New insights into the Cosquer art cave hydrogeological functionning (France)

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The Cosquer cave supports and protects some paleolithic paintings and engravings, dated to more than 31,000 years (Cal BP, Valladas et al. 2016). It's a coastal cave, located in the Calanques massif, near Marseille in south of France. This area is well-known for its karstic landscape, in the white urgonian limestones (Barremian, early cretaceous). Nowadays, the cave has no water-free entrance. The only way to access to the cave is to dive to a submarine entrance giving access to a karst conduit connected with the non-flooded part of the cave (Figure 1). During paleolithic times, the seawater level was lower (down to 135 m). The access to the cave to the paleolithic men was flooded by the Mediterranean Sea rise around 10,000 years (Cal BP, Lambeck & Bard 2000). This specific location of the cave offered a protected area for the conservation of the rock art: no man entrance during the historical time, climatic and environmental steady conditions. Moreover, the karst also protected the rock art because it limited the sea-level rise within the cave. Indeed, the water level inside the Cosquer cave is lower than the sea-level, although only a tens of meters of limestones separate the cave to the sea. Obviously, the cave is a confined environment and is an interesting case-study to understand the impact of permeability contrasts between open karst features and the surrounding matrix. The aims of this work are: (1) to present a first long pressure time series ever recorded in the Cosquer cave, (2) to show which phenomena control the water level variation inside the cave, in order to answer to the following questions: when, how high and why the water level varies in the cave?

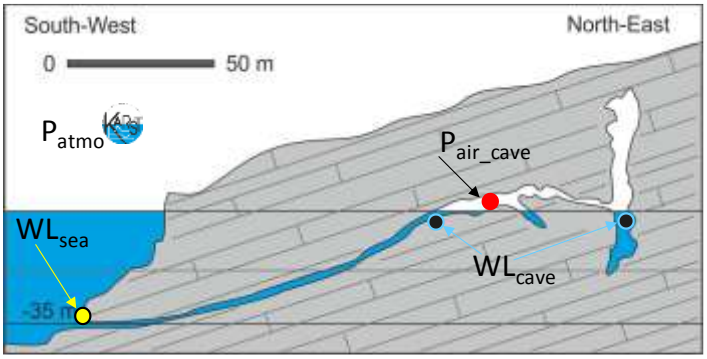

Figure 1 : Schematic cross-section of the Cosquer cave, in the Calanques National Park, Marseille, France. Automatic pressure sensors have been installed: (1) in the sea in front of the submarine entrance (WL_{sea}), (2) inside the cave in two pools (WL_{cave}) and in the air (P_{air_cave}), (3) in the air outside the cave (P_{atmo}) at the Port-Miou observatory (SNO Karst) located 5 km eastward from the cave.

This unexpected low water level in the cave was shown since the first pressure measurements following the discovery (Vouvé et al. 1996). The air pressure in the cave is higher than the atmospheric pressure outside the cave. This air overpressure pushes down the water level and

avoids the water to rise on paintings and engravings located close to the sea-level, e.g. the horses panel. The air overpressure changes over the year and influences the art conservation. However, few measurements have been done to study this phenomenon. In 2014, on request of the regional agency of cultural affairs in charge of the study and conservation of the Cosquer cave (DRAC PACA, France), the CEREGE laboratory started a new scientific survey of the hydrogeological functionning of the cave. Pressure sensors have been installed in-situ, with a 5 minutes time-step recording, inside the cave in the air and in the water, in the sea, and in the air outside the cave (Figure 1). Pressure is converted to fresh or salted water column. We also beneficiated from the measurements done at the Port-Miou observatory (SNO Karst) located 5 km eastward from the cave, that gives access to pressure data and that can be used as reference for the hydrological states of the karst aquifers in the area (Arfib & Charlier 2016).

Figure 2: The water level inside the Cosquer cave at three hydrologic periods: a) 04/10/2014, the water level is low, the air pressure inside the cave is high; b) 24/08/2017, the water level is high, the bottom of the horses panel is flooded; c) 27/09/2017, the water level is very high, the air pressure in the cave decreased close to the outside atmospheric pressure.

The three years of data show that the cave air pressure is always higher than the normal atmospheric pressure. The air overpressure ranges between a few centimeters to 1.2 m. Water level in the cave is the same in the several pools. It varies at the annual scale up to 1.2m, correlated with the air overpressure variations. Taking the horses panel as a reference art rock in the cave, the paintings are usually out of water (Figure 2a), but can be partially flooded from 1 to 3 months depending on the year, during summer and early autumn (Figure 2b,c). Water level (or air pressure) varies at several scales. Daily, the sea tide is transferred within the coastal cave, but the water level variation is limited by the cave air volume. This clearly confirms that the cave behaves as a confined medium. At the annual scale, short events have a very high impact, decreasing the water level in the cave to more than 1 meter in a few hours. In this case, the water level decrease is mainly due to an equivalent increase of air overpressure. We showed that these events are generated by waves outside the cave. Waves can transfer air through the limestone massif by karst or cracks usually flooded. When flooded the submarine karst paths are limited to water transfer and the cave remains confined. The karst massif can be conceptualized by a vadose zone with very low permeability, and a saturated zone below the mean sea-level where karst network is open (Figure 3). Karst network geometry should be special and connected with the waves properties in order to allow the air to flow only in one way from the sea to the cave. As a first step of the further work still needed, we showed that the overpressure events are linked with direction and height of the waves.

This study shows that karst environment plays an essential role in the conservation of our archeological natural heritage. Permeability in a karst massif can be highly heterogeneous at various scales; we show that even at the scale of a karst cave the permeability could be contrasted, e.g. very low in the vadose zone and high in the saturated zone in the Cosquer cave.

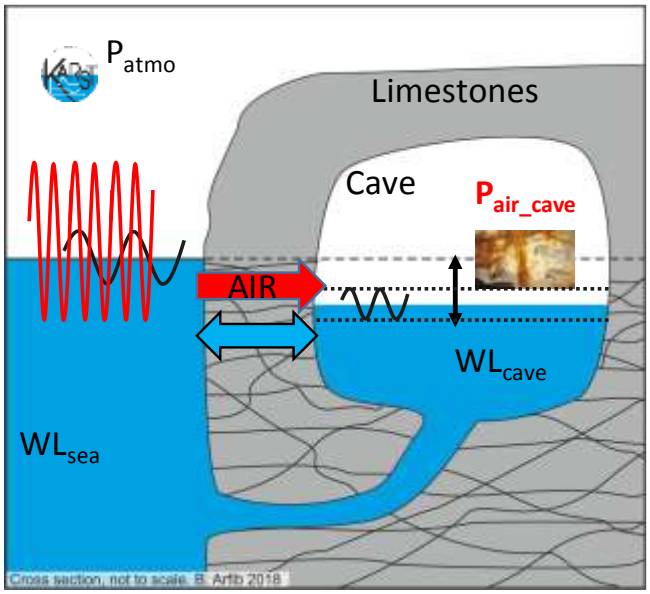

Figure 3: Conceptual cross-section of the Cosquer karst functionning. The cave is partly confined. Tide variations propagate inside the cave but are lower than the sea-tide (black curve). Specific waves height and direction (red curve) inject air inside the cave and generate an air overpressure that decreases the water level inside the cave.

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