ROMANIA'S EXPERIENCE IN DEWATERING AQUIFER FORMATIONS IN MINING FIELDS

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Abstract:
While exploiting the deposits of useful mineral substances underground waters display a considerable importance. In the case when mining fields include aquifer formations, they have to be dried so that the carrying out of the production processes could occur under normal conditions and full safety. This study exhibits the dewatering methods, schemes and patterns generally used in mining as well as those implemented in various areas of exploitation belonging to Rovinari mining basin, depending on the existing technical, mining, and hydrographical conditions. The study also shows the results and the future preoccupations with a view to improving the dewatering process and economic results.
Key words: *deposit, aquifer formations, dewatering, draining, drilling, methods, schemes, types.*

1. Introduction

While exploiting the deposits of useful mineral substances, underground waters display a considerable importance and interest. A small amount of water that impregnates the rocks turns the cutting process easier and prevents the dust gathering at shafts; on the contrary, larger amounts of water determines exploitation difficulties, increasing the final cost per ton of useful substances extracted. This is the reason why, beginning with the stage of a deposit's geological research, they also have to precisely settle its hydro-geological characteristics.

The presence of aquifer formations in the roof and floor of the deposits of useful mineral substances determines their difficult exploitation due to the danger of inundating the mining works and the shafts in the case of underground exploitation or due to inundation and deterioration of shafts, of transports ways and of those carrying the equipment belonging to the technological fluxes as well as due to the sliding and fracturing of the benches, work and definitive embankments in quarries. In order to eliminate such drawbacks, they have to perform the dewatering of aquifer formations.

The *dewatering of aquifer formations* represents the whole range of water draining and evacuation measures within the formations of sterile rocks and useful mineral substances with a view to digging mining works and exploiting the deposits under normal work conditions and labour security.

It targets gravitational water and, partly, capillary water in the mass of rocks. In the case of aquifer systems with important dynamic resources, only a temporary decrease of piozometric pressure (tension relieving) is produced, in the draining area; the hydrostatic level quickly recovers after draining is stopped. In the case when draining is increased, the dynamic level gets to the roof of the aquifer system and dewatering begins.

The dewatering of aquifer formations involves a series of draining works meant to intercept and capture underground waters, outside or inside the exploitation field, which should function according to a settled succession and located in accordance with various schemes.

In the case of day exploitations, dewatering is required, whenever possible, about 2 or 3 years before starting the opening, preparation, and exploitation works, in order to provide optimal conditions both for digging the mining works and for the transport of the equipment to specific areas and to the dump.

2. Dewatering measures used when exploiting lignite deposits in Romania

Dewatering measures comprise methods, schemes, and types according to a first criterion, and dewatering works employed according to another criterion.

Dewatering methods are defined in comparison with the location of the draining works and their stage and are divided into: *preliminary dewatering, parallel dewatering,* and *mixed dewatering,* which includes both preliminary dewatering and parallel dewatering. Depending on the manner dewatering is done, there are: *day works dewatering methods, underground works dewatering methods, and combined dewatering, which is used both in the case of day works and of underground works.*

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Preliminary dewatering is used in the case of deposits displaying complex hydrological conditions, mainly in the case of quarries; it is carried out through hydro-technical measures including defence works against superficial and deep waters, deep and medium deep vertical draining, absorbing drilling and underground mining works allowing the performing of short vertical draining before starting the opening works.

Parallel dewatering is simultaneous with the carrying out of the mining works and targets the complete dewatering of the aquifer horizons in the roof, the decrease of water pressure in the floor of the mining works and the dewatering of quarries benches. Parallel dewatering is mostly done through underground mining works including penetrating filters, large diameter drilling and horizontal drilling in shafts and work and definitive perimeters of the quarries.

In the case of thin clay floors succeeded by sands with water under pressure, it is necessary to decrease hydrostatic pressure through penetrating filters and draining drills in order to avoid the fracture of the floor and the uncontrolled penetration of water in the mining works or quarries.

Mixed dewatering is a dewatering that started before the opening of the deposit and continues during its exploitation. Such a dewatering is implemented in the case of complex hydro-geological conditions and occurs in accordance with a succession providing their maximum efficacy.

Dewatering schemes are defined by the location systems of the draining works that function in interference. There are *linear systems, shape systems, and surface systems.*

The types of dewatering are defined by the features of the forces that determine the translation of water to the draining works and include: *gravitational dewatering* (when water flows through free fall), *vacuum dewatering* (vacuum pressure acts within the draining works), *over-pressure dewatering* (pushing force acts outside the draining works), and *electro-osmotic dewatering.*

Dewatering works concern the means and practical works of dewatering and differ from one deposit to another, depending on the dewatering method and scheme, and the manner of dewatering, through day works, underground works or combined works.

According to the present-day stage of technical development, aquifer rock dewatering in mining exploitation is carried out through the following means: large diameter drain drilling with submersible pumps; absorption drilling; drilling without filter with free eruption at the level of the quarry’s floor or of the basement of the underground mining works; horizontal drilling placed in the quarry’s embankments of the benches; simple, vacuum or compressed air penetrating filters; simple, vacuum or compressed air fall filters; acicular filters, dewatering entrenchments, and embankment draining.

Each of these draining means display certain technical, economic, and technological features that limit their applicability to a series of specific hydro-geological, technical, and mining conditions. Such limits should be taken into account when choosing the dewatering type and schemes.

Drain drilling that pump water from sandy rocks with a filtering coefficient lower than 3.0-5.0 m/day usually stops functioning early. In order to use them for lower filtering coefficients than the one previously mentioned, they recommend the implementation of a vacuum dewatering scheme.

In the case when through drilling they get only the decrease of the aquifer deposit pressure, then such drilling may be also used for lower filtering coefficients (1.0-3.0 m/day). Employing drain drilling with submersible pumps is mainly determined by the limits of the flows and the discharge heights of such pumps.

Penetrating filters are adequate for underground dewatering and may be placed in the gallery’s roof or floor.

Absorption drilling may only be used for draining high permeability aquifer deposits, placed in the floor, in the case when the floors’ piozometric level does not exceed a certain limit.

Acicular filters installations are usually used in quarries as a local and temporary dewatering means.

The choosing of the methods, schemes, and types of dewatering is influenced by a series of factors, such as: the deposit’s geological structure; rocks’ hydro-geological conditions and characteristics; the flow and characteristics of underground waters flow; opening and exploitation method applied; technical possibilities of carrying out dewatering works; planned economic efficiency, etc.

3. Surface dewatering

The choosing of the type of dewatering depends on the hydro-geological characteristics, as follows: granulometric composition, porosity, hygroscopic features, permeability, storage capacity, release capacity, etc.

The optimal method and scheme of dewatering for a mining field should be chosen according to economic calculations out of the rational methods and schemes possibly applicable for the existing hydro-geological, geo-technical, and technical and mining conditions.

All targeted dewatering methods and schemes should rely on sufficient data extracted from field and laboratory researches. The schemes examined with a view to be applied in the field should also observe filtration calculations or modelling.

When choosing and implementing in the field a dewatering method or scheme, they should take into account experience and the results already obtained when having dewatering mining fields in the same basin or in basins with similar geological and mining characteristics. The most efficient methods should be preferred and a special attention should be given in the case of aquifer deposits both in the roof and in the floor of the strata of useful deposits.

Deep draining

Deep vertical draining is frequently used to dewater mines and quarries. This manner is proper for dewatering thick aquifer horizons, located at small and medium depths, with filtering coefficients higher than 1 m/day, fig.1.

