arrangement of access roads for road transportation etc.

2. Work technologies in open pits

In open pits, depending on the extractive rock hardness, there are used continuous work technologies or discontinuous work technologies.

The most frequent extraction, loading, transport or tail dumping technologies from open pits are presented in figure 1, while for mineral ores they are presented in figure 2.

As we can see in figure 2, the mineral ore extracted from the deposit is transported and unloaded in the stores of the processing plants, or, when there no processing is needed, it is sent to the consumers.

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The specific work conditions from open pits, the large volumes of works to be done in time and the rational use of workforce, demands and justifies the complex mechanizations of the main production operations from open pits**.**

3. The mechanization of production in open pits

By complex mechanization of production in open pits we understand the system for the execution of open pit works, where the entire main and auxilliary connected operations are fully mechanized and the technical equipment for the mechanization of every operation of production corresponds functionally, in terms of power and capacity, with the power and capacity of the main machines and exploitation installations, which, in most cases are one or multiple bucket wheel excavators.

Figures 3 and 4 presents the specific equipment used to form in open pits the production technologic lines with continuous and discontinuous work

The intensive and extensive mechanization of production in mining in general and especially in open pits, ensure:

- the continuous increase of production and work productivity and the decrease of costs on production unit;
- the continuous supply and operation of all industry branches whose production activity is related to the processing and consumption of mineral ores and rocks;
- optimal work conditions – light, air, hygiene – therefore good work safety;
- the decrease in number of needed workforce, especially for technical and surveillance personnel;
- applying exploitation methods on large fronts and over 15-20 m heights, capable of ensuring great work production;
- production entering of open pits is done in less time than for underground exploitations, therefore the investment amortization duration is lower;
- the possibility to adapt the production level to the requirements of the consumption industry, since the work fronts with reserves ready to be exploited have big lengths and heights.

3.1 Particularities for the mechanization of production in open pits

The current mechanization of open pits in Romania and abroad is characterized, from the point of view of machinery and equipments used, by two main particularities:

- the diversity of tools needed to execute various operations of production;
- by the impressive size and power of the machines which may get up to thousands of kilowatts.

The first particularity, the diversity of the machines is conditioned by the type of rocks and mineral ores to be extracted, their physical-mechanical properties, the operation way of the workers, the type of electrical energy used, the displacement system etc.

Thus, for borehole drilling in case of hard rock excavation through drilling-blasting works, considering the work method of the shovel on the bottom of the borehole, there can be used three types of drilling instalations: percussion installation, rotary installations and rotary-percussion installations.

For the loading or extracting of tailings and mineral ores from workfronts there are used five types of machines: scrapers (conveyors or wheeled), loaders (bucket tractors), discontinuous action excavators (rotor excavators with cutting buckets and ladder excavators) and hidromonitors which dislocates and transports the rock by using water under pressure.

To displace the mineral ores and tailings from workfronts to the unloading points there are five types of mechanized transport: railway transport, cableway transport, road transport, conveyor belt transport and hydraulic transport.

Depending on the transport machine type, the railway transport can be internal combustion engine or electrical engine.

Railway transport is used mainly for open pits with large productions and long transport distances and low depth pits. This type of transport is mostly used outside the pits, from the delivery point to the costumers being hundreds of kilometers away.

Cableway transport is used for open pits with small productions of hard rocks. Nowadays it is rarely used.

The road transport in open pits is used more and more, with trucks, tows and wheeled or tracked tractors. This type of transport is used: in pits with low productions and short operation life; in horizontal or small slope deposits, in high speed workfront deposits, for deposits with complicated configurations, for rough surface where a selective exploitation is needed, on high depth open pits when the railway transport would require big lengths due to the slope restriction to maximum 45 ‰; or when the transportation length is lower than 3-4 km. The road transport is used with good results also to big open pits with long operation life. Considering the rock hardness it is recommended for hard rocks which may also be abrasive.

