PREVENTATIVE MEASURES AGAINST FLOODING IN TWO UNDERGROUND MINES

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ABSTRACT

"La Oportuna" and "Innominada" are two underground black lignite mines situated in the Andorra coalfield (Teruel) that are operating in an Albense deposit.

The overlying material is basically formed by soft clays and sands that collapse quickly into the mined cavity, creating problems caused by water and mud floods.

In "La Oportuna" mine the geometry of the exploitation and the hydrostatic pressure are the main factors that control the intensity of flood risks.

In the "Innominada" mine the intensity of the floods is related to the hydrostatic pressure and other geological factors suet as the presence of fractures that weaken the rock and paleochannels that are main water circulation ways.

The origin of the water, the causes of the flooding and the preventative measures that have been adopted will be explained in this report.

STRATIGRAPHY

"La Oportuna" mine - East area

The lignite layer is 10 to 20 m. thick and is exploited at the present moment at a depth of 330 m. A layer of clay is situated above it at the northern edge of the present exploitations at 7th and 8th levels with a thickness of between 50 and 75 meters, and at the southern edge with a thickness of from 25 to 60 meters.

Over this layer of clay there is a plot of altenating clays and sands of about 150 m. thick, which concludes the Albense sedimentation. The layers of sand form better defined and thicker packs at the north side, while towards the south they appear much more digitated with several clay intercalations that make its correlation difficult. The total sand thickness is 30-50 m.

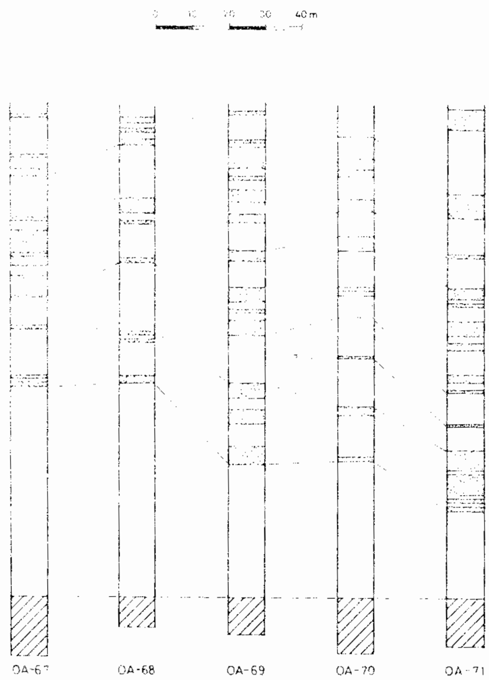


Fig. 1 : Geologic disposition of lignite and sand beds in "La Oportuna" mine-East Sector.

Over the Albense sedimentation there is a layer of limestone seam from the Paleocene and a thick layer of clay with sandstone and conglomerate intercalations from the Eocene-Oligocene.

La Oportuna mine - West area

The exploited lignite seam is 10 m. thick and over it there is a sand pack up to 37 m. thick which passes laterally to sandy clays until disappearing towards the East.

Over this clay pack there are some lignite seams 30 to 70 m. thick intercalated and all other stratigraphy is the same as at the East area.

"Innominada" mine

The exploited lignite layer is 6 to 10 m. thick and is being exploited at a depth of 350 m. at the present time. Over it there is a 10

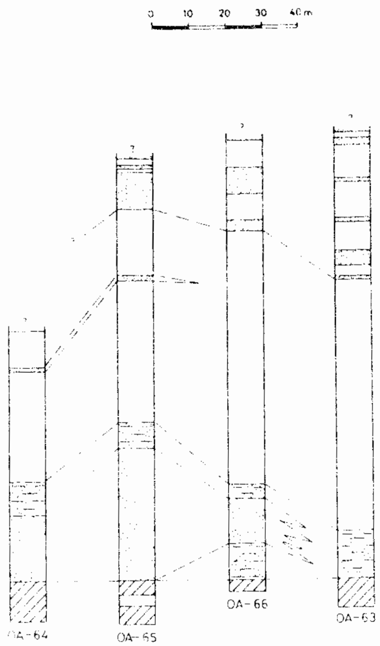


Fig. 2 : Geologic disposition of lignite and sand beds in "La Oportuna" mine-West Sector.

to 20 m. thick sand pack. Over this there is a 20 m. clay plot with some lignite levels. Over it there is a 150 m. clay plot with small levels of sand intercalated.

