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The influence of relative humidity on the rate of convergence in an underground gypsum mine

Christophe Auvray*, Françoise Homand, Dashnor Hoxha

Laboratoire Environnement Géomécanique et Ouvrages, Ecole Nationale Supérieur de Géologie, Institut National Polytechnique de Lorraine, Rue du Doyen Marcel Roubault-BP 40-54501 Vandoeuvre-lès-Nancy Cedex, France

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Abstract

Pillars of gypsum from the underground mine located at Grozon (Jura region, France) reveal degrees of instability that vary depending on the mining period. Observations carried out with a scanning electron microscope (SEM) shed light on the dissolution of gypsum, especially on the walls of pillars and in older zones. The time-dependent behavior of the gypsum is thus investigated in the laboratory and found to be a result of forced relative humidity. Variations of relative humidity have an influence on convergence values that are measured in situ. The analysis of this data reveals seasonal developments that are a function of variations in relative humidity.

Keywords: Underground mine; Gypsum; Time-dependent behavior; Aging; Pillar

1. Introduction

This paper deals with the behavior of a gypsum mine (Grozon quarry, Jura) as it relates to changes in relative humidity. The underground mine of Grozon offers the classic example of zones mined at different periods on a site that spans an area of around 500 ha. Gypsum from the Keuper period has been extracted there since the end of the 19th century, using the room and pillar method on one or two levels locally stacked on top of each other. With the abandonment of this underground gypsum mine in sight, it is particularly important to understand the rock's aging mechanism. In this framework, the impact of the relative humidity on the overall behavior of this mine seems to be of a great importance, given the hygro-sensitive character of this material [1–7]. Two approaches have been combined: (a) laboratory observations and characterization of samples from areas of different mining ages (b) in field measurements of deformations rate, temperature and relative humidity.

For laboratory studies, the samples have been fabricated from boreholes drilled in such a way that allowed precise observations of the samples, tests of physical and mechanical characterization, as well as creep tests under different hydric conditions.

The in situ studies have taken advantage by the fact that for nearly 20 years, between 1978 and 1998, the mining company conducted convergence and expansion measurements. The monitoring stations were later re-calibrated and the galleries were measured for convergence and the pillars for expansion from 2003 to 2005. This was done in order to examine their behavior with respect to conditions of ventilation and therefore as it relates to the relative humidity present in the mine atmosphere.

First, the laboratory observations on samples are presented. Then, following the description of laboratory characterization of the mechanical behavior, a detailed study of the mechanical behavior in situ is presented. The results are then interpreted and discussed.

2. Observation of traces of dissolution

Scanning electron microscope (SEM) observations were conducted on samples of gypsum extracted every 10 or 15 cm over the entire horizontal borehole length going towards the center of the pillar. This observation

*Corresponding author.
E-mail address: christophe.auvray@ensg.inpl-nancy.fr (C. Auvray).

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technique, having already been used [8,9] has allowed a development in the intensity of the traces of dissolution to be highlighted [10,11]. Initially observations from samples taken from the wall and the core of the pillars showed that at the wall of the pillar the crystals are corroded, and towards the center they are without traces of dissolution (Fig. 1). Since in the gypsum mine there is no free-water table, the question is raised as to the cause of this corrosion, and in view of the hygro-sensitive character of this material the variation of the relative humidity were supposed to play a role on the weathering process of this rock. In order to verify such a hypothesis, these initial observations were recently completed, by using observations of an accelerated weathered samples using an environmental scanning electron microscope (ESEM). The advantage of the use of such equipment as compared to SEM is that the exchange surface of the sample remains ''intact'' during the observation since it does not need to be metallized.