Tabelul nr. 1

Tehnologii de extragere, încărcare, transport și haldare a sterilului în cariere

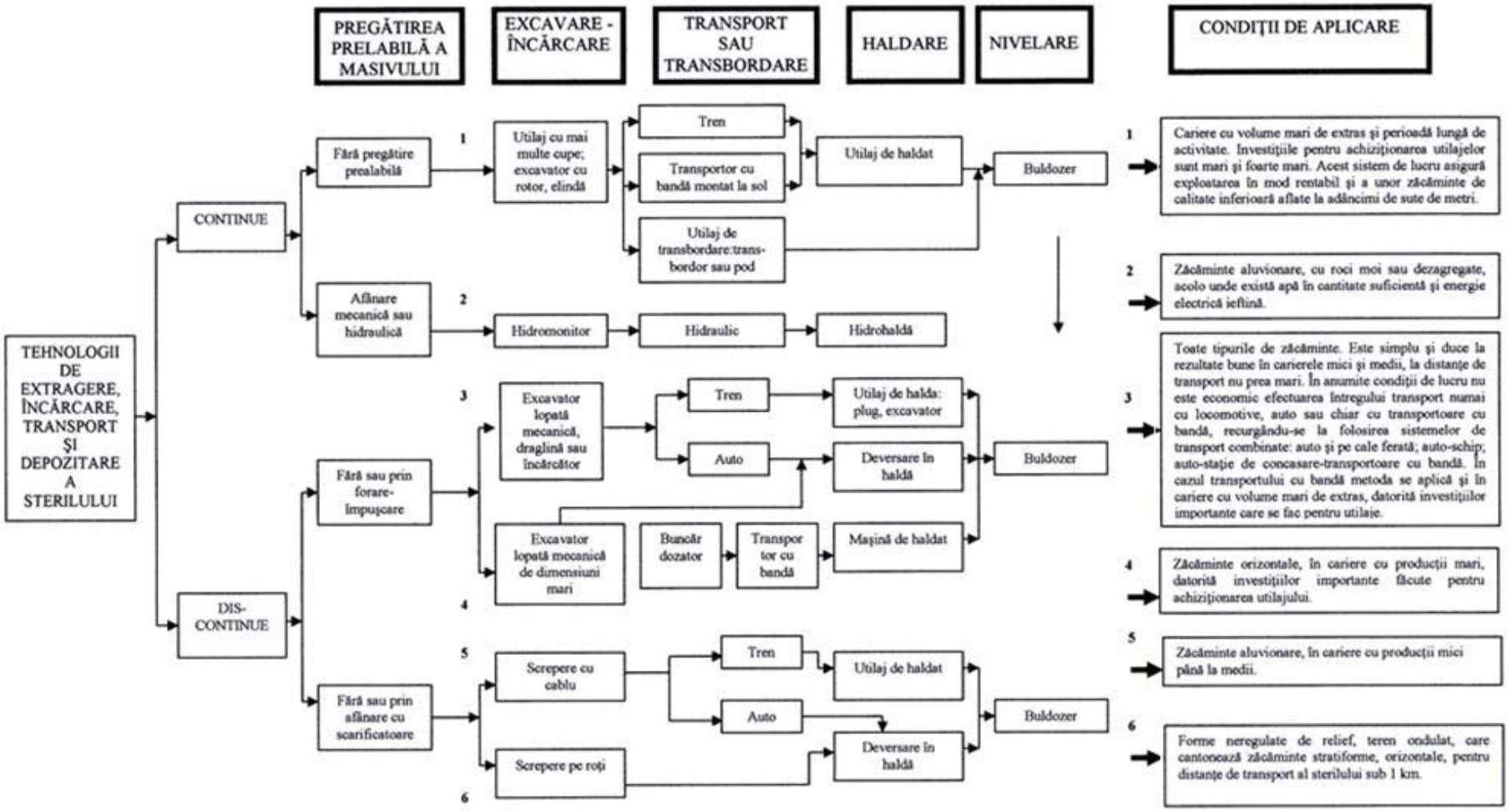

Fig. 1 **Technologies for extraction, loading, transport and tail dumping in open pits**

