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Seismic and hydro-geophysical monitoring in the Jura mountains

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1. Introduction

Seismic activity in the Jura-bresse area has been investigated based on the CEA catalog (see Fig. 1, Larroque et al., CRG, 2021). The station coverage has been recently improved with the development of RESIF-EPOS.

In 2018, the regional seismic network JURAQUAKE has been deployed. The objective is to better characterize the local microseismicity affecting the northern part of the Jura arc and investigate the potential role of fluids in triggering earthquakes in this faulted and karstified region.

Seismicity in the Bresse-Jura area

- about 1642 events recorded between 1996-2019
- superficial events in the SW ($z > 15$ km) and deeper events in the NE (down to 25 km)

Largest events

1. Besançon-Roulans 2004/02/23, Mw 4.5 (Delouis-Géoazur)
2. Rumisberg 2005/05/12, ML 4.1 (Deichmann et al., 2006)
3. Jeurre 1971/06/21, ML 4.4, (Sambeth and Pavoni, 1988)
4. Epagny 1996/07/15, ML 5.3, (Thouvenot et al., 1998)
5. Bresse 2018/11/21, Mw 3.8, (Delouis-Géoazur)

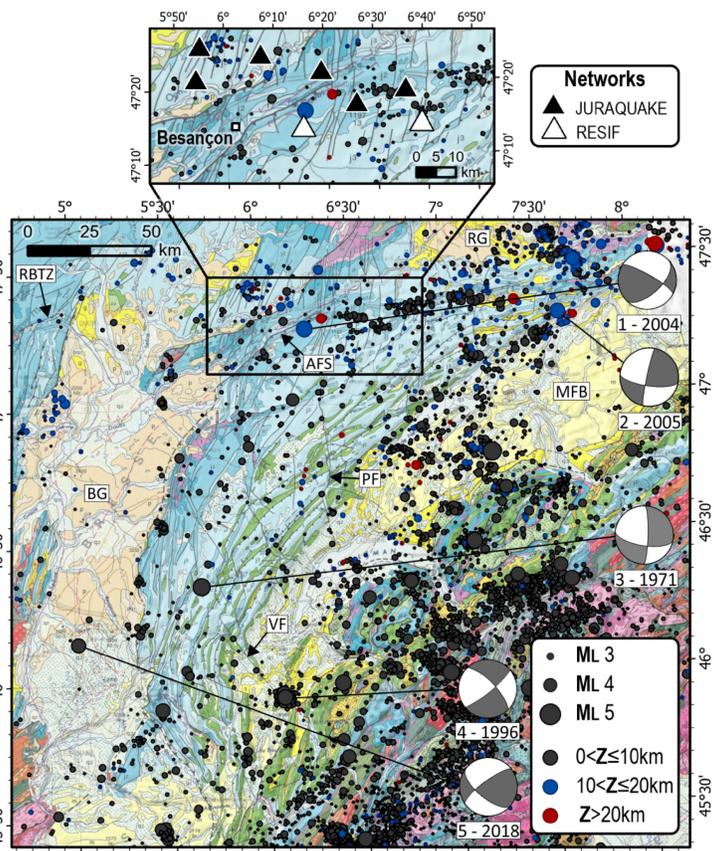


Fig. 1 : Seismicity overlaid on the geological map of the Jura area, from the CEA_1996–2019 catalog (all magnitudes) and Chantraine et al. (2003) (from Larroque et al., CRG, 2021)