The Albense sedimentation finishes with a 30 m. thick sand pack, and over it there is a 2-4 m. limestone bed from the Paleocene and a thick pack of clays with sandstone and conglomerate seams from the Eozene-Oligozene.

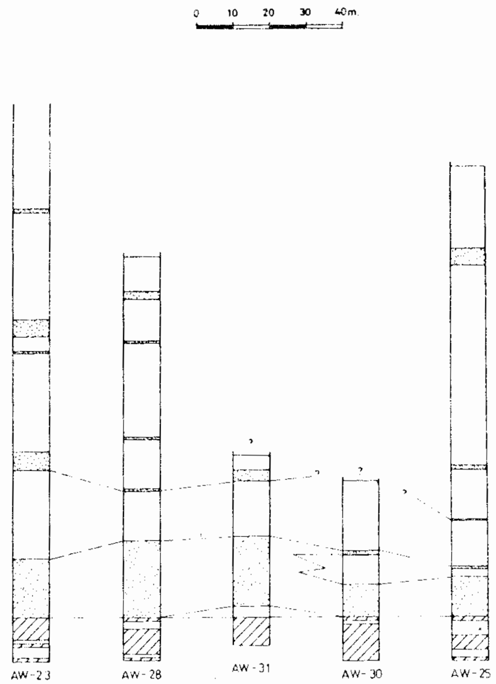


Fig. 3 : Geologic disposition of lignite and sand beds in "Innominada" mine.

STRUCTURES

Both mines are situated in the nothern flank of a synclinal with a NW-SE direction. The dip angle is 25º-30º at the Oportuna area and 10º-15º at the Innominada area.

The structure is affected by fractures that run E-W or NE-SW and occasionally N-S or NW-SE partitioning the deposit into different areas and forming the present material disposition.

HYDROGEOLOGICAL CHARACTERISTICS

The several sand seams are low permeability confined aquifers, while the clays have an acuiclude character.

"La Oportuna" mine - East area

The sand level has an average permeability of 22 x 10^{-4} cm/s (0.19 m/day). Piezometry varies from 650 and 620 levels, so there is a water table in the explotation areas varying from 110 m. at the top edge and 230 at the lower edge. The water-flow direction is Sw with a hydraulic gradient of 0.05. The porosity has an average of 20%.

"La Oportuna" mine - West area

We are only going to consider the sand seam lying directly over the lignite layer, because is the only one that affects the mine works.

No field tests have been conducted in order to determine the permeability, but some laboratory tests have been carried out, and an average value of 1.7 x 10^{-4} cm/s (0.15 m/day) has been obtained.

The water-flow direction is towards the mining operations with a hydraulic gradient of 0.08. That means that there is a water table when work is begun at a new level which varies from 0 m. at the head (top) gate and 80 m. at the tail (lower) gate.

"Innominada" mine

The sand pack lying over the exploited lignite layer has a permeability of 1.5 x 10^{-4} cm/s (0,13 m/day), the effective porosity is 20% and the water flow direction is towards the mine works, with a 0.5 hydraulic gradient, meaning that there is a maximun water table when works are started at a new level of 70 m. (at the tail (lower) gate level).