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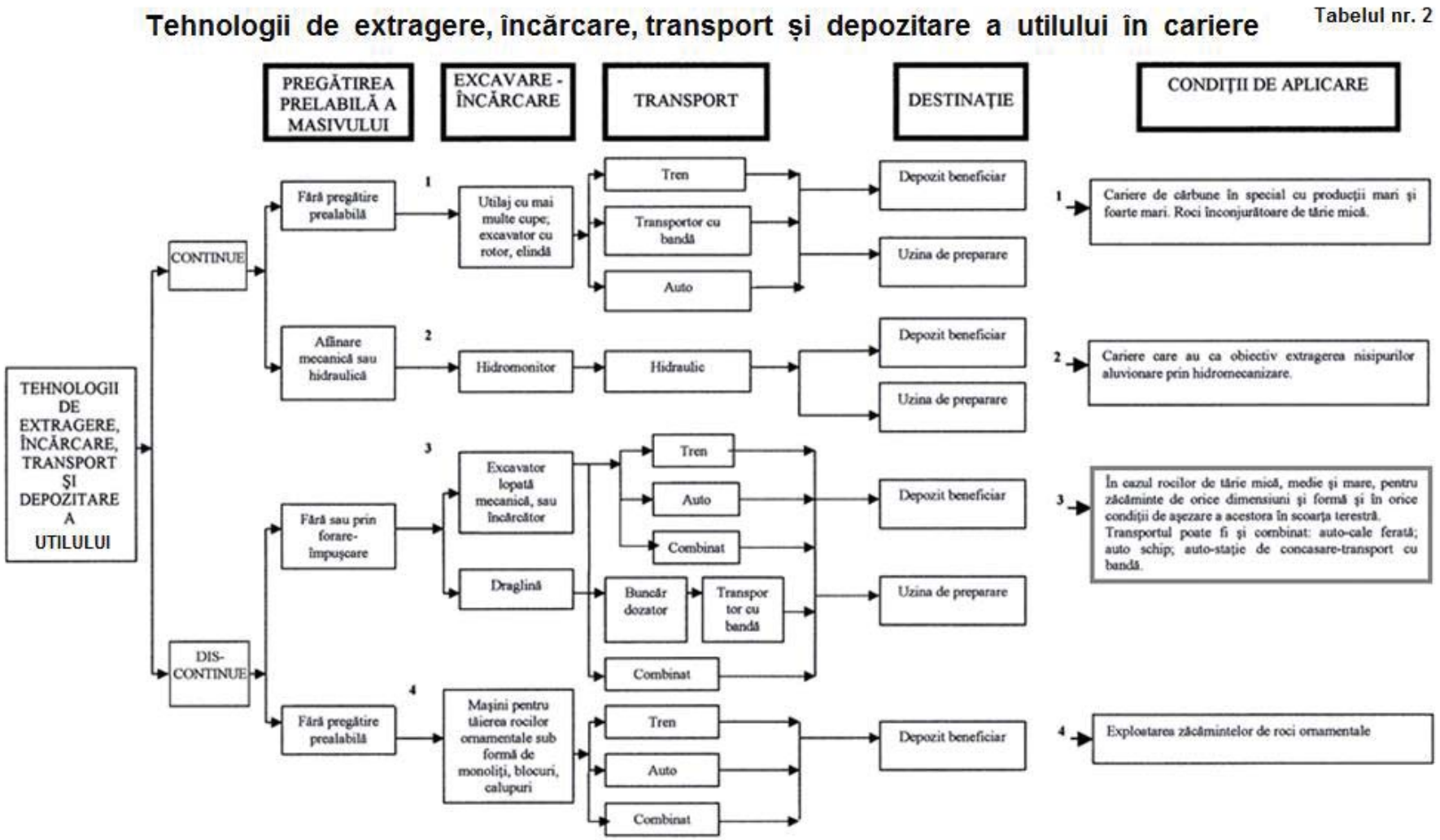

