Cavers of the Lost Groundwater Collector

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Abstract

Many caves have been explored in the Devoluy karstic system developed within Upper Cretaceous calcareous rocks in the French Alps. The Devoluy watershed is around 160 km squared. Its geological structure is a north-tilted syncline where the main outlets are the Gillardes springs located at 880 m altitude. The first speleological explorations of Devoluy’s karst happened at the end of 19th century with Edouard Alfred Martel. Since, it has never stopped motivating mainly French speleologists.

In the late 2000s, the “Tune des Renards” cave, which known depth was 330 meters, aroused the curiosity of a group of speleologists. They led the exploration to a depth of 946 meters, matching with the elevation of 910 m, just above the saturated zone. During explorations, the expected groundwater collector was not found and raised the question about the water flow organization in this karstic system. Therefore, speleologists proposed a dye tracing program supported by the Hautes-Alpes French Department, the National Water Agency and Electricité de France company. One of the recent dye tracing was carried out in august 2019 at the bottom of the “Tune des Renards” cave during a two-day speleological exploration.

Résumé

Depuis plus d’un siècle, de nombreuses grottes ont été explorées dans le Dévoluy. Ce massif karstique des Alpes françaises est composé principalement de roches calcaires du Crétacé Supérieur et présente une structure géologique en synclinal incliné vers le nord. Son bassin versant d’une surface de 160 km² a pour exutoires les sources des Gillardes, à 880 mètres d’altitude. Les premières explorations spéléologiques du massif ont lieu à la fin du XIXe siècle par Edouard Alfred Martel. Depuis, les spéléologues français n’ont cessé son exploration.

En 2007, le Chourum de la «Tune des Renards», connu jusqu’à une profondeur de 330 mètres, suscite la curiosité d'un groupe de spéléologues. Ils mènent son exploration à une profondeur de 946 mètres, soit 910 mètres NGF, juste au-dessus de la zone saturée du système karstique. Cependant, le collecteur d'eau souterraine attendu n'est pas découvert et soulève des questions sur l'organisation des écoulements dans ce système. Les spéléologues proposent alors un programme de traçage soutenu par le département des Hautes-Alpes, l'Agence nationale de l'eau et la société Électricité de France. L'un des récents traçage a été réalisé en août 2019 au fond de la «Tune des Renards» lors d'une exploration spéléologique de deux jours.

1. Introduction

The Dévoluy massif is an important karstic system in the French Alps. With more than 600 caves known to date, it has long-time attracted French explorers.

In 1899, E.A. Martel attempted to explore the large pitch of *Chourum (local name for cave) Martin* (MARTEL, 1928). In 1927, R. de Joly led a successful exploration in the same pitch and was followed by A. Bourgin, also known for its explorations at the *Puits des Bans*, spillway of the *Gillarde*s hydrological network. Then, numerous explorations camps were undertaken by tens of local clubs and from the whole France in the early 1950s until today.

Explorations in the karstic system have always been tough due to mountain conditions supplemented by an unstable rock very rich in flint beds, making narrow passages very arduous. Among the 630 caves distributed in the massif, tens are major by their depth, their length but also their characteristic.

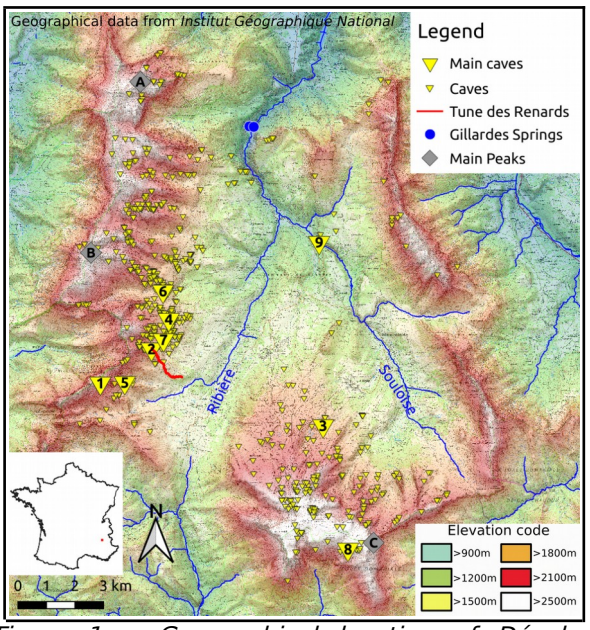

Figure 1 : Geographical location of Dévoluy massif and known caves distribution. The red line shows the Chourum de la Tune des Renards extent (2).