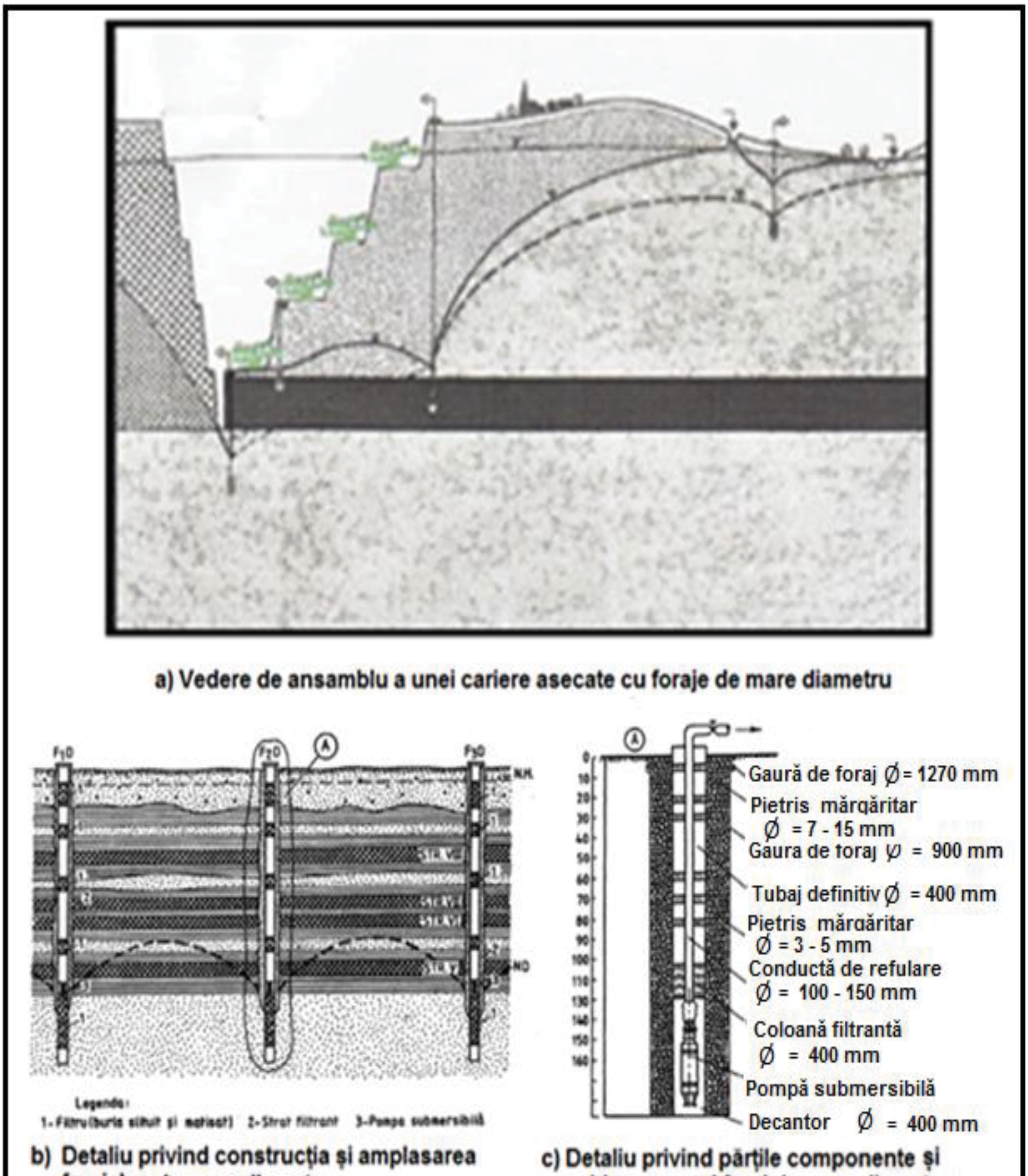


Fig. 1 *Large diameter drilling dewatering*

In the case when the filtering coefficient is lower than 1 m/day, vertical draining may only be used for decreasing the piozometric level of underground waters under pressure as it is not proper for a dewatering.

The depth limit for vertical draining is determined by the pumping technology at hand.

In order to evacuate the waters from drilling, submersible pumps, vertical axle pumps or airlift pumps may be used, fig.2. Submersible pumps of various types and sizes are mainly employed nowadays.

Vertical draining with large diameter drilling may concomitantly drain several aquifer horizons and may be applied irrespective of the stage of the opening or exploitation mining works that occur in the mining field.

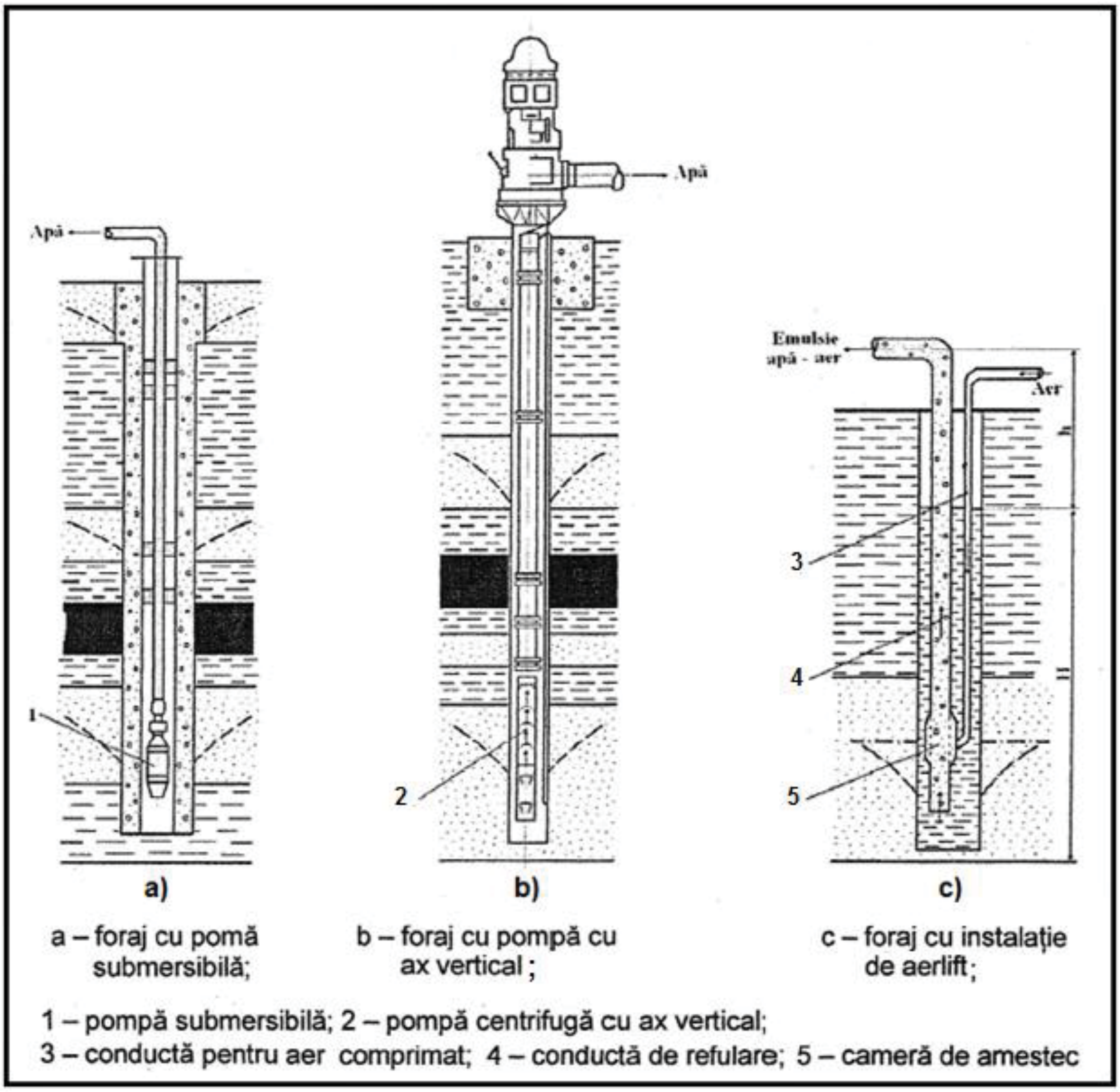


Fig. 2 *Water evacuation from dewatering drilling*

Enlarging the domain of use depends on the size of the diameter and the increase of the number of drilling in progress, the size of the permeability in the area around the drilling through proper gravel crib rings and their chemical un-clogging, as well as through improving the working hours of the pumps owing to automation and central command and intensification of dewatering through emptying the drilling machines and injecting the air in the aquifer layer.

The dewatering procedure with large diameter drilling becomes economically inefficient in the case of dewatering underground deposits when aquifer horizons are not regionally spread, are thin or lenticular; this is due to the fact that the amount of water that should be drained from the deposit and drilling machines functioning time are decreased and do not entitle the carrying out of the drilling and operation of the pumping installations. In such a case, they recommend the used of absorption drilling that leads waters, through free flow, to a horizon that is inferior to the drained one, fig.3.

The drain method with absorbent drilling is used when the aquifer horizon that should be drained is placed in the higher part of the deposit, and the inferior part includes a dry permeable layer or water with free level or under pressure. In the last case, the piozometric level of the absorbent layer should be under the drained horizontal floor.

In order that the absorption drilling procedure functions in good conditions, no natural hydraulic link between the horizon that cedes water and the horizon that receives water should exist, while the permeability of the inferior horizon should be higher than the permeability of the higher horizon.

The ratio between permeability levels should range between 1.5-2 and 6-8. In aquifer deposits with a high percent of clay (3-7%), the filters of absorption drills are quickly damaged.

