EVOLUTION OF THE PERMEABILITY IN THE ROCK MASS RELATED TO MINING WORKS

Oscar Cudeiro Cudeiro, Rafael Rodríguez Díez and Javier Toraño Álvarez

Escuela Técnica Superior de Ingenieros de Minas. Universidad de Oviedo
Independencia 13
33004 Oviedo, Spain
Phone: + 34 985 104254, Fax: + 34 985 104245
e-mail: jta@correo.uniovi.es

ABSTRACT

When mining exploitations with sinking under one water bearing level are carried out is produced movements in the land that could cause an increase in the permeability of the water bearing, as a consequence of which one could increment the inflow of water to the mine.
Knowing the magnitude of the hydrogeological changes produced in function of the grade of exploitation could result fundamental for the so much desing of the mine exploitation like of the net of drainage of the mine.
Starting from a sequence of campaigns of hydraulic test (pump, injection, "slug test") previous to the beginning of the exploitation, during the exploitation and once concluded this and with a continue measurement of the water bearing in borings that have been instrumented with piezometers and located each one on the vertical of the exploitations that has a treatment with sinking is gotten to know the evolution of it permeability in the water bearing associated with the mining exploitations.
With this information could carry off a meticulous control and pursuit of the water bearing and of their possible influence on the own mining works.

INTRODUCTION

Change that has taken place in the coal mining of Northern Spain, abandoning gradually the conventional methods with extensive backfilling for new caving mining methods, has created a problem because this methods induce the opening of joints and fractures in the rock mass increasing the permeability and the water inflow in the mine.

For all it has been carried out a hydrogeological study that has allowed us to know the magnitude of the hydraulic changes produced in function of mining works and it possible influence in the aquifers.

GEOLOGIC DESCRIPTION OF THE DEPOSIT

The Carboniferous deposit are located in a horst limited by two direct faults with vertical displacements of 180 and 340 meters (Figure 1) and an inverse fault in the North.

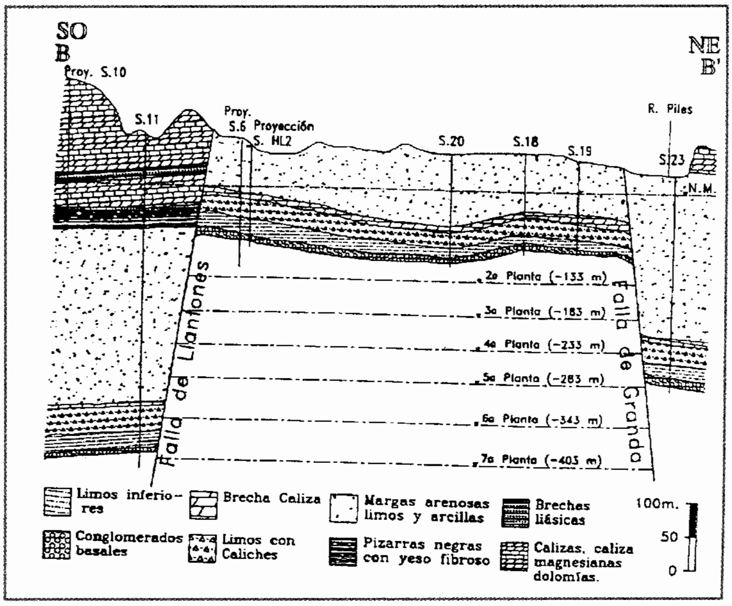

Figure 1:Transversal cross section of the horst structure.

Within the horst Carboniferous is a synclinal with vertical coal seams at Southwest and fairly steeps coal seams (30º-40º) at Northeast (Figure 2). The overburden deposits are flat Permian strata.

In the Permian, there are two aquifers, the upper at level of red marl, with a thickness of 18 to 24 m and 80 m depth, and the lower, in level of conglomerate, about 10 m thick and 160 m of depth. The water comes to these aquifers mainly from infiltration of rainfall water, and from the Jurasic strata through the faults.