Fig. 2 **Technologies for extraction, loading, transport and storage of mineral ore in open pits**

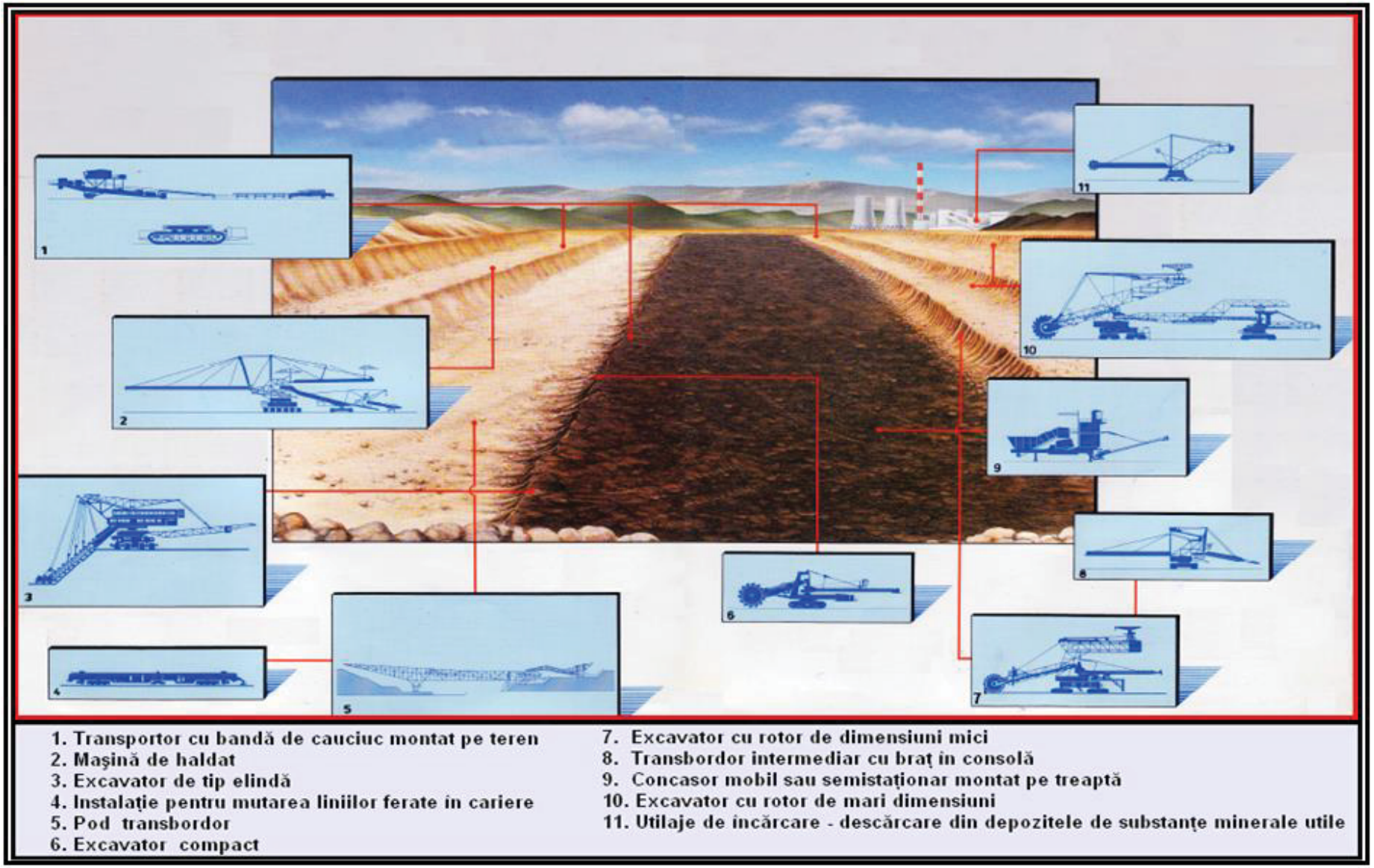

Fig. 3 **Specific tools used to ensure continuous works technology lines in open pits**