The list below indicates their name - depth - length preceded by a location index referring to Fig. 1:
(1) Rama-Aiguilles – 958 m – 6100 m ;
(2) Tune des Renards – 946 m – 2780 m ;
(3) Frigo – 560 m – 1600 m ;
(4) Combe-des-Buissons – 510 m – 4375 m ;
(5) Lily-Rose – 510 m – 820 m ;
(6) Réseau Gnocchis – Forcenés – Baume de France – 455 m – 6650 m ;
(7) Scarabée – 373 m – 3470 m ;
(8) Réseau du Pic de la Pare – 230 m – 4800 m ;
(9) Puits des Bans – 330 m – 1750 m.

One of these major caves, the *Chourum de la Tune des Renards*, has been explored over several decades. Fortunately, the explorers' efforts were not in vain. They reached the bottom of the cave at a depth of 946 meters corresponding to the lowest altitude reached in the massif as well as the nearest height to the karstic system saturated zone.
This has justified the implementation of dye-tracing experiments aiming to characterize the saturated zone.

2. Location and geology of the Dévoluy karstic system

The Dévoluy massif is located in the south-east of France, in the Hautes-Alpes French department (Fig.1). The three main peaks are : [A] the *Mont Obiou* (2789 m), [B] the *Grand-Ferrand* (2758 m) and [C] the *Pic de Bure* (2709 m).
The Dévoluy karstic system is mainly composed of calcareous rocks from Upper Cretaceous. Its geological structure is a north-tilted syncline where the main outlets are the *Gillardes* springs located at 880 m altitude.
The Dévoluy watershed is around 160 km squared. It drains mainly waters due to infiltration. Significative surface waters come from the *Souloise* river and its tributary, la *Ribière*.

3. Modern explorations at the Chourum de la Tune des Renards

The first exploration of the *Chourum de la Tune des Renards* started 44 years ago. Many exploration camps were organized to get to the current state of knowledge representing at least 700 cumulated working hours.
It started in 1976 during a technical training organized by the *École Française de Spéléologie (EFS)*. After passing through very difficult squeezes, the trainees reached the depth of 171 m (PAILLET, 1977). One year later, a new team reaches the depth of 330 m. The hard way of progressing, added to the possibilities of new explorations in the massif, caused the temporary ending of the explorations. 30 years later, in 2007, a new team starts the explorations again. The cave entrance is at 1 840 m elevation after a short walk and a vertical drop of 400 m. Fig. 2 shows the new discoveries performed between 2009 and 2014 and leading to the final depth of 946 m. The traverse ends on an impenetrable squeeze in which the water collected in the cave system flows. Over the five years of exploration, the topographic survey was performed and several climbing were carried out to continue exploring the network.
Explorations became increasingly longer so the team make it more comfortable by widening squeezes, securing the rigging and setting up a bivouac at the depth of 660 m.
To describe the cave, we can say that the entrance has a good size but it is quickly followed by a cave-in which was opened and secured during the EFS training. Then a squeezes succession was widened between 70 and 100 meters depth. The network developed mainly along the local dip, which is 30° South-East.