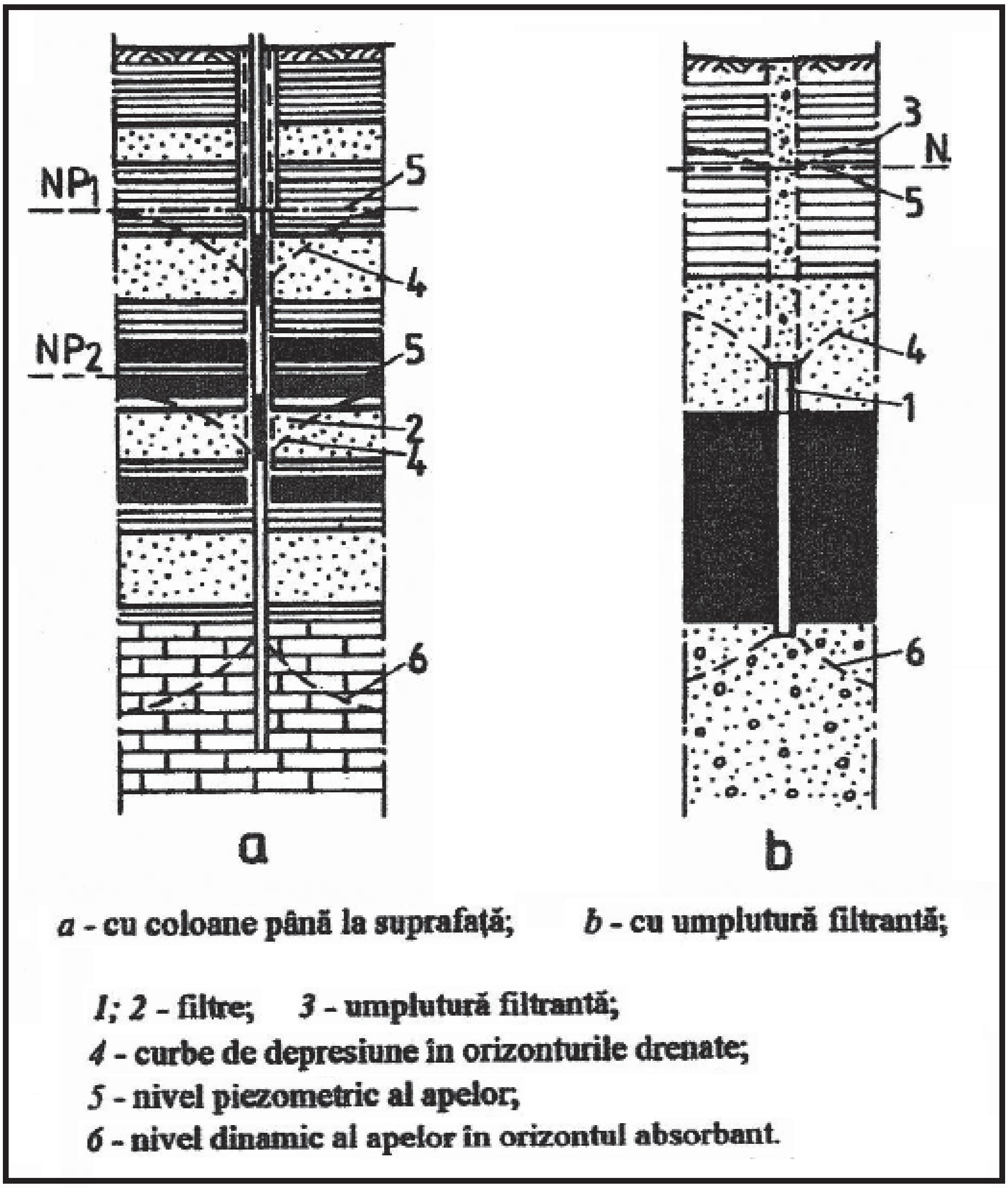


Fig. 3 *Absorbent drilling*

Absorbent drills are analogous to the drain drills. Their construction should be carefully carried out, taking into account their long term working period. Their functioning may be improved through increasing the filter's diameter up to 400-500 mm.

Meanwhile, they frequently used, with positive results, absorbent drilling combined with drain drilling with submersible pumps, in the case of brown coal in the country and abroad, fig. 4.

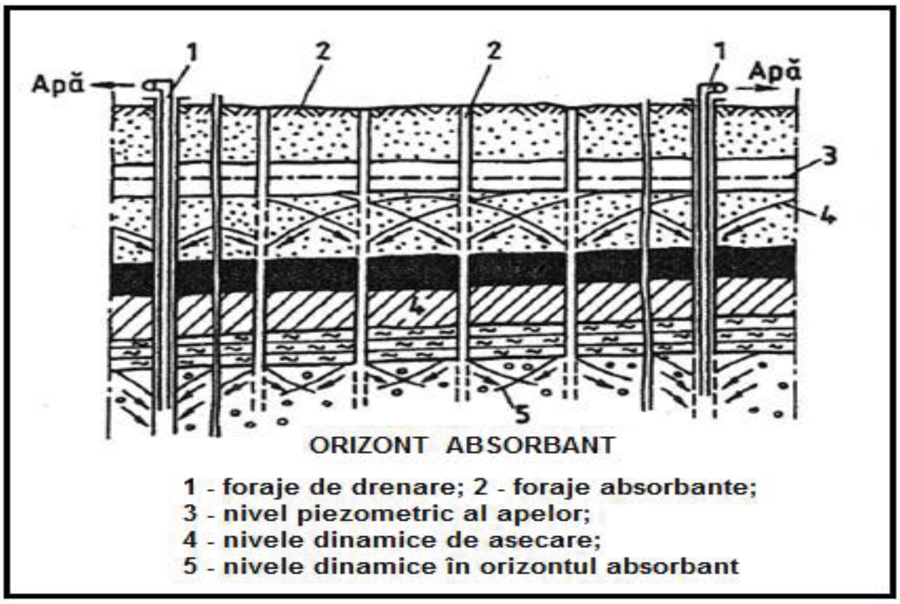


Fig. 4 *Dewatering with drain drilling and absorbent drilling*

The concomitant draining of the absorbent horizon with drills equipped with submersible pumps provide an increase of the functioning period of absorption drilling.

Dewatering through deep drilling should occur in several stages. As the mining works and the quarry advancement are carried out, certain drilling machines are gradually closed and new devices enter exploitation.

The dewatering of the mining field, in the case of deep quarries with more than four work stages, should not be done through draining drilling that open all the aquifer horizons due to the fact that drill cutting along stages and their subsequent opening for more than two times is not possible although it may be done accurately.

Such quarries require drain drilling along stages from the surface of the ground, in the case of the first aquifer deposits up to the most important one, but no more than 40 m deep and the subsequent use, after having opened the first two or three stages, of a series of new drain drilling dug from such stages for the next aquifer deposits.

In the case of a quarry whose floor length represents 100-120 m from the surface, they recommend dewatering drilling in the quarry's field with three depth stages, chosen depending on the quarry's geometry (number and height of the stages) and on the number and importance of the aquifer deposits in the cover, fig.5.

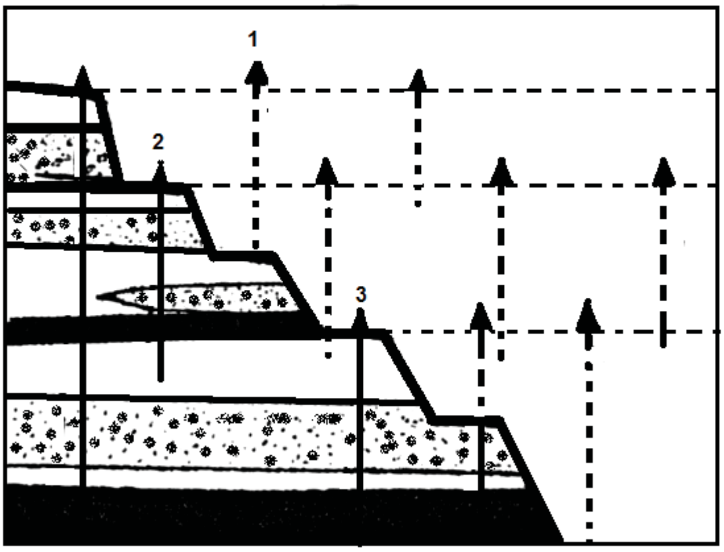


Fig. 5 *Stages of dewatering scheme*
(1st stage of dewatering; 2nd stage of dewatering; 3rd stage of draining)

Large lignite quarries frequently contain lentil-form aquifer horizons that develop only in certain areas of the quarry's field or even only in certain areas of the opening region, a fact that should be taken into account when locating the drain drilling.

Especially in the case of large lignite quarries, work stages in sand remain during a period of several months to almost a year in the same position that allows significant infiltrations through the large opened surface; this is the case of those deposits located in an area with abundant rainfalls, such as the sub-Carpathian region or intra-mountainous regions where heavy and long-term rainfalls occur during spring and autumn.

The main strong point of the deep vertical draining dewatering method consists in the possibility of previous decrease of the pressure and level of underground waters, before digging the mining works of opening, preparation, and exploitation.

Deep draining provides the short term creation of safe conditions and the guiding of the dewatering process in time.

Among the independent dewatering methods, deep draining is most adequate in the case of less complicated or medium complication and tectonics deposits.

The best effect is displayed by the draining drilling machines located and made functional in deposits exhibiting rocks with decreased stability.

The main drawback of deep draining consists in that it requires the simultaneous functioning of several pumps, whose supervision is especially difficult in conditions of poor weather. Accordingly, the automation of the functioning of such pumps is quite important. The providing of the perfect functioning of the cycle including the building, functioning, disassembling, and repair of the submersible pumps determines the effects of the dewatering methods.