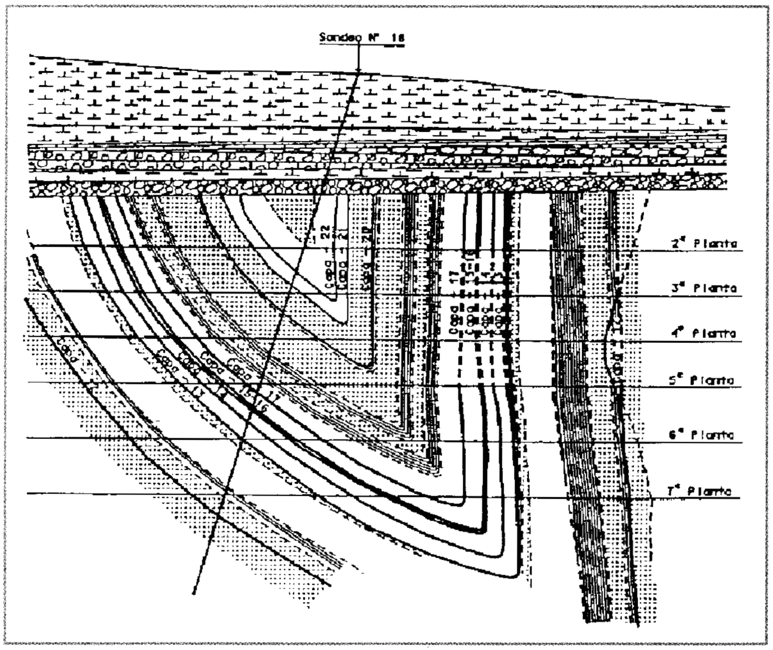

Figure 2: Transversal cross section of the Carboniferous structure.

Figure 3. Vibrant rope piezometer.

Figure 4. Teams for the registers of the water bearing levels.

STUDIES ABOUT HIDROLOGIC EFFECTS

In order to study the hydraulic parameters some geologic investigation boreholes has been used as control wells. Three of them, H5, H6, and H7, have equipped with vibrating wire piezometers and automatic system that registers periodically the water level.

Figure 3 shows a vibrating wire piezometer before introducing in borehole.

Figure 4 shows automatic station during it calibration based on conventional method.

The well H6 is located on the fairly steep seams area (30º-40º), where the 15/16 coal seam was working by room and pillar method. Near, the same seam but in the vertical zone, was working with sublevel caving method, and the borehole was influenced by it too.

The well H5 is located on the vertical area of the deposit where 8/9 seam was exploited by sublevel caving (Figure 5).

The monitoring and control tasks were:

- water level measuring in wells;
- hydraulic tests; and
- surface subsidence control near the well sites.

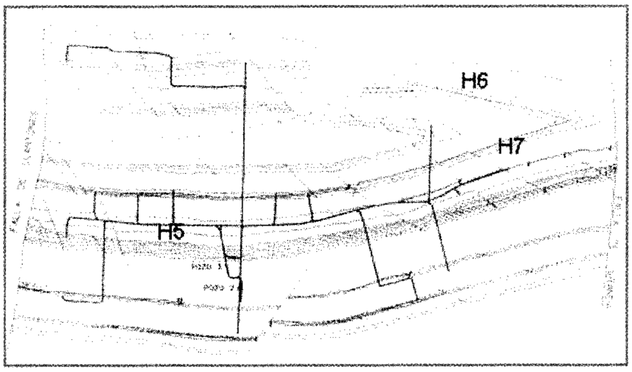

Figure 5. Situation in plant of the borings.

Variation of the hydraulic conductivity

Acquisition of field data

In order to measure the changes of permeability originated in the aquifers, or generally in the rock mass, due to mining works, six groups of hydraulic tests have been carried out. that allows us to see the evolution of the permeability associated to the mining works.

Hydraulic tests carried out was of these types:

- pumping tests;
- injection tests; and
- slug tests.

Figure 6 shows the performance of a pumping test in one of the wells.

Thiem, Theis and Jacob methods was employed for analysing the response of water levels in the tests (both permanent and transient regimen).