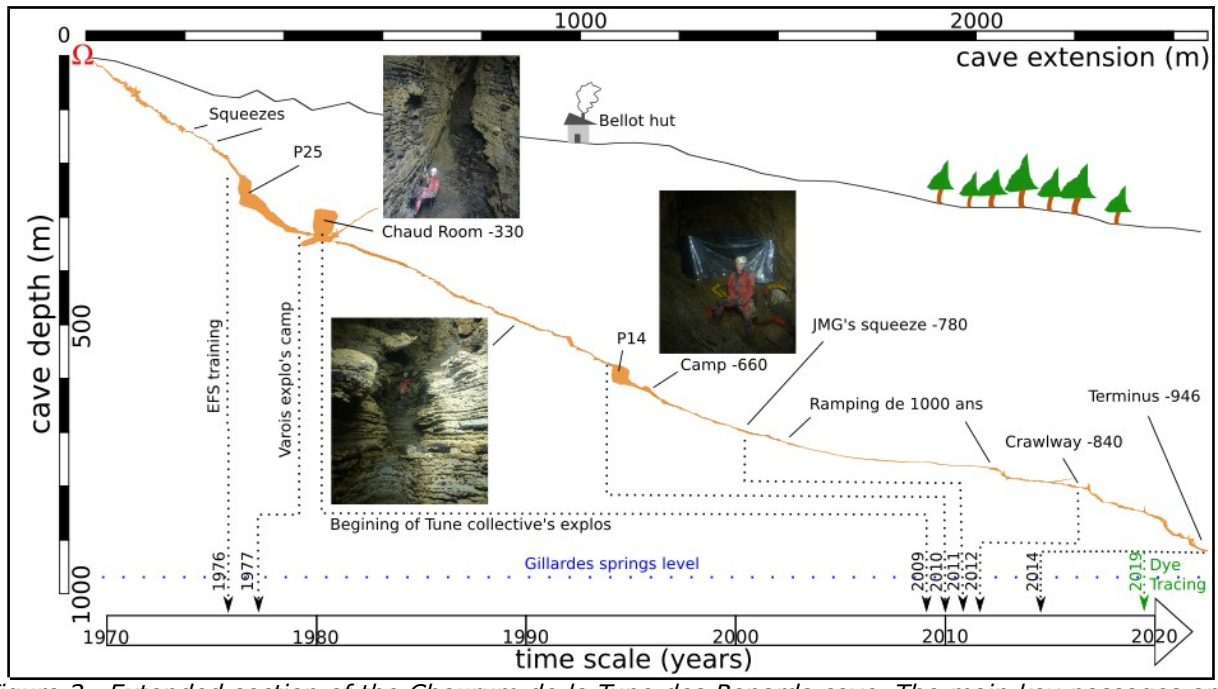

Figure 2 : Extended section of the Chourum de la Tune des Renards cave. The main key passages and breakthroughs are shown. The blue level corresponds to the Gillardes springs (880 m ASL).

There are a lot of small vertical passages up to 25 m depth. Although most of the passages have a moderate size, there are some larger rooms as the *Chaud Room* at 300 m depth or the *Camp* at 660 m. Beyond the *Camp* room, several narrow and wet passages are difficult to cross. At the depth of 840 m, a tough crawl-way has long been impenetrable before being widened. To the end of the cave, small pitches are intersected by meanders. The last one follows a fault leading to a very narrow, muddy and watered squeeze which is the current terminus at 946 m deep. At this point, we are only 15 m above the *Gillardes* spring level i.e. at the elevation of 910 m. Taking into account the tributary proximity and the absence of permanent flow into the cave, the existence of a groundwater collector was questioned.

4. August 2019 : Dye-tracing experiment in the Chourum de la Tune des Renards

Since 2014, scientific measurements were conducted in the *Chourum de la Tune des Renards* for the understanding of the hydrology of the karst system.

Pressure and temperature measurements probes were set down at the cave end to register the water loading level in the network. The recording lasted 4 years and Fig. 3 shows the water loading data due to winter 2018 rainfall. As the the probe is set down 15 m above the *Gillardes* springs level, small rises were not recorded. The data show that the water loading exceeds regularly 100 m in the cave, which is confirmed by clay deposits on the cave walls. A strong link between the water level and the *Gillardes* springs water flow is highlighted on Fig. 3. LISMONDE et al. (2007) shown the same water flow/level link at the *Puits des Bans* cave. Both caves are located upstream and downstream of the hydrological system meaning that the existence of a single ground-water table should be the simplest hypothesis.