Another drawback of the method consists in that it is impossible to carry out a complete dewatering in the case of performing a drilling dewatering of several aquifer horizons. Although they are more economic, absorption drilling machines, nonetheless, cannot be used in the peculiar conditions previously mentioned.

The cost price of dewatering through large diameter drilling holes includes the expenditures afferent to the drilling of the drilling hole (~30%), the expenditures for equipping them with filters, pipes, and submersible pumps (~30%), and the expenditures for exploiting the drilling holes (~40%).

Exploitation expenditures consist in: electricity costs, costs for the periodical cleaning of the drilling holes and filters and for changing the pumps, which wear out rapidly.

Low depth draining: - is used for draining ground-waters, for successively draining quarries' stages or for draining the dump.

It is done according to dewatering entrenchments (fig.6 A), small depth wells (fig.6 B), discharge drilling in the floor of the quarries (fig. 6 C), ejection installations (fig.6 D), drilling with horizontal filters (fig.6 E), and inversed embankment draining (fig.6 F).

Low depth draining is mainly employed in the benches of the quarries, to dewater horizontal aquifer deposits with low depth, alone or in combination with deep draining or underground dewatering.

Lately, horizontal draining for dewatering the definitive embankments of quarries and work embankment have been used. Horizontal drilling proved to fit the drainage of ground waters in embankments and especially those remaining after previous dewatering with large diameter drain drilling. Such drilling is mainly used in the case of definitive embankments drainage.

The lignite quarries in our country and abroad they are also used in draining the waters that remain in shafts, after the previous dewatering through deep drilling, in order to prevent the sliding of the embankments due to water infiltration at their basement.

Filter-less drilling may be employed for decreasing hydrostatic pressure in the floor of the quarries or underground mining works, especially in aquifer deposits in fissured rocks.

Horizontal drilling displays a large capacity of eliminating the influence of hydrostatic and hydrodynamic force upon the stability of the quarries' embankments, with reduced expenditures for equipment, investments, and exploitation.

In the case of a temporary decrease of water in quarries, light installations with acicular filters and ejectors gain importance. Nonetheless, such installations are rarely used as means of dewatering.

Dewatering entrenchments are largely used when draining the waters in the ground horizon. They represent means of dewatering employed only under such conditions and only in the case of quarries.

The dewatering of the quarries with fissured stony and partly stony surrounding rocks exhibit a series of characteristics mainly determined by the fact that underground waters does not disturb the stability of embankments.

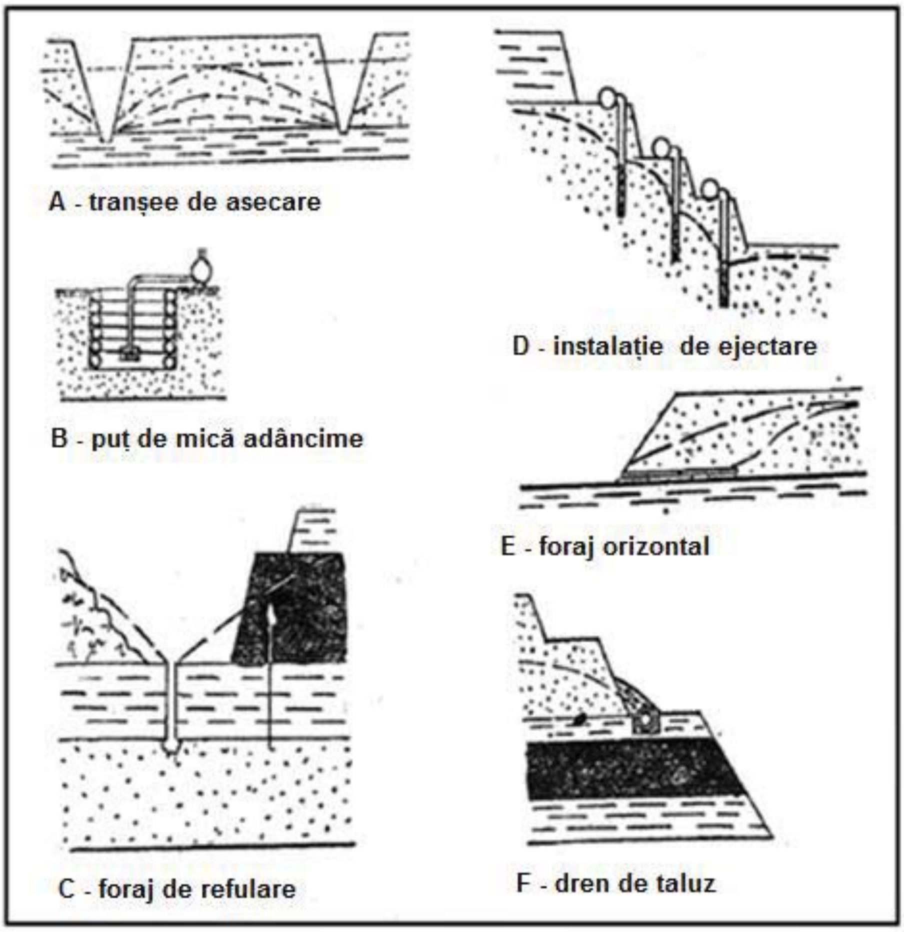


Fig. 6 *Low depth draining*

In the case of decreased affluxes quarries, dewatering is done through open drilling during exploitation. The draining system includes transversal draining canals, on each bench, which guide the water to the lowest work horizon, where it is collected by a longitudinal ditch and evacuated outside the quarry. When water evacuation outside the quarry may be provided through free flow at each level, longitudinal ditches are employed on each bench.

Surface dewatering exhibits the following advantages: reduced expenditures afferent to capital works; complete independence regarding the location of the mining works; increased mobility; possibility to be carried out before the opening of the mine or quarry.

The draw backs of surface dewatering mainly consist in: its negative influence on the opening and exploitation works, mainly in the case of quarries; the incomplete support of the dewatering system due to the dispersion of the installation of water evacuation and the maintenance of a large number of means of water pumping.

4. Underground dewatering

The methods and schemes of dewatering used for underground exploitation are different, depending on the opening or exploitation stage of the deposit, on the opening method (hillside galleries, inclined planes, wells) and the exploitation method applied.

Underground exploitation dewatering schemes should:

- Provide the safe crossing, in normal working conditions, of aquifer sands while executing the opening works that are going to be undergone with a view to opening the deposit
- Providing normal working conditions and avoiding eruptions, in the case of underground mining works of opening, preparation, and shaft;
- Elimination of the mining works danger of inundation.

In the case of important aquifer horizons, with regional spread, which comprise important resources and exhibit an important thickness, the dewatering scheme adopted should mainly provide the prevention of outside water afflux penetration into the defended precinct represented by the opening panel and exploitation panel.

Secondly, the dewatering scheme should provide the evacuation of the static reserves inside the opening or exploitation panel, in the aquifer horizons placed in the roof in the gliding and fissuring area in the case of sliding exploitation and the decrease of the pressure of the aquifer deposit’s (if it exists).

The most largely spread method is the method of penetrating filters placed in the roof or floor of the galleries, depending on the position of the aquifer horizon that should be drained. At the same time, in order to dewatering the aquifer horizons with high initial pressures (30-40 atm), located in the bottom of the coal layer, draining wells were used.

The increase of the mining pressure and the deformation of a series of underground works limit, in time, the possibility of maintaining them for a long period as well as the possibility of using penetrating filters for such works.

In the case of several aquifer layers placed in the roof, fall filters should sometimes be used together with penetrating filters. The effect of the system of underground dewatering with penetrating filters may be increased through:

- Improving the building of penetrating filters and increasing their diameter;

- Extending the methods of intensifying dewatering (air injection, vacuuming).

Underground dewatering methods are used, under certain circumstances, for dewatering quarries, too.

The advantages of the underground method as compared with the surface one consist in the evacuation of the water coming from dewatering through the same installations through which mine waters are evacuated; the relatively simple maintenance of pumping aggregates; the gravitational collecting of the waters in dewatering installations; the size of the draining installations is determined only by the natural afflux and not by the capacity of the pumps as in the case of surface dewatering.

The drawbacks of underground dewatering as compared with surface dewatering consist in: important expenditures for capital works; lack of mobility; the determination of dewatering speed in the mining field by the digging speed of the mining works; carrying out of the mining works in advance (required in order to place penetrating filters), under dangerous conditions determined by the eruption of underground waters.

5. Combined dewatering

Deposits dewatering also employs combined methods where dewatering works are done both at surface and underground.

In the case of the opening mining works at the basic horizon or of panel main dewatering scheme should contain combined works: previous dewatering drilling carried out in advance and penetrating filters or fall filters for the opening mining works, fig.7.