In Figure 7 it is shown a cross section with relative location of the wells and the mining works. In each site two wells exist, one, called short or HC, to make hydraulic tests in the upper aquifer (marl) and other, called long HL, deeper, capable for the hydraulic test in the water bearing conglomerate. Investigation works can be divided in:

- Fields work
  a) In the H5 site: six groups of injection and pumping tests, both in the well H5C and H5L, in order to determinate hydraulic parameters of the two aquifers;
  b) In the H6 site: five groups of injection and pumping tests with the same objective.

Date	H5C	H5L
Apr-95	$1{,}27 \times 10^{-7}$	$4{,}00 \times 10^{-8}$
Sep-95	$6{,}40 \times 10^{-8}$	
Dec-95	$5{,}20 \times 10^{-7}$	$7{,}60 \times 10^{-8}$
May-96	$7{,}47 \times 10^{-7}$	$2{,}20 \times 10^{-7}$
Ago-96	$1{,}27 \times 10^{-6}$	$4{,}60 \times 10^{-7}$
Nov-96	$6{,}60 \times 10^{-7}$	$1{,}10 \times 10^{-7}$

Table 1. Permeability obtained with the hydraulic tests.

Figure 6. Pumping test.

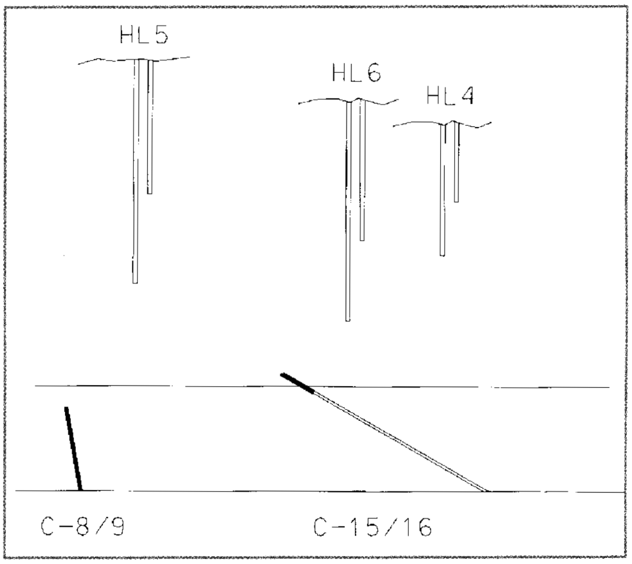

Figure 7. Relative location of borings and mining works.

- Thecnical office work
  a) analysis of the permeability changes;
  b) determination of correlation between the variations in hydraulic conductivity and the mining works.

Results of the tests in H5C and H5L

The wells H5C and H5L are located above an exploitation of sublevel caving. Seam, called 8/9 seam, had a thickness of 3 to 4 m and a dip of 70º, and was working between 5th and 7th levels (leaving a vertical safety pillar of 25 m below upper level).

The permeability in m/s estimated from the tests carried out between April 95 and February 97 are listed in Table 1.

In Figure 8 is plotted the relationship permeability measured/initial vs. time with the evolution of the mining works. Related to the upper aquifer (H5C) we can observe that in the first months it is produced a very light decreasing of the permeability for later go increasing until a maximal value, in which the change is of one order of magnitude (relationship measured/initial about 10) and later decreases again to a value near to the initial one.

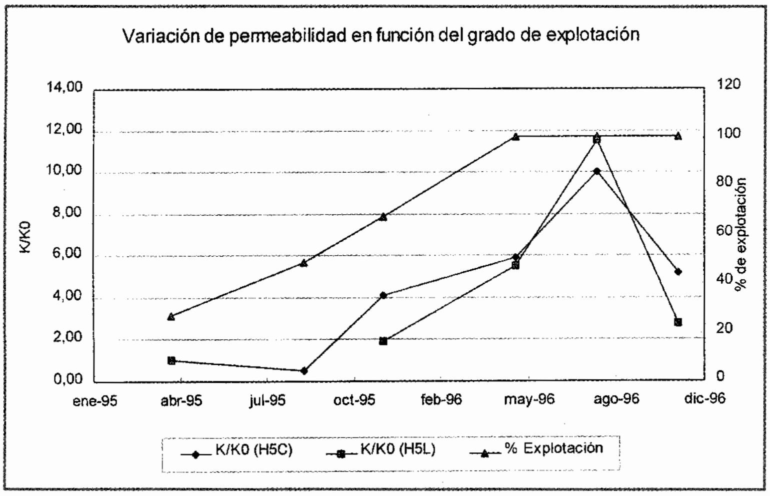

Figure 8. Variation of permeability measurement in the boring H5.

