A STUDY OF THE CHIMIO-HYDRO-MECHANICAL PROCESSES IN THE ROCK MASS AT A MINE IN ABITIBI, QUÉBEC, CANADA: PRELIMINARY RESULTS

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ABSTRACT

The present state of a geological environment is the result of the continuous interaction of mechanical (M), hydraulic (H), chemical (C) and thermal (T) processes. This study on M, C and H processes and their coupling in a rock mass, is carried out at the Bouchard-Hébert Mine located in the Abitibi mining district, Québec, Canada.

The Bouchard-Hébert Mine hosts two complexes of massive sulfides : the "main" complex and the "1100" complex. The former is the location of the old mine workings and extends from the ground surface down to a depth of 300 m. The latter is presently being mined; it lies at about 250 m to the south-east of the "main" complex and stretches from 300 m to 700 m in depth. The acidic water migrating from the old mine to the new one, in combination with the perturbed geomechanical stress field caused by the excavations, may be affecting the rock mass permeability.

Both field work and laboratory experiments are being conducted in order to investigate the M, C, and H processes and their coupling, particularly in the rock mass portion located between the two mines.

Three sets of fractures have been identified based on discontinuity mapping : a subvertical set, a subhorizontal set, and a set oriented north-east with a moderate dip. Fractures density is irregular with values ranging from 2 to 4 m^{-1}.

The hydraulic conductivity of the rock mass has been estimated by hydraulic testing in boreholes. For example, the rock mass located between the old and the new mines shows the highest hydraulic conductivity values, between 10^{-10} m/s and 10^{-6} m/s. However, at the eastern extremity of the site, the hydraulic conductivity is considerably lower with values between 10^{-9} m/s and 10^{-10} m/s. The rock mass separating the old and the new mines should be the area the most affected by the acidic water flow due to its high permeability, since this high permeability presumably favours a rapid dissolution rate of carbonate minerals contained in the fractures.

Preliminary results from ongoing laboratory experiments conducted on fractures sampled at the site have revealed an important change in their permeability over a short period of time.

INTRODUCTION

In a geological environment, mechanical (M), hydraulic (H), chemical (C) and thermal (T) processes are continuously interacting, and the present state of this environment is a result of these interactions. Tsang (1991) has presented an overview of the H-M-C-T processes in rock fractures. Very few studies have been devoted to the understanding of the coupling of these processes within a rock mass. This has resulted in an incomplete knowledge of the actual behaviour of the groundwater and the enclosing rock mass, particularly at a mine site. Figure 1 illustrates some of the interactions amongst M, C, H and T processes in a fractured rock mass.

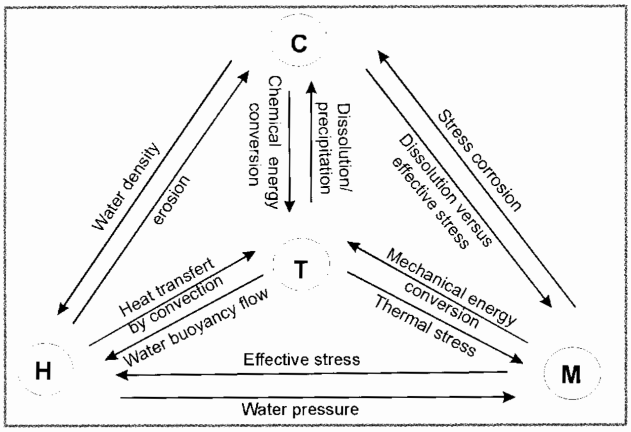

Figure 1. Coupled chemical (C), hydraulic (H), mechanical (M) and thermal (T) processes in a fractured rock mass.

A field and laboratory study of M, C and H processes and their coupling in the rock mass is being carried out at the Bouchard-Hébert Mine (Cambior Inc.) in the Abitibi Mining District, Québec, Canada. The geomechanical stress field around the excavations is perturbed, as at every mine site, and the natural groundwater geochemistry is altered by acidic water production. Interaction between these two types of processes presumably affects the permeability of the fractured rock mass, causing potential adverse effects, such as infrastructure instability, increased inflow into mine workings, and acidic mine effluents.