For these observations gypsum samples taken from somewhere in the middle of the boreholes are observed before and after undergone an accelerated weathering by placing them at a constant relative humidity of 98% and a temperature of 20 °C for 220 days. Initially, a surface of several square millimeters of a given sample was mapped at a magnification of 300×, and the position of the samples in respect with the observation device was carefully marked in order to find the area that had initially been photographed. During observations, the exchanges between the sample and the atmosphere are still possible. However, during our observations with ESEM in the microscope, because of technical difficulties the conditions are slightly different from those during weathering and the compromise of 8 °C and about 95% relative humidity were assured.

After an initial observation and artificially weathering samples are observed a second time. By comparing the morphology of the crystals between the two examinations, a significant deterioration of some of them can be noted (Fig. 2). This deterioration seems to manifest itself in different ways: The pores already present in the observed zones (P1: Fig. 2) appear to be larger after 220 days in a relative humidity of 98% (P2: Fig. 2). In the same time, some crystalline surfaces (S1: Fig. 2) seem to be more corroded after 220 days in a relative humidity of 98% (S2: Fig. 2). Even cracks (F1: Fig. 2) appear more open between the two observations (F2: Fig. 2).

Nevertheless some crystals, which show no pores and have completely smooth surfaces, do not seem to have been affected by a relative humidity of 98% for 220 days (Fig. 3). It would seem then that dissolution is facilitated in the zones that already present crystalline anomalies like lattice vacancies or in zones already more or less dissolved.

The exposure to a strong humidity was probably not enough long to be able to observe etching figures like that of Fig. 1.

3. Laboratory characterization of the mechanical behavior

The question that follows is that concerning the evolution of the macroscopic properties of gypsum with respect to the intensity of dissolution. Various physical and mechanical parameters have been determined on the set of two drilled boreholes from two different mining areas (Figs. 4 and 5): dry density (ρ_d), grains density (ρ_s), total porosity (n_t), water porosity (n_w), nitrogen permeability (K), velocity of ultrasonic compressional waves P and of shear-wave S (V_p and V_s), dynamic Young's modulus (E_{dyn}), dynamic Poisson's ratio (ν_{dyn}), uniaxial compression strength (R_c) and static Young's modulus (E).

In order to determine the values of these parameters, specimens 38 mm in diameter and 76 mm in height have been machined and then oven-dried at 50 °C for a 72-h period. The longitudinal axis of these specimens runs parallel to the pillar vertical axe. The mass density of the grains has then been measured on powder using a helium pycnometer. The water used for determining the water porosity was initially saturated in calcium sulfate so as to avoid any dissolution of the rock.

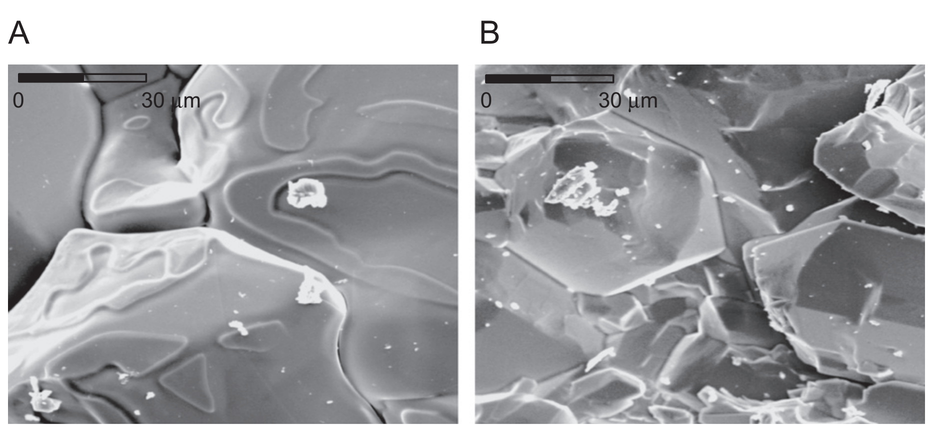

Fig. 1. Evolution of gypsum crystal morphology with respect to depth in the pillar: (A) pillar wall, crystals with traces of dissolution and (B) pillar core, idiomorphic crystals.