The beginning of the exploitation causes break in rock mass near the works that after certain time reaches to the materials of the Permian making changes in its permeabilities. These changes seem to be related with horizontal stress and horizontal strain consequence of the caving mining methods. When it are tensile strains, produce the opening of the existing joints in the rock mass and the permeability increases. Compressive strains produce a decrease in permeability.

In the same Figure 8 is plotted the evolution followed in water level in the lower aquifer (H5C). It appear similar to the other and it makes to think that the movements in the rock mass in the Permian overburden and in the Carboniferous near of contact, doesn't change of appreciable manner with the depth.

Results of the tests in H6C and H6L

The wells H6C and H6L are located above a panel of 15/16 seam worked by room and pillar method. The dimensions of the panel was 130 m and 290 m (along the strike). The dip was 30º-40º.

The results of hydraulic tests are listed in Table 2.

Date	H6C	H6L
Jun-95	$4{,}47 \times 10^{-7}$	$8{,}10 \times 10^{-9}$
Nov-95	$1{,}65 \times 10^{-7}$	$5{,}60 \times 10^{-9}$
Oct-96	$1{,}44 \times 10^{-6}$	
Nov-96	$1{,}42 \times 10^{-6}$	$2{,}50 \times 10^{-8}$
Feb-97	$2{,}31 \times 10^{-6}$	

Table 2. Permeability obtained with the hydraulic test.

The first test was done when works started. In Figure 9 is plotted the evolution of the relationship permeability measured/initial vs. time in the two aquifers with the grade of mining works. Like in other case, it is produced a small decreasing of permeability in the first months (maybe due to assessment of borehole walls). After this, the permeability increases until last value.

The behaviour in this case is similar to the H5 site. The last measuring have been taken when had not concluded the mining works and continued the movements in the rock mass.

Figure 10 shows the evolution of surface subsidence in the vicinities of the wells. In August 96 and March 97, when vertical displacements started: Boreholes are in zone of subsidence trough of horizontal tension strains, so the hydraulic conductivity in rock mass is increasing. At last subsidence measuring, in September 97 once concluded works, the horizontal strains near boreholes are compressive, moment that coincides with a decrease in the permeability.

Figure 11 shows the evolution of the water level in well H6 (registered automatically every six hours). We can observe that was produced a decreasing of levels, very accused in the conglomerate aquifer and moderate in the marl, coinciding with

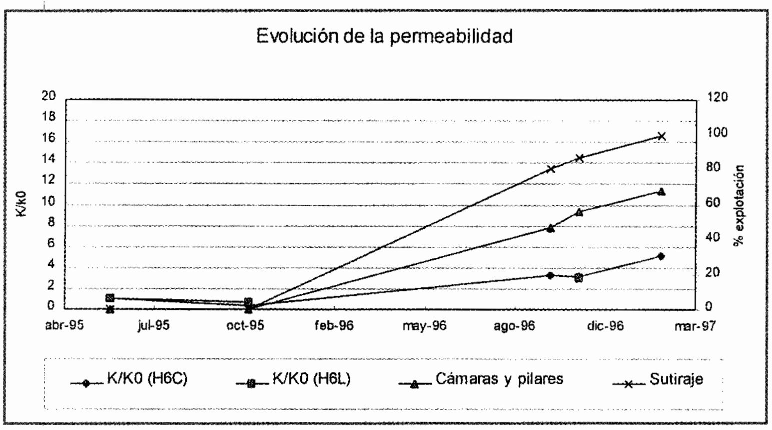

Figure 9. Variation of permeability measurement in the boring H6.