THE MINE SITE

The Bouchard-Hébert Mine is located in a greenstone belt of the Abitibi subprovince of the Superior Province, in the Canadian Shield. The vicinity of the mine is composed of a sequence of subvertical layers of metavolcanic rocks which host two complexes of massive sulfides consisting primarily of pyrite (FeS_2), sphalerite [(Zn, Fe, Cd)S] and chalcopyrite ($CuFeS_2$) (Ruel, 1995) (Figure 2). The "main" complex, where previous mining activities have taken place, is formed of several orebodies. Mining in this particular complex occurred both from an open pit and underground to a depth of 300 m. The "1100" complex is the object of the present mining operations. Lying at about 250 m to the south-east of the main complex, it stretches from 300 m to 700 m in depth.

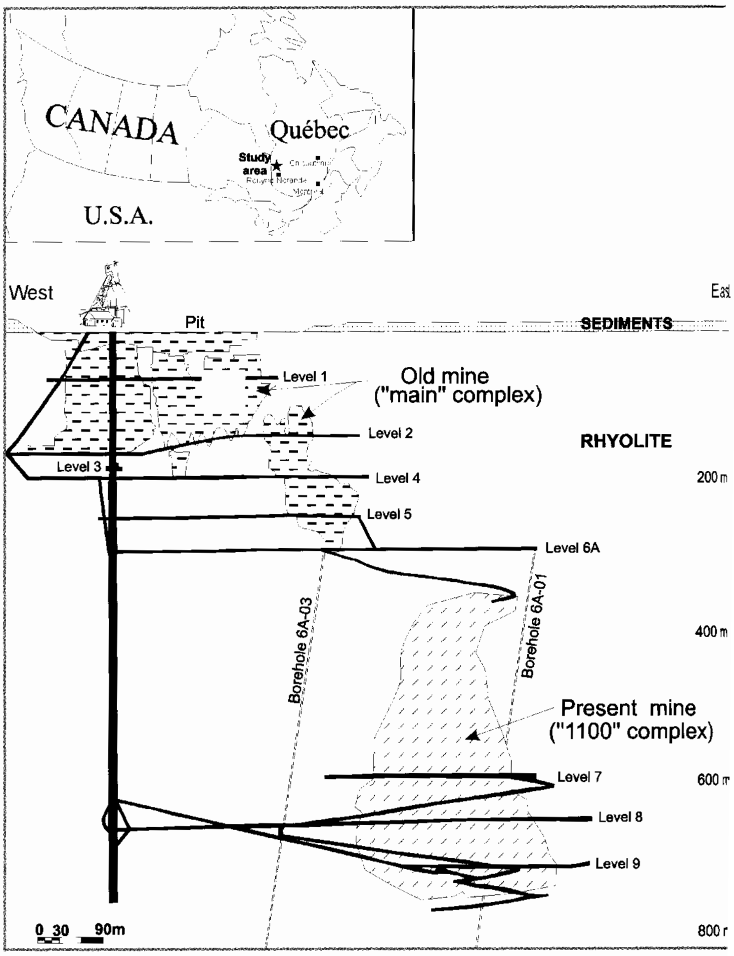

Figure 2. Location of the Bouchard Hébert mine and a longitudinal cross section looking north.

GROUND WATER GEOCHEMISTRY

The natural groundwater level at the mine site is at a few meters from the surface, and therefore, the old excavations are normally filled with water. Hydrogeochemical analyses have revealed a great difference in quality between waters originating from the old excavations and deep groundwater inflowing into the recent excavations (Benlahcen, 1997). Waters sampled at a bulkhead at the base of the old mine, at level 6A, have pH values as low as 2. These waters are also rich in dissolved metals, such as Fe, Zn, Cu, Mg and Mn with a concentration of 8400, 4500,1820, 500, and 128 ppm respectively. However, waters sampled from boreholes and fractures located either at the same level, but at some distance from the old excavations, or at a lower level within the mine, are of neutral pH and contain a very low concentration of dissolved metals. The effect of the acidic water is also noticeable in the mixed waters pumped from all of the mine excavations. These mixed waters have a pH value around 3, but a low concentration of dissolved metals compared to the water coming from the old excavations. The low metal concentration in these waters is possibly due to their precipitation at the bottom of the water reservoir.