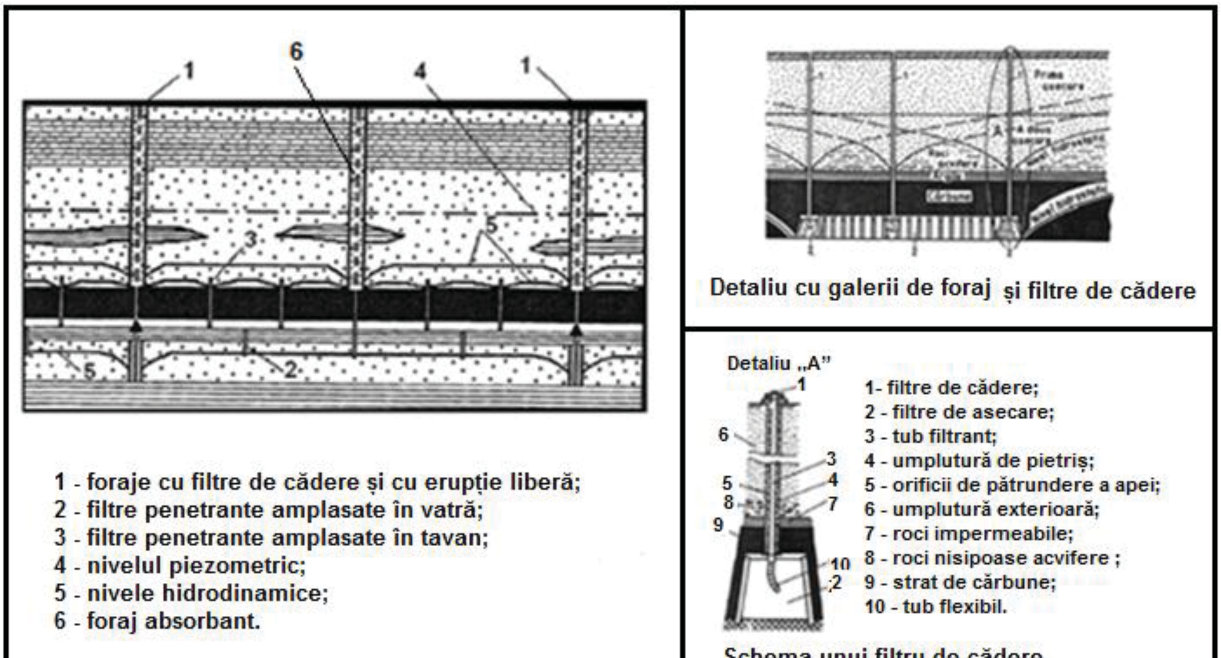


Fig. 7 *Combined dewatering scheme, with fall filters, free eruption drilling and penetrating filters*

The method where water is taken from aquifer deposits through drilling and evacuated in the underground represents the method of fall filters drilling machines.

It consists in doing drain drilling that open at the lower part of the mining works, while the water of the aquifer horizons opened through the drilling is drained through free (gravitational) fall in the mining works. Fall filters are used both for dewatering quarries and mines.

The combined dewatering method is used in the case of the deposits under complicated and very complicated hydro-geological conditions.

It is a dewatering method with a large field of applicability, with great flexibility and very operative when carrying out short term dewatering, and it is preferred to the underground method, with a more effective effect in dewatering aquifer horizons under precarious hydro-geological conditions. Combined dewatering method seems to be quite efficient in the case of low permeability and high pressure aquifer rocks.

As a rule, combined dewatering method comprises two stages. The first stage includes previous surface dewatering through deep draining.

The result is the decrease of the pressure of aquifer horizons and the isolation of the area of afflux of dynamic resources so that it provides the safe digging and support of draining galleries and other opening mining works enabling underground dewatering.

During the second stage owing to underground dewatering methods, the pressure of aquifer horizons is decreased and the evacuation of water static reserves also occurs.

During this second stage, drain drilling machines in the area of dewatering mining works open in the underground and turn into fall filters.

Combined dewatering methods are the most spread method of mine dewatering, nowadays.

Combined dewatering was used in the quarries of Rovinari mining basin, and initially employed dewatering entrenchments and vertical deep drilling, while subsequently, it employed large diameter drilling with submersible pumps, free eruption drilling, local dewatering entrenchments, and embankment filtering drain pipes, fig. 8.

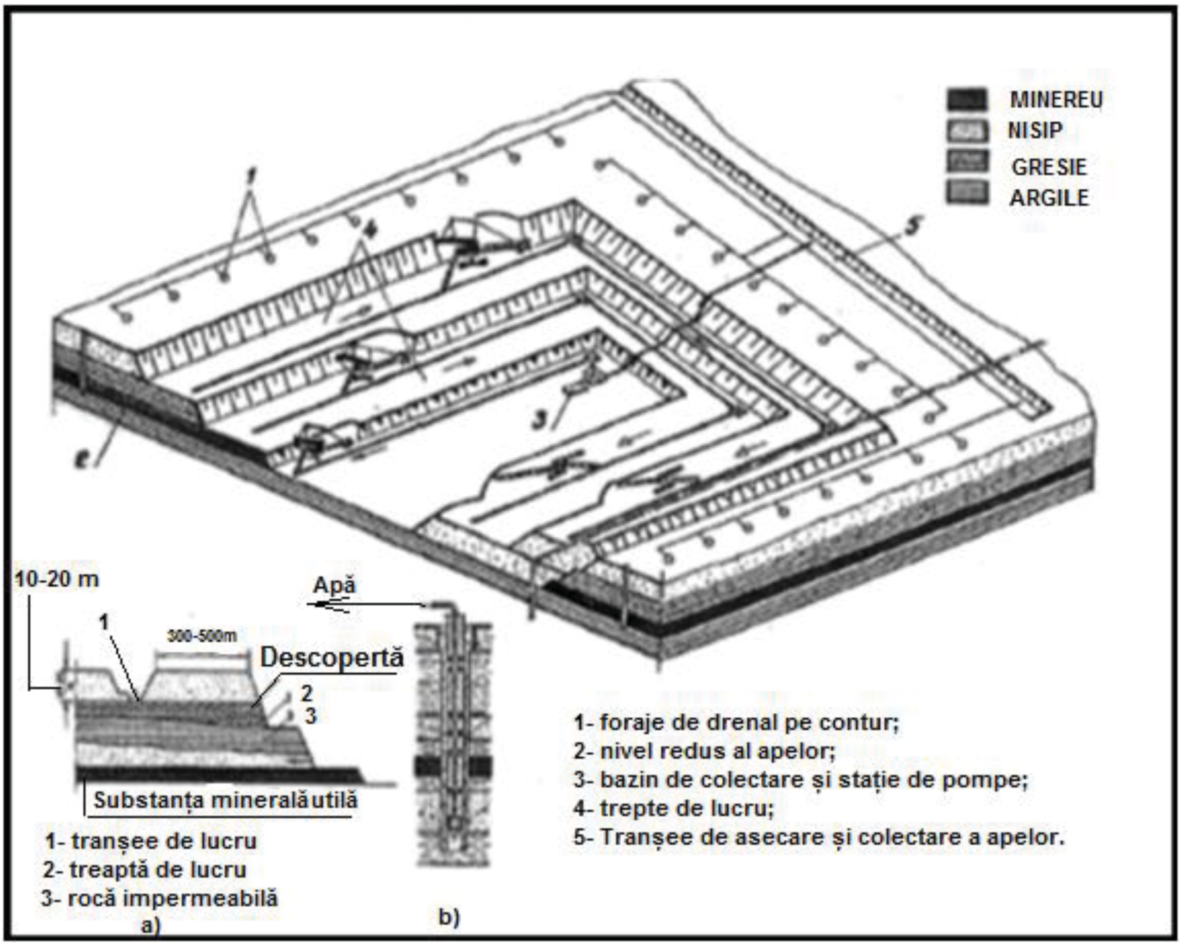


Fig.8 *Dewatering of quarries fields with dewatering entrenchments (a) and large diameter drilling with submersible pumps (b)*

Quarries dewatering under difficult hydro-geological conditions mainly encountered in the sedimentary structures of coal, iron, bauxite, manganese, etc., may be efficiently done through systems of shape drilling and combining several draining installations. The settling of the optimal dewatering scheme is done for each particular case according to technical and economic calculations.

The analysis of dewatering methods applied in our country and abroad allows the assertion that dewatering equipment required in order to open a quarry should be settled according to a rigorous analysis of the hydro-geological condition and minutely calculated in order to determine a proper safety of dewatering in due term.

The dewatering of the quarry's opening area depends on the geological and hydro-geological local conditions and, consequently differs a lot from one quarry to another. Nonetheless, one may consider that in the most appropriate circumstances, they should precede the opening mining works with, at least, 2 or 3 years.

Ranked first among the most adequate methods of dewatering, the method of drilling with submersible pumps represents a mobile means that can be used efficiently in dewatering quarries, alone or in combination with other means.

Secondly, the method of dewatering mining works and fall filters drilling machines, combined, if necessary with penetrating filters.

This method's effect of draining and safety of exploitation are so obvious as compared with the other methods that in all the cases when dewatering galleries digging is allowed it should be first employed.