WATER-FLOOD MECHANISM INTO THE MINING WORKS - FLOOD CAUSES

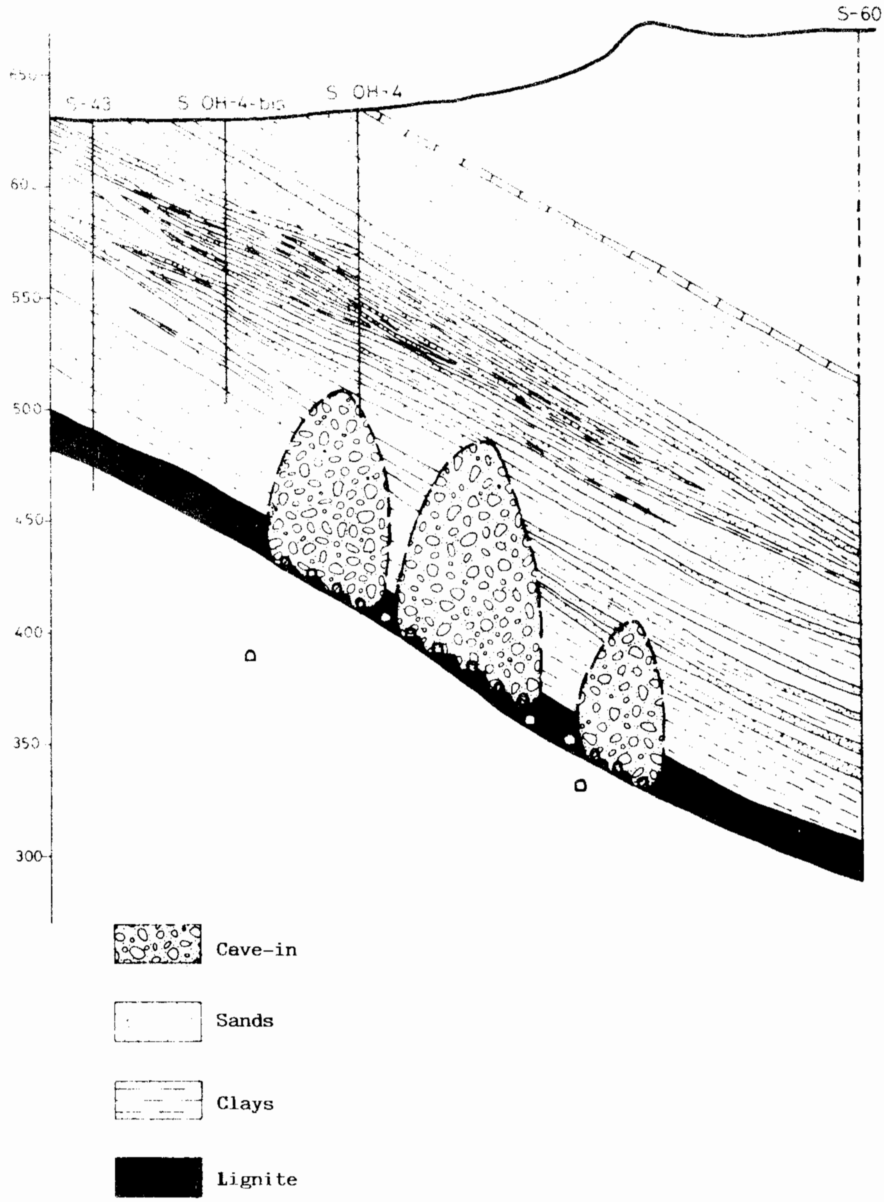
"La Oportuna" mine - East area

Since 1981, the mining method used is a coal gate "soutirage" previously opened by a continuous miner. The method consists in opening a horizontal gate at the bottom of the layer and, once it is open, to exploit it backwards making the coal from the top fall using explosives. To get to these gates in the coal from the general horizontal gates in limestone there are inclined shafts 10 m. below the seam and from these shafts horizontal accesses are driven to meet the coal. Once it is reached, two horizontal gates in both direction of that of the seam are opened. The gates length is 50 m. and the distance between them, measured on the dipping direction is 14 m. Six to eight gates are opened at different levels, resulting in an exploitation width of from 84 to 112 m.

At the first panels all the gates were exploited successively, starting with the one at the highest level one and it was noticed that when the third or forth gates were exploited, water and mud floods came into the gate and forced the abandonment of the exploitation and even the loss of some continuous miner.

In order to decrease the rock mass alteration due to the continuous miner action, it was decided to, at one panel, exploit the seam by two different runs one after the other; the first one being done at the top of the seam so that the cavity created was smaller and so that its effect wouldn't reach the sand seam. Nevertheless a sudden water and mud flood came into the fourth gate on the first run.

Fig. 4 : Scheme geologic and exploitation of "La Oportuna" mine



With these data a conclusion was made: the exploitation width is the parameter that controls the water floods, and when it reaches 40-50 m. the flood is produced.

Based on the subsidence at the surface created by the underground exploitations, it was observed that fractures developed with a 30º lower limit angle and a 10º higher limit angle. So that if we extend the fractures that would be formed during the exploitation of the panel gates, a cone is formed corresponding to the rock mass volume situated on top of the lignite seam that comes into the cavity created because of the exploitation in order to refill it. As it may be seen on Chart Nr. 4, where the possible domes are drawn, when coal is taken out from the fourth gate, the cone reaches the sand seams which are overlying the clay protection mass. As these seams are full of water, because they are confined aquifers with low permeability, they break loose and the stored water floods into the mining exploitations.

No studies have been carried out in order to find out the real shape of the collapsed area, but based on the existing data, it is known that it reaches a height, over the lignite seam, 1.3-1.4 times the exploitation width.