ROCK MASS DISCONTINUITIES

Groundwater flow at the Bouchard-Hébert Mine is mostly controlled by fractures, faults and the contact between different lithologies. This study is focusing on the role that fractures play in the acidic water migration and the effect of this water on rock mass permeability. For this reason, it is important to characterise the various fracture types and their distribution in the rock mass of the mine.

Discontinuity mapping was conducted in the exploration drift at level 6A, which is located between the old and the new mine workings, assuming that discontinuities at this level provide a representative sample of the rock mass fracture system between these two groups of excavation. The mapping consisted of measuring all the fractures on the north wall of the drift that have a trace length greater than or equal to 0,5 m. The recorded fracture parameters include the orientation, the trace length, the thickness and the types of infilling minerals.

Three sets of fractures have been identified on stereographic projection diagrams of poles to fractures planes (Figure 3; Benlahcen, 1999) : a subvertical set, a subhorizontal set, and a set oriented north-east with a moderate dip to the west. The presence of these sets is dependent on both the location and the lithology (Figure 3). The set of subhorizontal fractures is always present from west to east, while the subvertical fractures show different directions at different locations. As for the NE trending set with a moderate dip, it is absent at a few locations. High proportion of fractures are veins typically between 1 and 2 mm of thickness and with calcite as their infilling minerals.

In a horizontal drift, vertical fractures perpendicular to the drift are more frequently sampled than the subhorizontal ones. In spite of this orientation bias, the subhorizontal fractures are relatively frequent in our samples from this site. This might be due either to the presence of a subvertical foliation masking the subvertical set of fractures, or to the actual higher frequency of subhorizontal fractures.

The density of the fractures along drift 6A was estimated as the sum of the fracture trace length divided by the surface area of the drift face (Dershowitz and Herda, 1992). In this study, the unit surface area is set at 3 m x 3 m since the height of the drift wall is about 3 m. The fracture density is irregular along drift 6A (Figure 4). However, it is slightly higher at the