As a conclusion, let's mention that there is no generally valid scheme for quarries dewatering owing to the fact that it depends on the local conditions. Nonetheless, let's also stress that a valid dewatering project should contain not only the main dewatering scheme and the corresponding technological procedure, but also a combination of all available methods, even the local ones (horizontal filters, vacuum installations, sealing panels, embankment inversed drains, etc.) in order to provide detailed dewatering, also including the dewatering of small areas (usually considered of small importance) in the general scheme adopted.

Another principle to be observed in dewatering large lignite quarries located in sandy rocks regards the infiltrations due to rainfalls: they not determine a permanent afflux of water in the ground aquifer horizon, but also form an afflux in deep aquifer horizons displaying important surfaces after their uncovering on quarries benches.

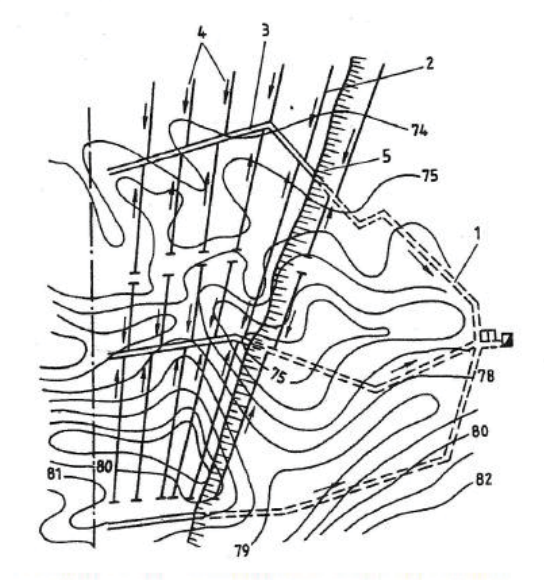
A proper administration of waters in a quarry is better than a perfect dewatering. In the end, let's mention that in order to open a quarry, they usually pay more attention to the strong points of the mining area (the most favourable amount of useful deposit and sterile, the movement of rock masses, etc.) and less to the hydro-geological conditions. Especially in the case of lignite quarries, they should observe the principle according to which dewatering carried out at the right moment is the main condition for doing economic opening works in due time.

6. Dump dewatering

External or internal sterile dumps resulting in the coal quarries comprise poorly consolidated rocks (clays and shale) or loosen rocks (sands, gravel) and loosen through the cutting, breaking, transport and storage processes; they represent permeable collectors that allow the inner formation of aquifer horizons resulting from rainfalls or infiltrations in the aquifer horizons of embankments (in the case of inner dumps), which form again after ceasing drainage in former quarries.

This possibility of forming aquifer horizons in dumps is avoided through the drainage works within the dumps.

The most adequate methods for dewatering dumps are the following ones: formation of a filtering bed in the dump's floor and, whenever the technology of the dump depositing allows, carrying out horizontal draining comprising entrenchments dug in the network, filled with gravel or ditches with perforated asbestos-cement pipes or macro-porous concrete pipes, fig.9.



1 - galerie de drenaj pentru asecarea rocilor din vatra carierei; 2 - drenuri de asecare; 3 - drumuri colaterale; 4 - direcția evacuării apei; 5 - frontul haldei

Fig. 9 *Draining inner dumps*

Another method employs embankment inversed filters at the basement of definitive dumps. Such draining prevents water coming out at the foot of the embankment that forms in the dump under a hydraulic gradient higher than the critical one, preventing suffusion and sliding of the dump.

In the case when water level increases and the danger of embankment infiltrations occurs, then dewatering is combined with drain drilling or sandy panels mounted on the embankment.

The effect of systematic horizontal draining considerably decreases in the case when the flooding source of the dump is the artesian aquifer horizon in the quarry's floor. In such a case, the vertical draining with free eruption drilling machine holes at the level of the quarry's floor or large diameter drilling with submersible pumps drilled in front of the stope may be used, fig. 10.

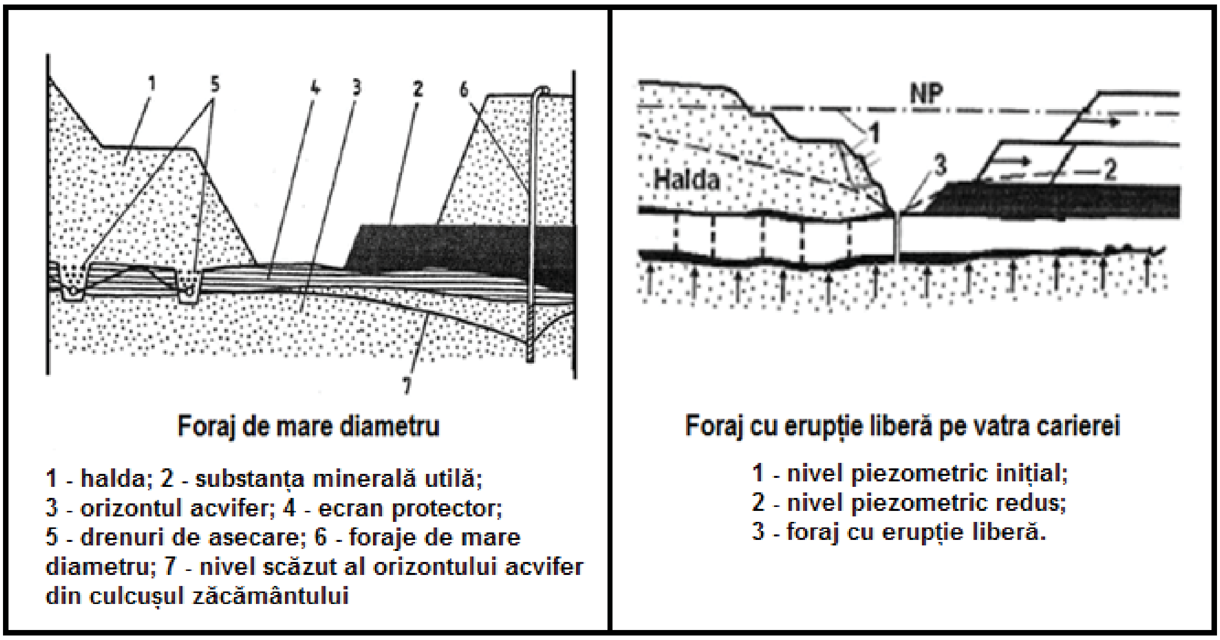


Fig. 10 *Draining through drilling of aquifer horizons in the quarry's floor*

7. Dewatering works made in the exploitation areas of Oltenia

The detailed analysis of the lignite basins in our country shows that all of them display difficult hydro-geological conditions.

In case we refer to the deposits exploited at surface, they appear to face both the issue of water coming from aquifer deposits and layers and of surface waters. This is the reason why dewatering works detain a leading part in the general activity of surface exploitations. In most cases, the improper solving of such issues determines difficulties in the normal exploiting of the deposits.

The depth of the quarries and the exploitation of the deposits under hydro-geological conditions harder than those generally encountered turn dewatering into a topical issue and require its improvement.

In this field too, the experience gathered in the quarries of Oltenia is quite useful, owing to the fact that the day quarries in the area encountered hydro-geological problems requiring different solutions in order to settle them, under real circumstances.

The need of carrying out dewatering works in due time and proper conditions, in all the areas and aquifer horizons, came out while exploiting coal reserves so that to provide the complete and optimal exploiting of the deposit.

In the case of Balta Unchiaşului experimental quarry, they used a separate dewatering of the ground aquifer horizon with dewatering entrenchments placed along three sides of the quarry. Dewatering entrenchments were mainly used for draining the waters from embankments. At increased depths, entrenchments were done according to benches. They had to be embedded in clays or shale, in order to avoid water infiltration in the stopes made by excavators.

The dewatering of intermediary aquifer horizon within the deposit was done through drainage galleries with penetrating filters.

The artesian horizon was tension-relieved through draining without filters and free eruption of waters, which were placed on the floor of the opening entrenchment.

Dewatering works were done simultaneously with the excavation works. Drilling was done in the quarry, while their functioning duration was determined by the stopes' advancement. Later, at the Northern limit of the quarry, the artesian horizon displaying an increased pressure and the protective panel exhibiting a decreased thickness were tension-relieved in advance through a gallery and drain drilling without filters.

Drilling was done at surface and intersected the gallery through a niche. Accordingly, ground waters and those from the coal complex were drained gravitationally with fall filters, while artesian waters erupted freely, fig.11. A pumping unit took over and evacuated the water.

Dewatering entrenchments were blocked quite quickly and lost their draining effect so that they continued dewatering through drilling with submersible pumps. Owing to them, draining could be done through filters placed towards the drilling's floor. The resulted water together with the water from the artesian water was discharged along main pipes outside the exploitation area.