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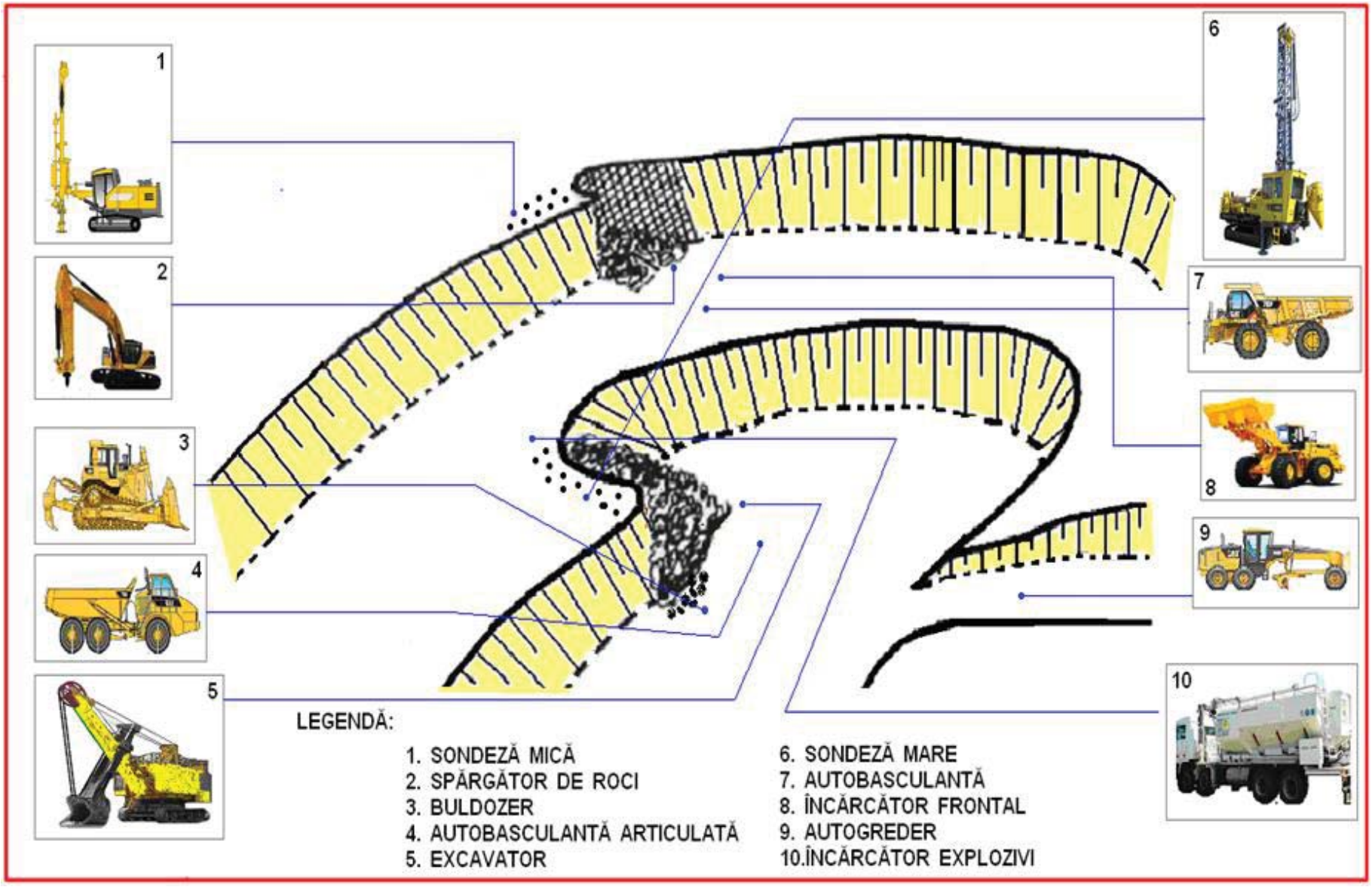

Fig. 4 **Specific tools used to ensure discontinuous works technology lines in open pits**

In case of conveyor belt transporters from open pits, there are three categories of transporters: stationary transporters, half-stationary transporters and mobile transporters.