2. The Fourbanne observatory

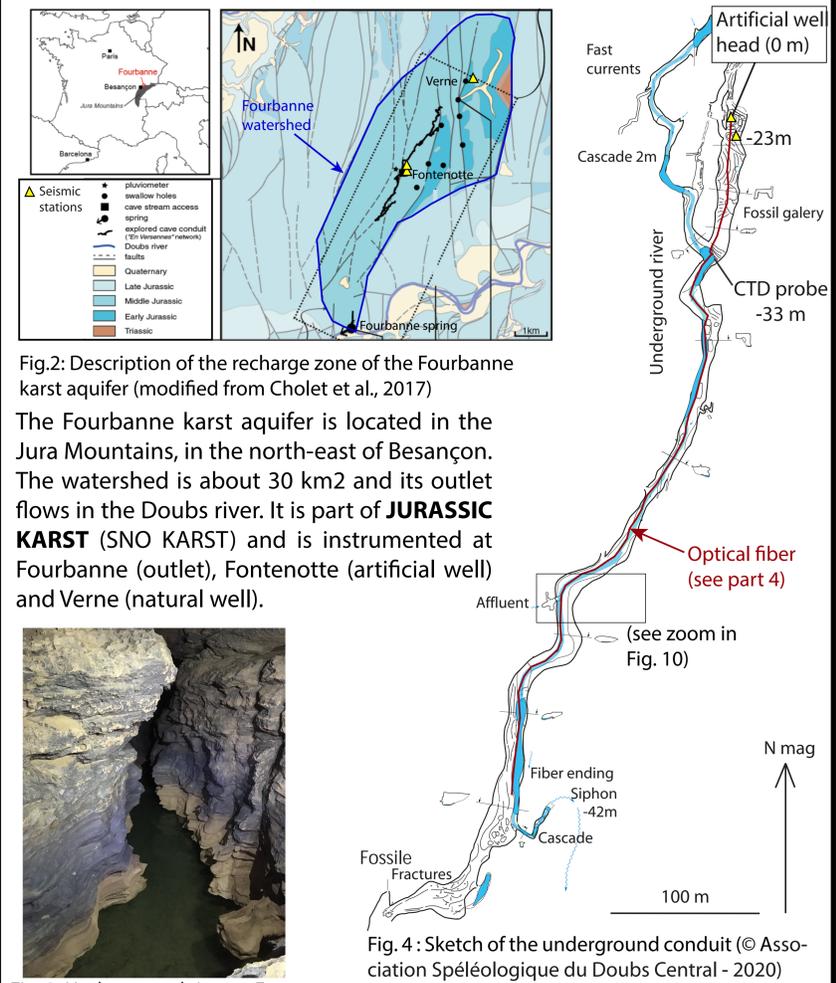


Fig.2: Description of the recharge zone of the Fourbanne karst aquifer (modified from Cholet et al., 2017)

The Fourbanne karst aquifer is located in the Jura Mountains, in the north-east of Besançon. The watershed is about 30 km² and its outlet flows in the Doubs river. It is part of JURASSIC KARST (SNO KARST) and is instrumented at Fourbanne (outlet), Fontenotte (artificial well) and Verne (natural well).

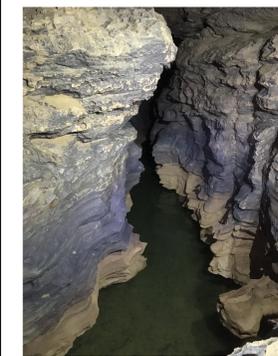


Fig. 3: Underground river at Fontenotte

3. Seismic monitoring of hydrogeological events

Spectral analysis

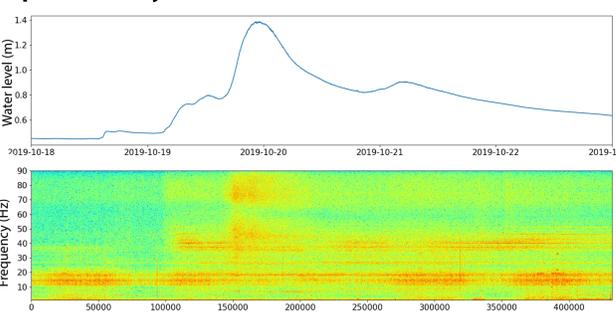


Fig. 5 : Hydrograph of the Fontenotte underground river and spectrogram of the underground seismic station for the Z component (see part 2 for the station location).

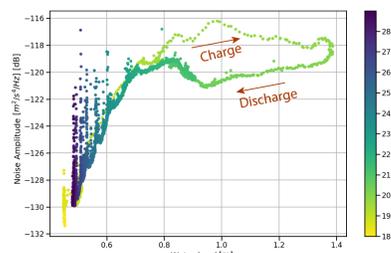


Fig. 6 : Noise amplitude as a function of water level during the flood event described in Fig. 5. Each point corresponds to the average of the values over 2 hour signals.

Three seismic stations have been installed on the karst aquifer of Fourbanne and coupled to the existing hydrogeological observatory, allowing to monitor water flow and sediment transport. **Charge and discharge cycles** are very well detected above ~0.75 m of water level.