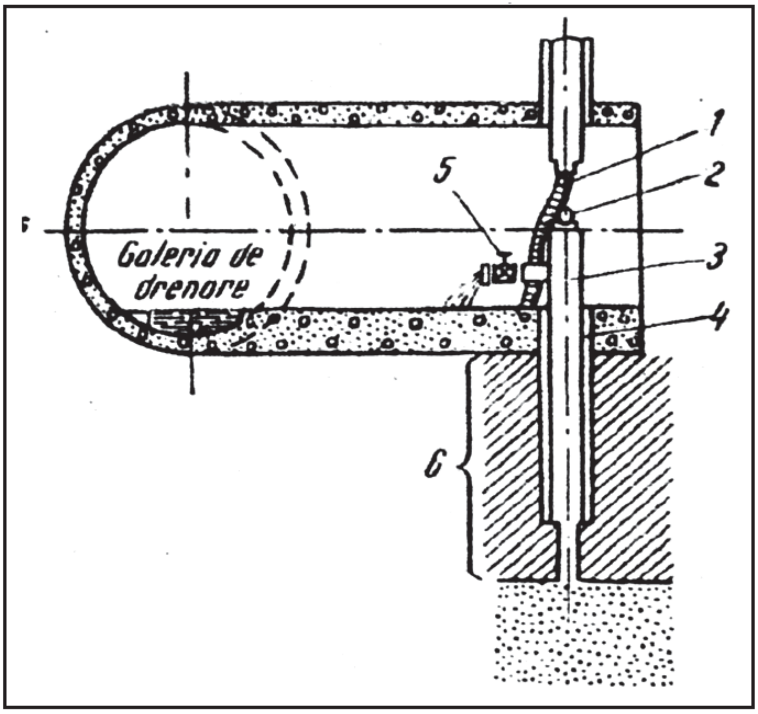


Fig.11 *Drain drilling without filters: 1- rubber hose 2"; 2- manometer; 3- irruption head; 4- pipe Ø 8 5/8"; 5- valve 8"; 6- impermeable formation*

Practice showed that dewatering works should be done1 to 3 years before the opening works so that excavations could be carried out in terms of an acceptable productivity.

Performing dewatering simultaneously with excavations determines a brutal dewatering of the formations and gives way to production malfunctioning as a result of the accidental activity interruption and the staff's sticking to the excavators ladles.

In the case of Cicani Quarry, they used the same dewatering scheme: two dewatering entrenchments and underground mining works for the artesian horizon. Here, mining works also included penetrating filters located in the roof.

At Cicani, they also performed three large diameters drilling with submersible pumps.

This solution was also adopted in order to dewater the other mining field. The dewatering of the aquifer horizon of the coal complex and the tension-relieving of the artesian horizon was done through large diameter drilling with submersible pumps and drilling without filters with free eruption, in the case of the other quarries in the area.

At Pesteana Quarry they performed, for the ground horizon, which is thicker than 15 m, dewatering entrenchments in benches, in order to provide the passing of the waters through impermeable rocks, fig.12.

Accordingly, the dewatering system with large diameter drilling with submersible pumps that drains the waters from the whole column of aquifer layers is generally used.

There are solutions allowing the avoiding, cutting, and protection of the dewatering drilling conceived with a view to avoiding their destruction due to the stopes advancement.

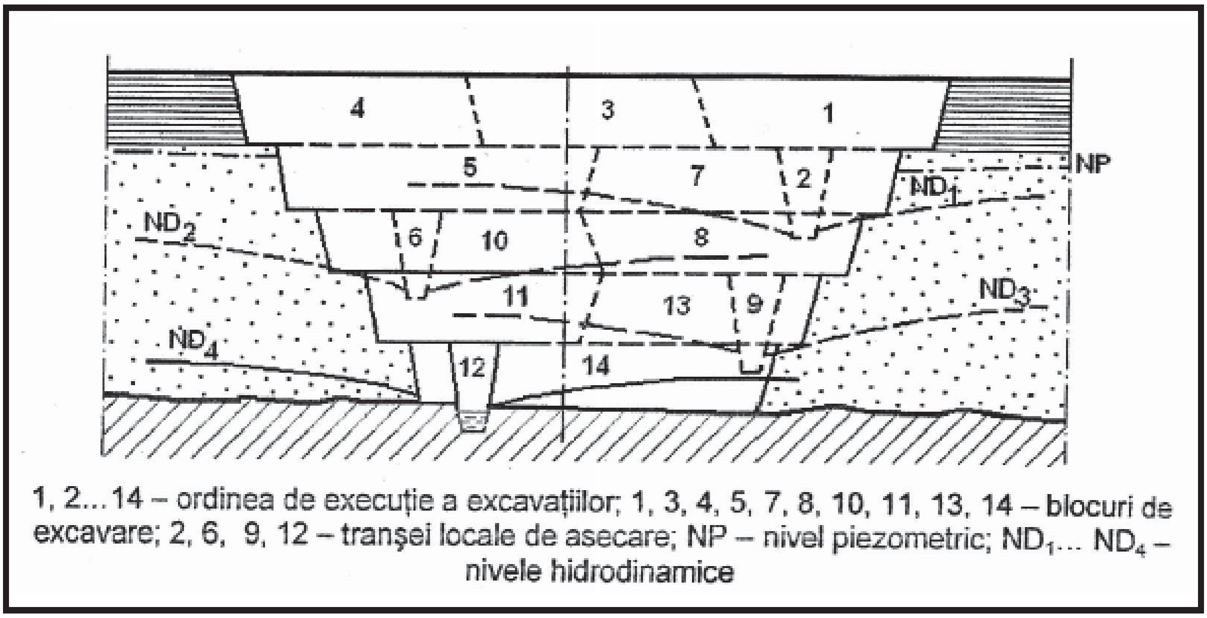


Fig. 12 *Dewatering scheme of the area of the opening entrenchments with local dewatering entrenchments*

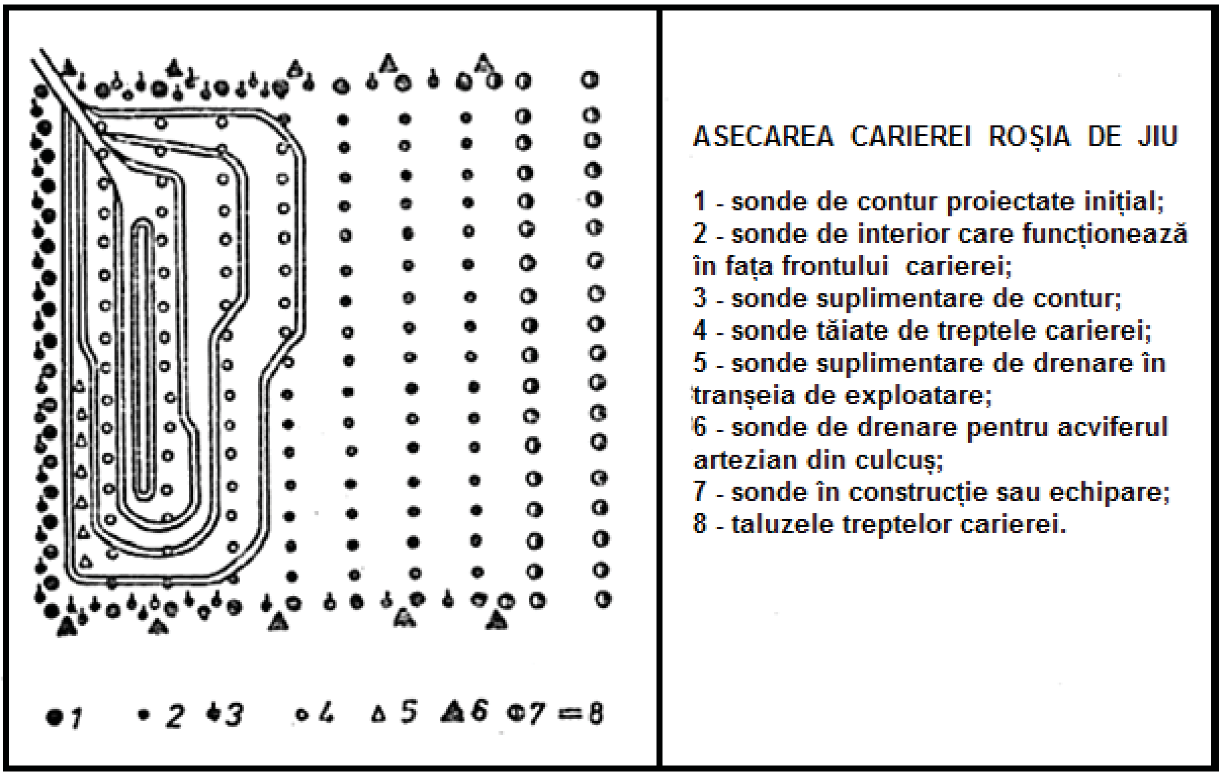


Fig.13 *Dewatering of Roșia de Jiu quarry*

Dewatering works and tension-relieving of the artesian aquifer horizon that currently occurred in the areas of Gîrla, Cicani, Beterega, Tismana and Poiana quarries displayed satisfactory results. They also showed that the decrease of the water content of the excavated rocks as well as the decrease of the pressure in the artesian horizon exerts a determining influence upon production.

Yet, we should also display the issues determined by the dewatering works within Roșia de Jiu perimeter, the largest quarry in the area exhibiting the most difficult conditions.