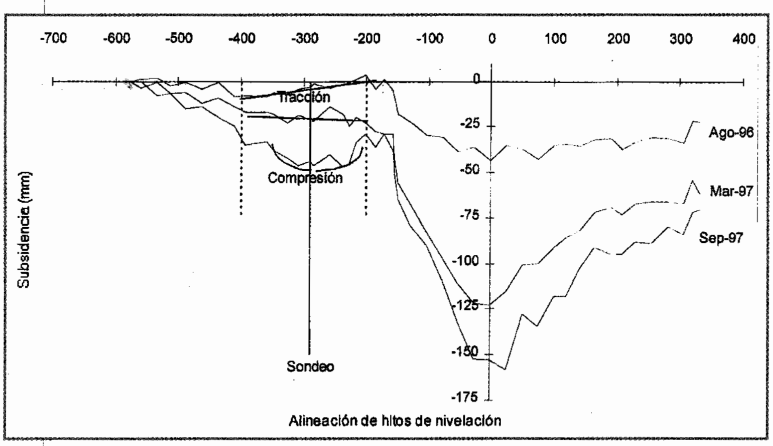

Figure 10. Movements of the land in boring vicinities.

the phase in that is produced an increase of the permeability (Figure 9) with a posterior recuperation of the level until the initial value in the marl or even major in conglomerate. At the same time is shows the grade of mining works. The beginning of the descent in the water level coincides with a grade of exploitation of 20% in the panel extracted by sublevel caving. The recuperation of the water level is produced when this panel is finish. The extraction in the other panel (room and pillar) continues and it produces the compressive strains near wells, the decreasing of permeability and the recuperation of water level. These results are the same of the investigations related with the influence that has the flat coal seams mining works in the water bearing strata.

Researching let us to evaluate importance of one and another aquifers in the mine. The mining works influence totally in the conglomerate aquifer, while is minor in the marl, due maybe to the major vicinity of the conglomerate, in direct contact with the carboniferous, to it minor hydrologic potential and that the mining is not yet important on order to affect to the upper aquifer.

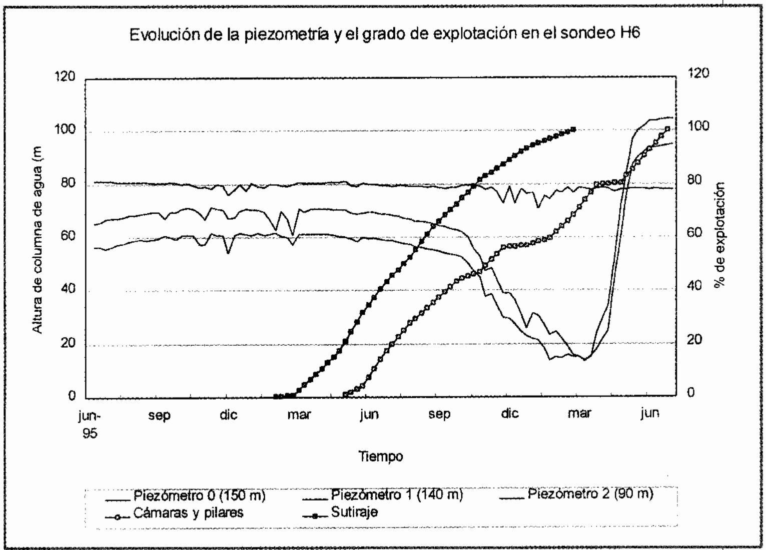

Figure 11. Water level evolution in the boring H6 and mining work grade.

CONCLUSIONS

This investigations has shown the relationship between the movements of the land and rock mass originated by the mining works and their effects upon the existent aquifers in the very steep coal seams mining. The conclusions that extracted are:

- generally, the permeability after a light descent, related to the borehole walls, increases until a maximum for later diminishing again until a value near to the initial;
- these changes seems to be related with the horizontal tensile strains that open existent fractures in rock mass making that permeability increases;
- generally, changes are moderate, in the case in study, maximum of one order of magnitude;
- the changes are of the same order of magnitude in the two aquifers; a major afecction in the deeper one is not observed; and
- for the grade of mining reached (limited extension) the important alterations in the rock mass only is produced near of works (a few meters over the roof) remaining a wide zone of rock mass with elastic behaviour, within it there was the wells and so the changes relatives are constant an of small magnitude.

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