This transportation system is recommended: in case of coal open pits or other mineral ores or construction materials which aren't extremely rough or abrasive and do not stick to the belt, for large and extremely large productions, for every depth of the open pits, especially for high depths, when the transportation distances aren't too high.

In certain work conditions, it is not economically effective to do the entire transport only on railway, road or with conveyor belts, so combined transport is required. The most used combined transport systems are: road and railway, road-slope skips, road-crushing station-belt conveyors. For example, when the work fronts from open pits displace with quite high speed and the pit depth is high, we recommend the internal transport to be done with trucks, while from the pit to surface to be done with conveyor belts.

The hydraulic transport is used in open pits to transport the scalping rocks and mineral ores which are excavated through hydro-mechanized operations. It is recommended for low or no cohesion materials, such as sands or alluvial deposits, which are easily extracted with hydro-monitors and do not require crushing.

For dumping works three types of machines are used:

- discontinuous or continuous action excavators, used for dumping works;
- console arm loading elevators for dumping foundation;
- big bulldozers for leveling or pushing the tailings brought into the dump by various transportation methods.

Moreover, for dumping works or road arrangements there are used scrapers, scarifiers and autogreders.

The second particularity, practically the unlimited power of the machines from open pits, is characterized currently by the following data:

- the action power of the drilling machines varies from 4 ÷ 12 kW – hard pneumatic percussion drills – up to 300 ÷ 500 kW – rotary probes for roll shovel drilling;
- the power of the force installations from single bucket excavators varies depending on the bucket capacity from 250 kW to 22.000 kW for a bucket capacity variation from 3 to over 150 m3;
- the installed power for continuous action excavators rotary type and cutting buckets varies depending on the number of buckets installed on the rotor and their volume from 200 to 15.000 kW;
- the electrical engine contact locomotives used in open pits have the power of more than 3.500 kW, and the high capacity conveyor belts are operated by action groups placed on both ends whose power may be higher than 4.000 kW

3.2 Choosing the work technologies and mechanization systems in open pits

The diversity and the power of the machines used in open pits is imposed by the variety of the natural and technical production conditions where these machines operate.

Choosing a certain type of extraction, transport and storage technology in an open pit is determined by three main factors:

- the physical-mechanical properties and especially the hardness of the mineral ore and of the rocks surrounding or covering the deposit;
- the geometric elements and the placement of the mineral ore deposit within the land and the tectonic of the deposit, highlighting the fissure or minimum resistance plans;
- the mineral ore deposits and their quality which determine through their volume and value the production capacity to achieve yearly in the open pit.

Choosing the general mechanization system and solving the problem of mining technologic process mechanization from open pits is more difficult compared to other industrial branches. This is mainly due to the following essential particularities:

- the work fronts where the cutting and loading operations take place are continuously displacing and they move together with the entire open pit machinery;
- the transport system of the open pit is fairly complicated, having multiple ramifications, points of loading and reloading and suffer continuous changes because of the displacement of work fronts they serve;
- the deposit conditions are different from one layer to another, being largely varied. The deposits may have various forms, stores, veins, layers, impregnations, etc. Those with the forms of veins or layers may have the thickness from a few centimeters to tenths of meters and slopes from 0 to 90º. The hardness of mineral ores and surrounding rocks vary from unconsolidated sedimentary – flowing sands –

up to erruptive or metamorphic rocks, extremely hard, such as granites, basalts, quartzites etc. The deposit conditions may vary even for the same deposit or layer, many times along a work front we notice variations of the geometric and placement elements that characterize the ore deposits.

The particularities above clearly show that the production mechanization in open pits is a problem hard to solve.

The main factors which influence the choice of the general mechanization system are: the hardness of the mineral ore and surrounding rocks; the form, dimensions and placement of the deposit on surface land and the production of mineral ore needed to be accomplished, which for the specific conditions of the open pit will determine also the volume of scalping works needed to be done.