The general dewatering solution accepted involved large diameter drilling located both on the outlining and within the quarry's perimeter, fig.13.

At Roșia de Jiu quarry they had to dewater the aquifer horizon with free level determined by

Jiu River silt of four aquifer horizons with irregular spread located between the coal layers and of two aquifer horizons under pressure with regional spread located in the roof and floor of the 5^{th} coal layer in the quarry's floor.

In this area, ground horizon is 13 m thick, while the other aquifer horizons are 42 and 77 m thick. In the case of this quarry, dewatering determined important difficulties. Difficulties were encountered in a series of areas belonging to the quarry and displaying a decreased filtering coefficient, due to the higher content of clay within the aquifer formations, namely in the South-Western part an area that was brutally dewatered while excavating.

This situation determined difficulties in using the equipment. When elaborating dewatering solutions they also took into account the fact that the artesian horizon was very close to the 5th layer, being separated by a thin protection panel.

Without special measures, the layer cannot be exploited as the decreased thickness of the separating layer (8-17 m) cannot face high pressures and may fissure. They adopted the solution of decreasing the pressure level of artesian waters.

Meanwhile, the maintaining of about 50 m difference between the dump's bench and the stope at the floor of the quarry ensures the avoidance of the breaking of the protective panel.

The different permeability of the rocks on the same drilling line determined the establishing of the measure valid for all the quarries where such conditions are encountered, namely: installing submersible pumps with variable flow, located in drilling depending on the rocks permeability.

In the case of sand and water lentils in the cover or the coal complex, they use horizontal drilling along work benches or within galleries. Their advantage is that they can be carried out along 100-150 m; they may not be coal intubated.

8. Conclusions

According to the experience in our country and considering the results obtained in other countries, there are several fields where the various methods of draining are used.

Galleries underground draining, penetrating filters draining and fall filtering draining are going to be widely employed under the following circumstances:

- When several aquifer horizons, separated by impermeable rocks, are found within the deposit's cover;
- In the presence of certain granular aquifer rocks, with a decreased filtering coefficient (dusty sands, dusts);
- When the decrease of the pressure of the aquifer deposit in the layers' floor is required;
- When they are necessary in order to evacuate the waters in the floor of the quarry or when the quarries are located in hill areas.

Surface dewatering with drilling with submersible pumps is to be developed in quarries located in meadow regions, under the following circumstances:

- When the quarry's contains thick packages of aquifer sands;
- When there are strong aquifer layers within the floor;
- When the quarry is close to the water source (rivers, lakes, etc.) and sandy rocks in the cover are present.

Protective panels represent a method that is going to be widely used as a result of their decreased prices owing to improving the execution procedures and installations; nonetheless, their use is also connected with depth increase, which determines the important growth of the areas where water reserves are going to be exhausted.

Protective panels are going to spread under the following circumstances:

- Existence of a powerful aquifer horizon, at a depth where sealing panels are able to be set (40-60 m, in the future, at 100 m);
- Presence of a water course or accumulation whose infiltration should be stopped;
- When the cover contains aquifer deposits with high transmission characteristics or when dynamic reserves overpass the static ones in the quarry's cover.

Horizontal drilling is used in the following cases:

- When dewatering thin layers in the case of which vertical dewatering means are less efficient;
- After opening important aquifer deposits provided by superficial waters, which tend to damage the stability of the embankments;
- When they intend the decease of the piezometric level in the massif through creating a small slope of water evacuation at the basement of the embankment;
- In order to increase dewatering when they use as a main method of dewatering surface draining or underground drainage with submersible pumps drilling, under improper hydro-geological conditions.

The proper dewatering of day exploitation areas requires the constructive and functional improvement of the filters and drilling. Meanwhile, large diameter drilling ($Ø = 1050 - 1250\,mm$) attempts both at avoiding the penetration of fine sands in the drilling and the decrease of the frequency of damaging submersible pumps.

The construction of new types of filters is under development, including a wide range of metallic and non-metallic filters to be experimented. Plastic filters represent a present-day and future solution.

The improvement of the technology and equipment required with a view to getting a selective sand removal and to clean drilling fluids is also important. The dewatering of the various geological formations should be analyzed and carried out through complex draining methods.

The automation of pumps functioning as well as their functioning control increases the general efficiency of dewatering.

Specialists concluded that through a proper dewatering they are able to decrease the characteristic of the sterile stuff to stick to the cutting machines, hopers and belts, accordingly increasing the available functioning period and productivity with about 25%.

During the next years, lignite quarries in our country are going to reach the opening-up ratios of 15:1 m^3/t and depths of 150-200 m that require the guiding of the research in the field of dewatering towards different directions.

First, as far as detailed hydro-geological prospection and exploration are concerned, there is a need for large scale improved geophysical methods.

Programming deposits dewatering according to informatics techniques used for hydro-geological calculations allows the drawing out of several-variant projects as well as the opportunity to change them whenever the real functioning conditions of the systems are modified; it also allows the quantitative evaluation of the various combined dewatering methods.

The spread of the dewatering method with drain drilling is considered as necessary and so is its use as a means of emergency use.

As far as the execution and exploitation of drain systems is concerned, they have in view the following:

- The widening of the range of drilling installations in order to carry out the parameters required by deep lignite quarries;
- The spread of coring outfits for horizontal and guided drilling as well as of other dewatering means to settle local issued afferent to parts of the embankment;
- The development and improvement of the construction of sealing panels, which proved to be the most efficient in the case of lignite quarries;
- The diversification and improvement of submersible pumps in order to match the new conditions (increased depths, difficult condition displayed by the deposits);
- Mechanization and automation of drainage works;
- Spread of control and automated exploitation methods of drainage systems.

In order to successfully settle dewatering under the circumstances previously exhibited, it is necessary to guide attention towards a series of major issues, during the next years.

First, it is important to settle the technical and economic criteria of choosing the different dewatering methods as well as the improvement of the technologies for draining the waters left by dewatering and the elaboration of new technologies capable of providing sealing panels at up to 100 m depths, etc. Meanwhile, it is necessary to elaborate a series of geotechnical criteria settling the degree of dewatering, to improve the methods for the optimization of drainage networks, to computerize the calculation methods employed, to replace deficient stuff and automatize the functioning of the installation, etc. These are a few elements that will determine the improvement of the efficiency of dewatering.

Further developments include the increase of the depth of quarries under more difficult hydro-geological conditions, which would determine the development of lignite quarries dewatering along a series of main directions, as follows:

- Continual improvement of the technologies and stuff used in dewatering;
- Providing of automation in order to exploit and control the process of underground waters dewatering;
- Protecting underground waters against pollution;
- Employing the waters extracted through dewatering within national economy.

The carrying out, in proper conditions, of aquifer formations dewatering represents a permanent and topical issue specific to the day exploitation of lignite in Romania.

No a priori prescriptions of valid solutions can be formulated for all the conditions existing in the various basins of the country.

Hydro-geological conditions are extremely varied and include specific elements, so that they require the establishing of an optimal solution to be adopted for each particular case, according to the experience in the country and abroad and according to the measured and calculated parameters.

References

1. Almăşanu B.
Exploatarea zăcămintelor minerale din România vol.I and vol.II. Technical Publishing House, Bucharest, 1984

2. Enache, C.
Asecarea Zăcămintelor - Scrisul Românesc Publishing House - Craiova, 1985

3. Enache, C.
Îndreptar pentru lucrări de asecare – “Oltenia” publishing House - Craiova, 1988

4. Fodor, D., Rotunjeanu, I.
Manualul Inginerului de Mine - Secţiunea “Hidrogeologie minieră” – Technical Publishing House, Bucharest, 1984.

5. Gheorghe, Al., Bomboe, P.
Hidrogeologie minieră - Technical Publishing House, Bucharest, 1963

6. Preda, I. Maroşi, P.
Hidrogeologie - Didactic and Pedagogic Publishing House, Bucharest - 1971

7. Baican G.
Contribuţii la dezvoltarea tehnologiilor de exploatare a stratelor de lignit situate în condiţii hidrogeologice grele – Doctoral thesis – University of Petrosani - 1998.

8. Rădulescu L.C., Matyaş, M., Guran I.
Efectele şi implicaţiile activităţii de asecare din Cariera Roşia de Jiu asupra mediului înconjurător – Mining Revue no.1/2009.

9. Rotunjanu I., Lazăr M.
Hidrologie şi Hidrogeologie Minieră – Universitas Publishing House - Petroşani 2014.

10. Matyaş, M., Rădulescu, L.
Evoluţia activităţii de asecare la cariera Roşia de Jiu - Mining Revue no.8/2006.

11. Fodor, D.
Exploatare în cariere a zăcămintelor de substanţe minerale şi roci utile - Exemple de calcul - AGIR and Corvin publishing Houses – Bucharest, 2010.

12. Fodor, D., Matyaş, M.
Asecarea și gospodărirea apelor din mine și cariere – AGIR Publishing House – Bucharest and Corvin Publishing House – Deva – 2014.