It looks like the "thickness of the exploited seam" factor plays a secondary role on preventing water floods, because when the two run method was introduced, they were produced independtly of the cavity height, being the whole of coal seam (20 m.) or just half of it (10 m.). But, it especially affects the propagation speed of the sunken area up to the - - aquifer levels. That was proven at a panel where the exploitation thickness was just 4-5 m. and a flood was not produced until the eigth gate was exploited (112 m. exploitation width).

As it has already been said, the water comes from the sand seams that are situated 50 m. over the coal seam. They are confined aquifers with a water table varying from 110 to 230 m. over the exploitations at the present moment.

It has been proven that the flood intensity is directly related to the hydrostatic pressure, so at greater exploitation depths the water table gets bigger and the floods get rougher. It has been observed that when the water table is less than 100-120 m. usually there is no free water in the flood, it just disolves the clays and pushes them into the cavity advancing to the exploitation front as a semisolid mud bank that advances 1-2 m. per hour. When the hydrostatic pressure is over these values, the flood is produced suddenly with a lot of free water and keeping a 80-100 cu m/hour water flow during several days.

It has also been confirmed that the intermediate clay pack between the sands and the coal, due to its plastic character closes itself at the end creating a protective mass that prevents that the water floods from lasting longer than 100 hours.

"Innominada" mine

In 1980 a new mining method was introduced at this mine. It is the longwalling exploitation by soutirage along the coal dip. It consists in advancing by use of backwards gates and forming a 100 m. long longwall at the bottom of the seam. Coal from the top of the seam is made to fall by explosives and taken out afterwards.

It has been proven, by installing piezometers, that the only aquifer affecting the exploitation is the one constitued by the 10-20 m. thick sand seam which is situated just over the top of the lignite seam or separated from it by 10 m. of argilite.

These sands are continuously bringing in water to the explotaition, so many problems are produced mainly on the coal transportation circuit, coal bins and coal storage. To avoid this waterflood from virgin areas to the coal front, dewatering gates are driven. These basically consist of parallel gates to the tail longwall gate driven at the bottom of the seam from these some boreholes which are drilled to reach the sands.

Despite the "dewatering gates", at the mine's central area two big water floods have been produced in 1981 and 1983 with 30-40 cu m/h average water-flows and important sand flows that refilled the longwall fronts and forced the abandoning of the exploitation.

The flood lasted for 100-120 days and the water flow was not continuous but intermittent, with "water hits", carrying water flows of 180-240 cu m/h that lasted 3-4 hours and produced a big sand and mud transport coming from the fallen material. The origin of these "water-hits" is related to obstructions produced by fallen material along the way that water has to go through until it arrives to the exploitation front. That causes accumulations of sand and water which break suddenly as the hydrostatic pressure increases.

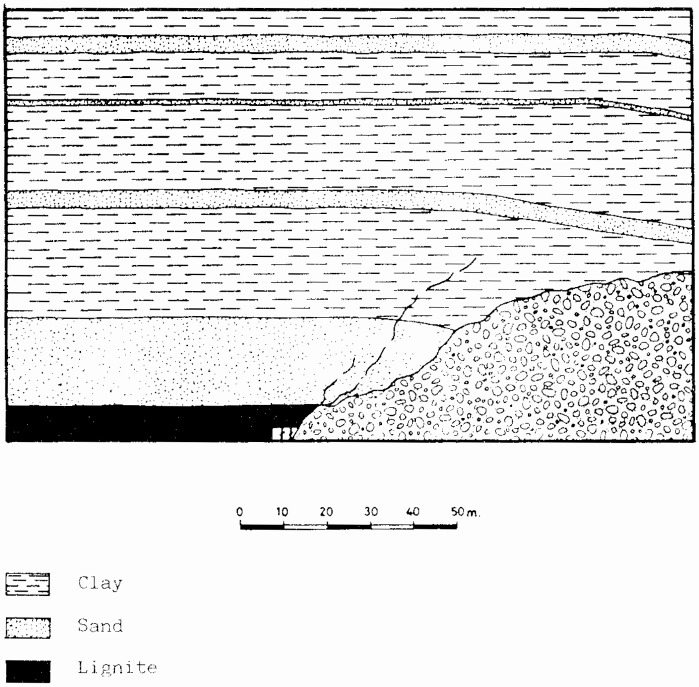


Fig. 5: Scheme of exploitation by "soutirage"

The biggest water and sand floods always took place at the center of the mine where the sand's thickness is greater and where there is a strong fracturation due to a synclinal formation and/or paleochannel, where the sand's grain size is bigger, and permeability increases.