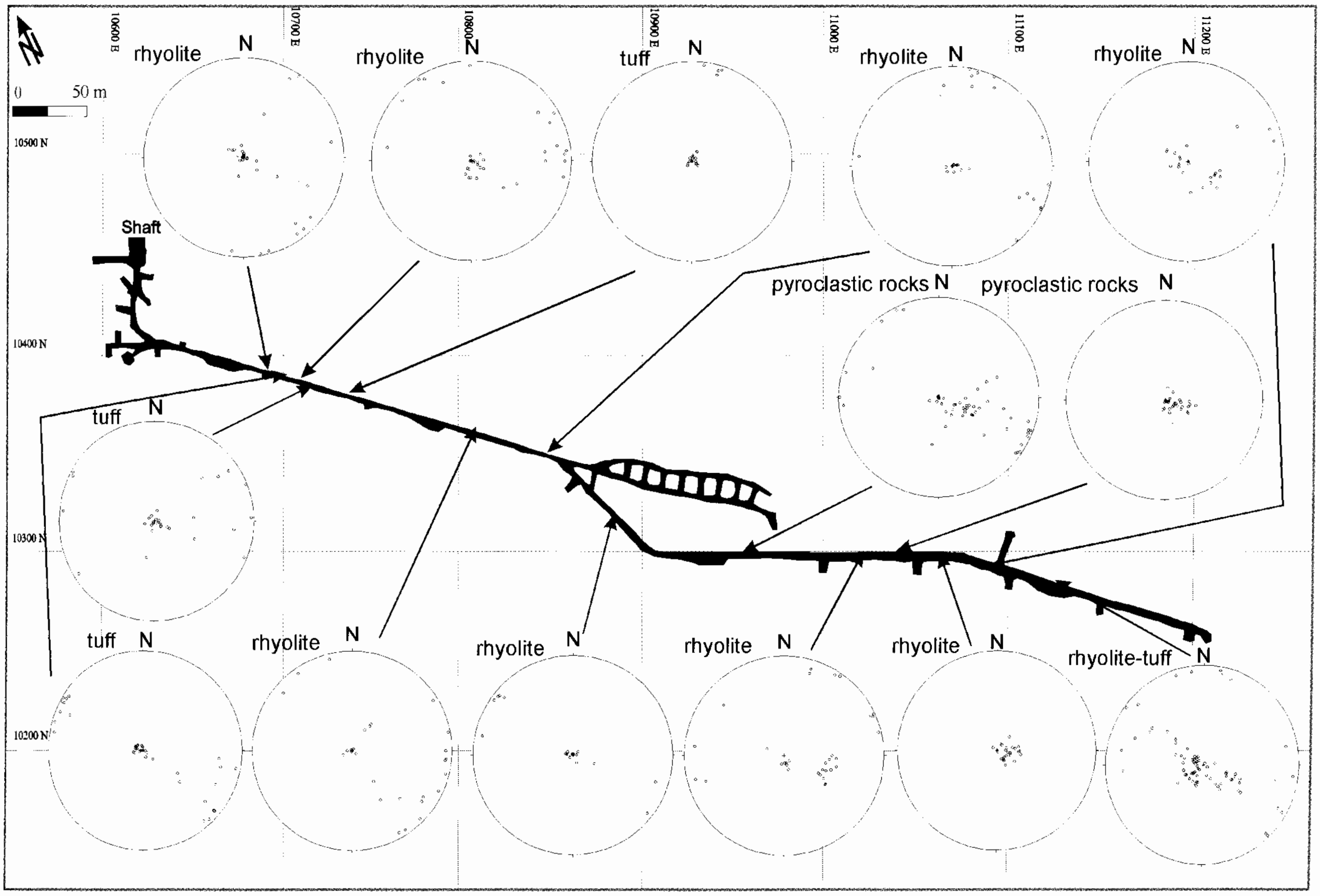

Figure 3. Fracture poles for different lithologies and locations at level 6ª of the Bouchard-Hébert mine on lower-hemisphere stereographic projections.