The hardness of the mineral ore and surrounding rocks determines the main type of machine used for scalping works and to get the mineral ore.

Therefore, in case of some hard rocks and mineral ores which require loosening works done by drilling and blasting, we exclude the possibility of mechanization with scrapers, continuous operation excavators and draglines. In this case we must apply the mechanization systems using single bucket wheel excavators and loaders.

The form, dimensions and placement of the mineral ore deposit in surface land determines the use of a certain exploitation method, while the rock and mineral ore hardness the use of certain machines to build the main production operations complex.

For layer deposits, horizontal or low inclination deposits, the most rational would be the exploitation methods with direct delivery of the stripping in the exploited area. To excavate and lay the stripping there are used mostly excavators with discontinuous action type mechanic shovel or dragline. For deposits with high and very high inclination the use of these exploitation methods with such machinery is not possible so we must apply the method of transporting the sterile to the dumps placed outside the open pit.

The size of the production capacity and the scalping works volume determines the machinery choice and its power. For mineral ore deposits of limited dimensions and low reserves, it is hardly possible the development of large extraction works, using expensive equipment, while for large deposits of big reserves would be irrational the use of low capacity equipment.

Considering the factors above and the limit of the possible development depth for open pits, but also the pit life length, it will be chosen a main mechanization system for the entire mining complex. In order to get favorable economic results the main mechanization system chosen is improved or combined with other possible systems for the chosen deposit.

For example, to exploit a thick deposit with high inclination, we may use as main system the one composed of single bucket wheel excavators and loaders for the loosen material, rotary mechanic drilling with rollers for borehole drilling and road or electric railway transport. In case of alluvial formations of high thickness, to excavate and remove them we may use the system of discontinuous operation excavators and road transport, and, as an improvement to the main system, we may use a system with roller scrapers, scarifiers and bulldozers.

After choosing the main mechanization system in the open pit we choose the machinery for the mechanization of various production operations composing the technologic process of the given system.

3.3 Choosing the equipment for open pit mechanization

The choice of the equipment for the technological mechanization in open pits is a hard to solve problem which requires the deep knowledge of the geologic-mining conditions of the deposit and, therefore, the characteristics of the mineral ore and the modern trends of this domain. The equipment must be adequate technically to the deposit in order to give a high work productivity and a low cost for every tone of mineral ore extracted.

Choosing the main types of equipment for work mechanization in open pits can be done in three ways:

- by choosing the best series of equipment produced by machine construction companies for the entire production process;
- by choosing a part of the equipment done by standard series while another part is special designed for the open pit;
- by special command of equipment for most of the productive operations in the open pit.

The choice of the last generation equipment, corresponding to certain deposit conditions is the first requirement for an efficient and economic mechanization.

In choosing the equipment we must carry one some mandatory stages:

- first we choose the equipment corresponding to the main characteristics of the deposit which can be integrated in the general mechanization system conceived;

- afterwards we choose the equipment type depending on the work methods fitting best to the physical-mechanical properties of the rocks to be extracted, ensuring the required productivity;

- the following choices will consider other factors such as: general activity organization, tools which will be worked upon in the complex, electrical energy consumption, etc.

The final choice will be done on detailed technical-economical comparisons.

The chosen equipment and its power must correspond to the deposit conditions and to ensure the planned production, in order to achieve the highest possible productivity and the lowest costs for every tone of mineral ore extracted.

The equipment used in open pits must be operated in security, to be used conveniently and to have higher efficiency than other types of equipment.

In choosing the standard equipment we have in mind the tools for scalping and for extracting the mineral ore. Since the volume of scalping works is usually 2-3 times (and sometimes even 5-6 times) bigger than the mineral ore extractive works volume, for scalping there are chosen usually the most powerful tools, for example, special designed scalping excavators of same kind which eases and simplifies their exploitation, repairing and use.