The water flood mechanism at the exploitation fronts seem to be the following:

As the cavity is created because of the exploitation, the sand pack begins to bend in order to adapt ítself to the cavity, provoking detachments between strata due to their different characteristics. Therefore temporal water dams between strata are formed and brake suddenly every 25-30 m. creating a big permeability increase and liberating large quantities of water that drag the falling materials (sand, lignite, and argilites) up to the exploitation front.

PREVENTING ACTIONS AGAINST WATER FLOODS

"La Oportuna" mine - East area

The actions adopted in order to prevent the water and mud flood may be clasified into two types:

- Mining actions.
- Hydrogeological actions.

The first type ones are related to the geometry of exploitation and are aimed at preventing the collapsed area from reaching the water-carrying sand seam.

The second ones are related to the draining systems employed and are aimed at decreasing the piezometric level so the hydrostatic pressure over the mining works is less than 10 kg/cm^2.

Mining actions:

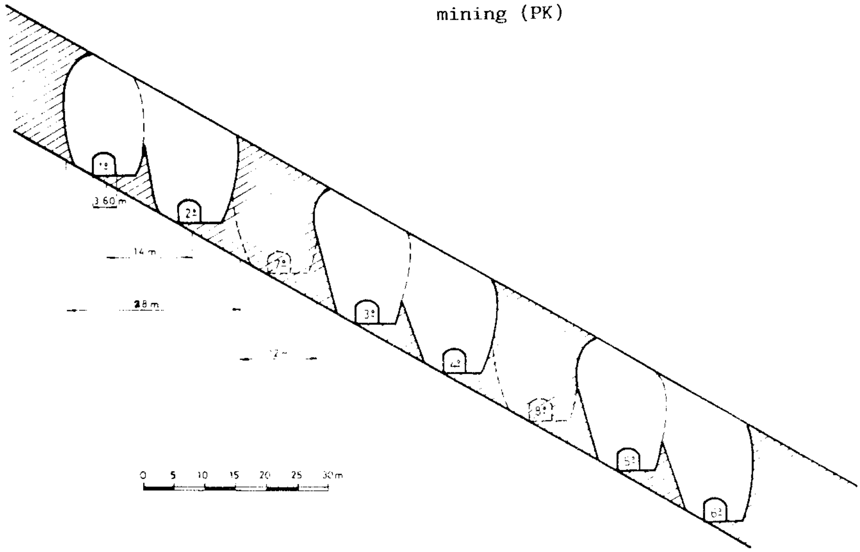
After it was proven during 1983 that dividing the mining exploitation in two different runs in order to make smaller cavities did not avoid - water irruption, and the excavated area height reached an approximate value of 1.3-1.4 times the exploitation width, it was proposed that the exploitation should not be more than 35 m., because the medium height from the lignite seam to the sands seam is about 50 m.

A sketch and sequence of the exploitation of a panel with wight gates may be seen on Chart Nr. 6. Two consecutive gates are exploited (exploitation width 28-30 m.), leaving an intermidiat rib pillar of 12 m. So that the heigth of the excavated area is about 40 m.

The two intermediate lignite rib pillar were exploited about six and eight months after the panel exploitation was started, so the six first galleries are already exploited and the roof material has collapsed and stabilized.

Using this method, eight consecutive panels have already been exploited and no water and mud floods have occurred. This confirms the theory height reached by the collapsed area.

Fig. 6 : Sequence of exploitation with continuous mining (PK)



Hydrogeological actions:

These actions are related to the drainage of the aquifer placed over the lignite seam.

At the beginning drainage was intended to be carried out from the mining works, with inclined drillings that passed through the lignite seam, the clay pack and the Albense sand seams. A rotary drilling system with direct mud flow was used, but it was impossible to go through the clay pack because they dissolved and came off through the borehole walls creating big cavities and stopping the mud circulation.

Because of the difficulties in carrying out the drainage from the underground works at a reasonable cost, drainage from the surface was started, drilling vertical water hamessing boreholes that went through the Eocene-Oligocene materials and the upper part of the Albense ones. A triangular drilling net was designed, placed at the north and south of the exploitation at 7^{th} and 8^{th} mine levels with an equal distance of 300 m., drilling a total of 8 holes.

The drilling net design was carried out in order to mantain a 100 m. maximun water columm over the mining works, because it was proven that this was the maximun hydrostatic pressure that could be mantained. Thus if the clay protection mass broke, the flood intensity would not create big problems at the mining works because of free water absence.