Velocity change estimations

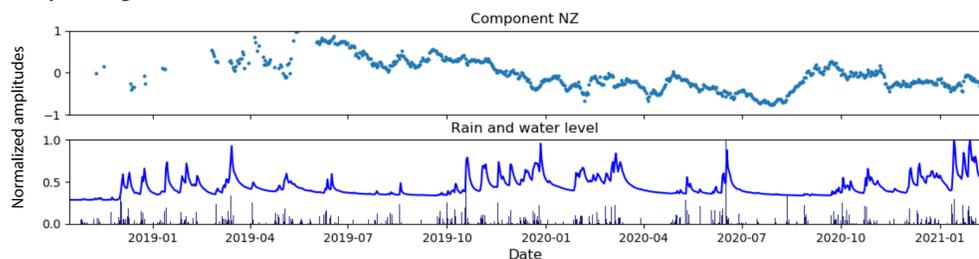


Fig. 7 : Normalized amplitudes of the NZ component velocity variation (dv/V with a 20-day moving average for the 2-4 Hz frequency band), rain and underground river water level.

Preliminary outcomes of the autocorrelation applied on the signals collected from the station in depth show a long term **decrease of velocity** potentially related to a long term water level increase/soil saturation at Fontenotte.

Perspectives

An acquisition period of 4 months will be held in winter 2021 in which data will be collected from a **60-node seismic array** and **20 rain gauges**. Combining seismological and atmospheric data, the target will be to image the flow of water over time and space on the whole of the watershed (SISMEAU-CLIM project).

Reference

Christophe Larroque; Stéphane Baize; Julie Albaric; Hervé Jomard; Jenny Trévisan; Maxime Godano; Marc Cushing; Anne Deschamps; Christian Sue; Bertrand Delouis; Bertrand Potin; Françoise Courboulex; Marc Régnier; Diane Rivet. Seismotectonics of southeast France: from the Jura mountains to Corsica. Comptes Rendus. Géoscience, Online first (2021), pp. 1-47. doi : 10.5802/crgeos.69.

4. Detecting water recharge with fiber-optics

500 m of **fiber optic** cable has been placed along the underground karstic conduit for Distributed Temperature Sensing to detect points of recharge since rain water will be hotter/colder than the karst water. A high resolution **3D scan of the cavity** was also acquired with a long-range Zeb-REVO (GEOTOPO) to document the geological structures. The objective is to process jointly data from the fiber optic and the 3D scan to obtain a better understanding of the **recharge and transfer process** of the system.

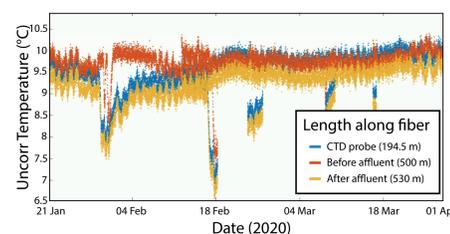


Fig. 8 : Plot of the uncorrected fiber temperature in function of the date for 3 positions: at the vicinity of the CTD probe, right before a potential affluents and right after it. The fiber indicates cooler water is entering through the affluents.



Fig. 9 : Installation of the optic fiber in a vertical plane for water level detection inside the cavity.

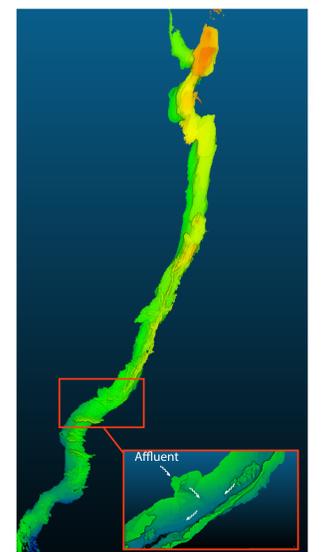


Fig. 10 : Top view of the 3D scan of the underground conduit; the northern part shows fractures that are oriented in the direction of the conduit (N-S), in the last quarter of the conduit appears a change in the geomorphology with fractures oriented E-W that can be also observed through the appearance of the affluents (zoomed section).

5. Conclusion

To have a finer investigation of this area, the JURAQUAKE network has been deployed in the north of Besançon to capture local microseismicity and monitor hydromechanic behavior of karstic reservoirs.

The heterogeneity of karst aquifers makes the use of multidisciplinary approaches mandatory to discern their functioning, as well as the spatio-temporal variation that occurs along their networks.

Acknowledgements

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