In 2015, a dye tracing campaign started aiming to understand the underground water flow organization. Many dye tracing were carried out : *Chourum des Aiguilles* (2015), *Chourum de la Tune n°10* (2017), *Chourum Napoléon*, part of the *Pic de la Pare* network (2018).

In august 2019, we performed a dye tracing at the *Chourum de la Tune des Renards* during the low water period to inject the dye closer to the saturated zone. First, climbing and dye tracing gear were carry to the Camp by two cavers during a 10 hours exploration at the end of july 2019. Then, on august 3rd, 4 cavers went down the cave for a 30 hours exploration, one

bivouacking night included. One goal was to climb a shaft close to the end of the cave while the dye tracing experiment was conducted. It took one hour to inject 3 kg of fluorescein with hands and feet into a 6 °C water.

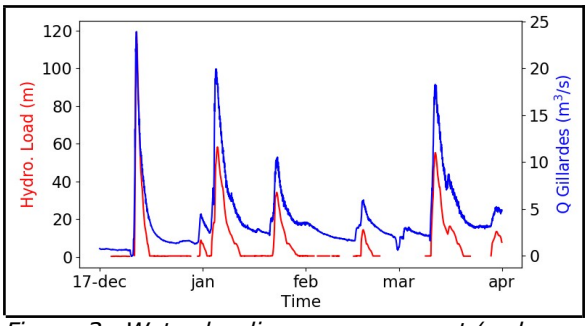

Figure 3 : Water loading measurement (red curve) in the Chourum de la Tune des Renards and water flow measurement (blue curve) at the Gillardes springs as a function of time.

36 days later, the dye-recovery starts at the G*illardes* springs where two fluorimeters were set up on august, 1st, 20 m below the tributary. Fig. 4 shows the dye-recovery curve. The maximum of dye-recovery occurred 46 days after injection and stopped 62 days after injection. The whole collected data (topographic surveys, water flow and electric conductivity of springs, dye tracing experiments) have to be analyzed to propose an organization of the the water flowing in the Dévoluy's karstic system.

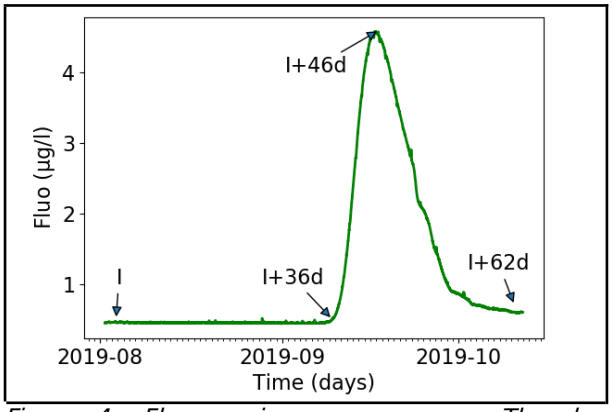

Figure 4 : Fluorescein-recovery curve. The dye was injected (I) at the end of the Chourum de la Tune des Renards on August, 3rd, 2019.

We plan to conduct a new dye tracing at the cave end before low water period. The aim is to refine the groundwater path in the saturated zone. Does it go through narrower karstic tubes or in larger passages?

5. Conclusion

Dévoluy is a promising massif which still has many secrets to unveil but the tough approach and way of progressing add difficulties to the explorations. In the *Chourum de la Tune des Renards*, explorations allowed to discover a large network not common in the Dévoluy's karstic system. The current terminus gathering squeeze, water flowing and mud, should not be cross for a long time.

However, parallel vertical networks still need to be explored.
Anyway, the cavity retains scientific interest for the understanding of speleogenesis and hydrogeology at the scale of the massif. All of these discoveries and advances in understanding underground networks are only possible with the motivation of cavers. For us, mixing caving as a sport and a science is the DNA of our activity.

Acknowledgments

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