In choosing the equipment for mineral ore excavation works it must be considered the possibility of multiple kinds of ore qualities, characterized by different metal composition and metal harmful components. When there is a large number of deposit sectors with different ore qualities, the extraction works cannot be concentrated in 1-2 work fronts, since this prevents respecting the conditions regarding ore quality, so the exploitation will sometimes work upon rich mineral ores and other times on poor mineral ore. The extraction of all quality ore must be done uniformly, according to the established volumes and quantities, so for the mineral ore excavation works are required more machines and reserve work fronts. The excavators must also be same type, for the same considerations as above.

After the excavators for scalping and mineral ore extraction were chosen and their possible capacity was determined, we choose the drilling equipment and estimate the drilling-blasting works.

The needed number of probes is calculated according to the scalping and mineral ore volume to be extracted, considering the capacities of the excavators which will be used for scalping and for extracting the mineral ore.

Together with choosing the drilling equipment for the boreholes towards the initial mass blasting of work fronts, there is established the possible quantity of oversize material and is chosen the method to crush them in front. If for the secondary crushing we choose for normal size material the drilling-blasting method, then, considering the work volume, we choose the drill types and make calculations for the compressed air and force equipment.

The next important and responsible stage is choosing the transport equipment, since in open pits, in case of large scalping and mineral ore extraction works, the transport is an important link in the work chain. A well chosen and organized transport in open pits determines the maximum possible capacity of the main equipment – the excavators from the work front.

The most important factors which influence the transport system and equipment choice are: the size and plan configuration of the open pit; the scalping and mineral ore extraction works volume; the distance for the transportation of mineral ore and tailing dump; the possible limit depth of the open pit; the existing type of energy or fuel and the excavator power (bucket capacity).

When designing the open pit, the choice of the transport system (railway, road, transporters or mixed) is done together with the choice of scalping method and drawing the open pit borders in its final form.

The extraction works with excavators in work fronts and the transportation tools must be strictly coordinated considering the equipment chosen and the machines used to store the mineral ore and to transport the sterile to the tailing dump.

The machines for the dump works (dump excavators and console arm loading elevators) and for mineral ore storage must be chosen so, through their capacity, to not limit in any way the capacity of the excavators from the scalping and mineral ore extraction works. In their turn, the dumping works must be coordinated with the mechanical movement of mobile transporters or with the railways in dumps

and work fronts, so together with choosing the dumping vehicles there are chosen the machines for the displacement of railways and for mobile transporters.

After choosing the basic equipment for the entire complex system there is chosen the auxiliary equipment and the section equipment (drill and shovel sharpening machine, heating ovens, material transport installations, tool transport to work front machines etc.)

Special designed equipment is chosen rarely, determined only by certain specific geologic conditions of the deposit, when using standard equipment cannot give the needed results and is not suited economically.

For example, if we have a mineral ore deposit with layers which alternates intercalations of sterile rocks with constant thickness, the global extraction would lead to mixing the mineral ore with sterile rocks and to separate them we would need a complicated and expensive processing installation. Therefore, we need to use bucket wheel excavators with a complex with a complex port-bucket frame, especially designed, to allow the selective extraction of mineral ore and sterile rock, without mixing them.

A lower cost for exploiting horizontal deposits is achieved by applying exploitation methods with direct storage of sterile in the exploited space, when the scalping rock is deposited in the internal dump of the exploited area. To use these procedures there are required excavators with large work parameters or special large dumping machines.

Thus, if using a special designed machine guarantees a better technical and economic effect, based on the new superior technique, this mechanization solution will be correct or rational. If the use of the command equipment does not ensure the desired technical and economic effect, the mechanization problems must be solved by choosing the most rational standard equipment, whose construction was done in series.

The tools for the mechanical repairing sections are chosen according to the basic equipment which is used in the open pit, considering the possibility of doing all the repairing required by the main and auxiliary equipment from the open pit.

In the future, in Romania and in the world, we will see a growth in number of open pits for various mineral ores, considering the advantages of this exploitation type compared to underground exploitation and considering the need of production increase of mineral raw materials.

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