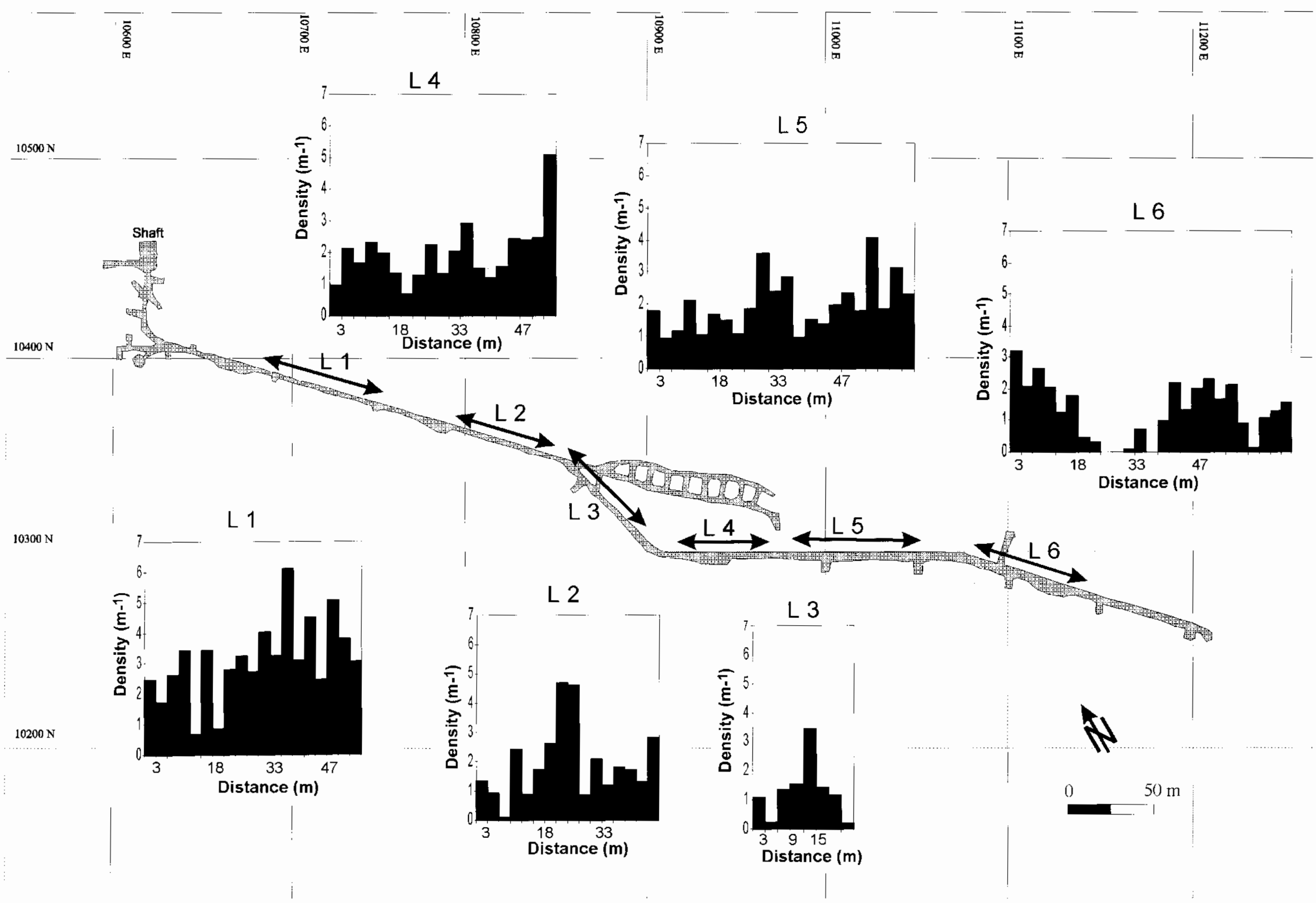

Figure 4. Fracture density versus location (L) along drift 6ª of the Bouchard-Hébert mine.

western end, at about 3 to 4 m^{-1}, while it decreases to 2 to 3 m^{-1} towards the east. It appears that both fracture density and orientation are closely related to the location and to the lithology.

ROCK MASS PERMEABILITY

The hydraulic conductivity of the rock mass was estimated using constant-head injection tests conducted in two boreholes (Figure 2), in 1.5 m intervals limited by two packers. Borehole 6A-01 is located at the eastern extremity of drift 6A, while borehole 6A-03 is located at the centre of that drift. The total length that was tested in each of the boreholes is about 50 m starting from drift 6A and descending toward the new mine workings. The results are given as a continuous profile of hydraulic conductivity along each borehole (Figure 5).

The hydraulic conductivity profile is quite different from one borehole to the other. The borehole 6A-01 profile shows relatively homogeneous hydraulic conductivity values. From drift 6A to a distance of 20 m, in a foliated rhyolite, the hydraulic conductivity increases from 10^{-9} m/s to 10^{-8} m/s. From 20 m to 50 m, in an hematized rhyolite, the hydraulic conductivity decreases from 10^{-8} m/s to about 10^{-10} m/s. In borehole 6A-03, the hydraulic con-

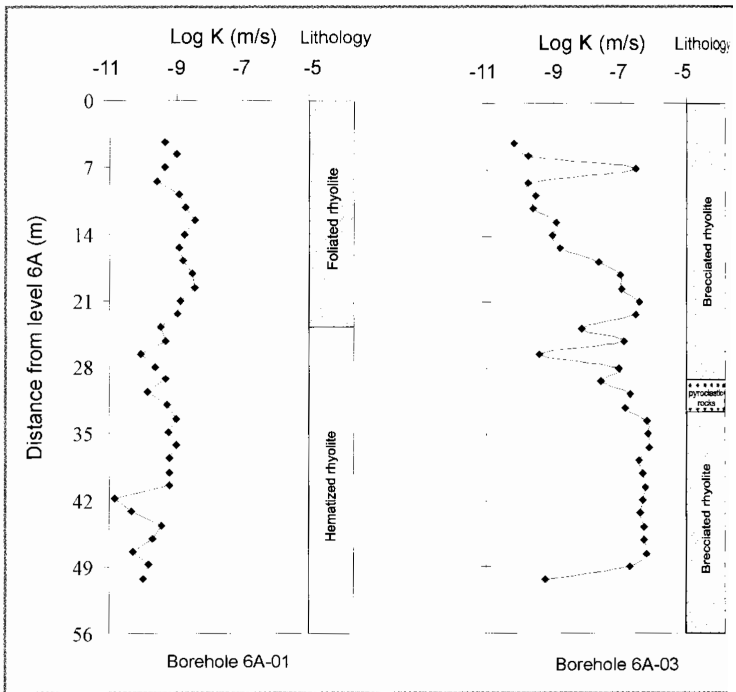

Figure 5. Hydraulic conductivity along two boreholes from level 6ª of the Bouchard-Hébert mine.

ductivity value changes radically with distance. From drift 6A to a distance of 30 m, the hydraulic conductivity of the brecciated rhyolite increases from 10^{-10} m/s to 10^{-7} m/s. From 30 m to 33 m, in pyroclastic rocks, the hydraulic conductivity continues to increase to about 10^{-6} m/s. Then, from 33 m to 50 m, in a brecciated rhyolite, the hydraulic conductivity is constant at about 10^{-6} m/s.