Mantaining a continous pumping from these drillings was found difficult, due to breakdowns created basically by the sand's transport which eroded the pump, decreased its efficiency. Also, having to place the drilling holes out of the subsidence bassin created by the underground works so they would not break because of the fractures created, decreased the efficiency of this drainage system; so more boreholes have to be drilled up to twice the preliminary designed. On the other hand, for the next works at 10th level drilling would have to be 450-500 m. long with a 660 mm. as drilling diameter.

All these things make drainage from the surface very expensive and a new drilling machine with two rotary heads is being designed, so it can drill and tube at the same time. That way it is expected to be able to go through the plastic clays pack and drain from underground at the mine.

"Innominada" mine

Different from "La Oportuna" mine, mining actions to prevent the flood risk are difficult to adopt because either there is no water-proof protection clay mass or it is very small. The flood prevention measures can only be hydrogeólogical and basically consist of the sand pack drainage carried out simultaneously from the surface and underground.

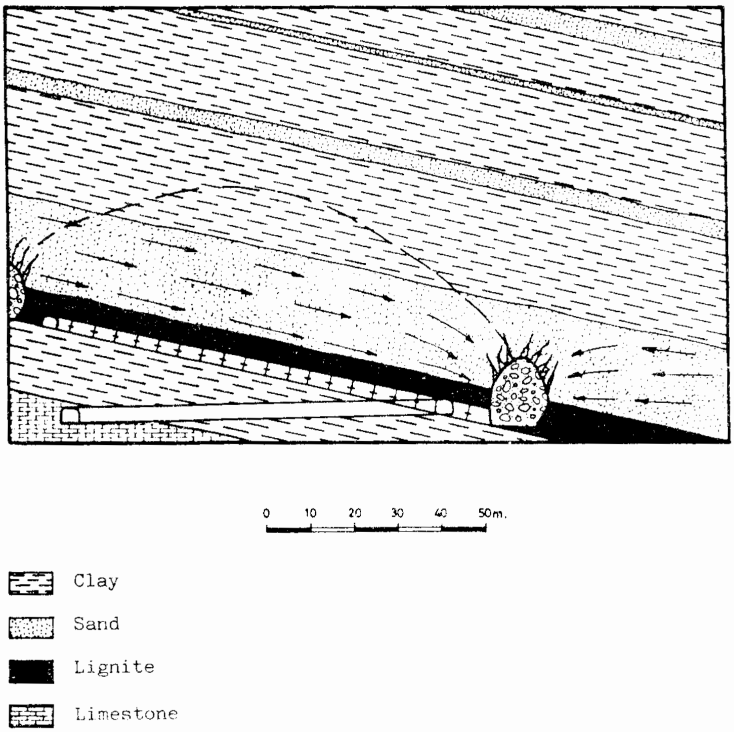


Fig. 7: Drainage by gallery

A net with 10 boreholes equidistant 350 m. has been designed so it covers the whole area to exploit during the next few years and has the purpose of decreasing the water column and inverting the flow direction outside of the exploitation.

Drainage from underground is carried out in order to drain the 100 m. wide and 10-20 m. thick sand mass that is overlying the exploitation face and to keep the water floods from areas not yet exploited.

Drainage gates are carried out to prevent this possibility. These gates are parallel to the longwall tail gate carried out 10 m. away from it by the coal bottom, and from them ascending boreholes are drilled to go through the sand pack. These drills are done with an equidistance of 7 m. and are cased with 50 mm diameter PVC pipes.

The efficiency of the drainage system has proven only to be partial because the clays come into the drillings through grooves and block them, so that the water flood is not completely avoided. In order to improve the efficiency of this drainage method, a continuous miner is being used to exploit the gates as it is done at the "Oportuna" mine so a sand pack collapsed is obtained, refilling the excavated cavity, creating a natural barrier, that drains the existing sand mass between the head and tail longwall gates and prevents the water flood from unexploited areas.

In order to get a greater efficiency, it is necessary to develop these gates 8 months before the lignite exploitation begins, so the drainage has to go 200 m. ahead of the exploitation.

"La Oportuna" mine - West area

No exploitations have been carried out in this area during the last few years. However, at the present time the 10th level is being developed, at a 450 m. average depth. The exploitation will start in july 1985 with 150 m. width panels.

Since the geological and hydrogeological comditions are equivalent to "Innominada" mine, the same drainage system has been applied, this is to say, drainage gates exploited with a continuous miner.

These gates are scheduled to open 13 months before the exploitation is started, so that the existing mass between the 9th level 10th level tail gate is completely drained.

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