These results suggest that the permeability of the rock mass between the old and the new mines is higher than that surrounding the mine, particularly at the eastern part. Therefore, the rock mass separating these two mines is a zone where the M-C-H processes are likely to evolve and interact rapidly.

PRELIMINARY RESULTS OF THE LABORATORY EXPERIMENTS

Due to the important presence of calcite as an infilling mineral, the fractures of this mine could be affected by the migration of the acidic water through the rock mass. Laboratory experiments are being conducted in order to investigate the M, C and H processes and their interactions in individual fractures sampled at the site (Figure 6). Preliminary results of these experiments have shown a rapid increase in the fracture permeability for low-pH water. The acidic water injected into the fractures dissolves the infilling minerals within a period of few hours.

CONCLUSION

Acidic water generation is very common in mine workings located in sulfides deposit. The presence of this type of water, in combination with the perturbed geomechanical stress field caused by the excavations, could modify the permeability of rock mass discontinuities, especially those discontinuities having calcite as an infilling mineral.

Since discontinuity mapping has indicated that calcite is a common infilling minerals in these fractures, the rock mass permeability could be significantly affected by the acidic water migration from the old mine.

The rock mass separating the old and the new mines has the highest permeability with values between 10^{-10} m/s and 10^{-6} m/s, while that found at the eastern extremity of the new mine has the lowest, with values between 10^{-10} m/s and 10^{-9} m/s. Rock mass immediately surrounding the new mine should be the area the most affected by the acidic water flow due to its higher initial permeability, as this high permeability should favour a rapid dissolution rate of carbonate minerals in the fractures.

Preliminary results of the laboratory experiments carried out on the fractures sampled at the site indicate that an important change in the fracture permeability occurs over a short period of time.

Further studies, combining field work, laboratory experiments and simulation, both on a single fracture and on a fractured rock mass, are needed in order to obtain a better understanding of the M, C and H processes and their coupling in a fractured rock mass.

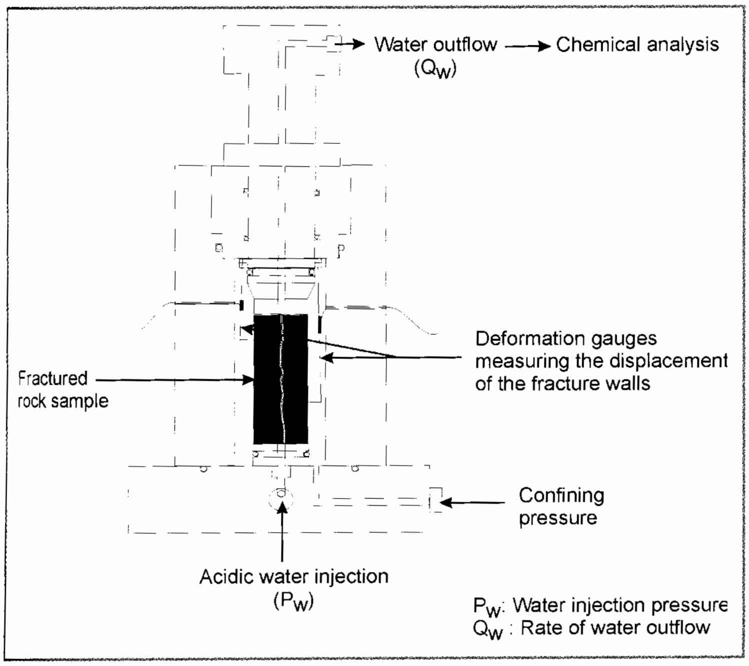

Figure 6. Schematic illustration of the triaxial-cell of the laboratory set-up containing a fractured rock sample.

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