UNIVERSIDAD DE MÁLAGA

CEHIUMA CENTRO DE HIDROGEOLOGÍA DE LA UNIVERSIDAD DE MÁLAGA

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MONITORING AND PRELIMINARY ANALYSIS OF THE NATURAL RESPONSES RECORDED IN A POORLY ACCESSIBLE STREAMBED SPRING LOCATED AT A FLUVIOKARSTIC GORGE IN SOUTHERN SPAIN

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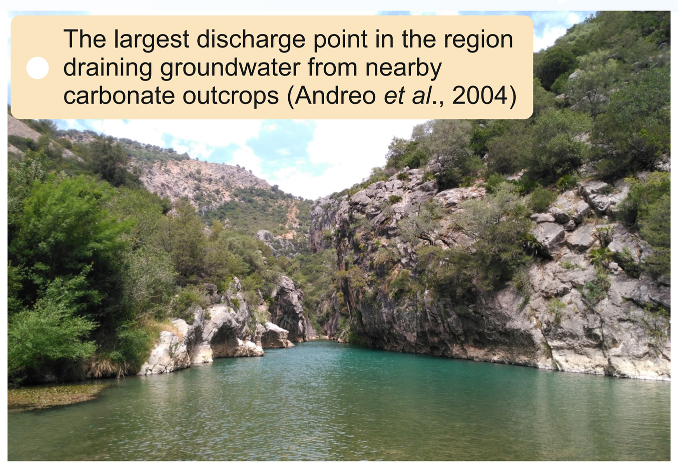

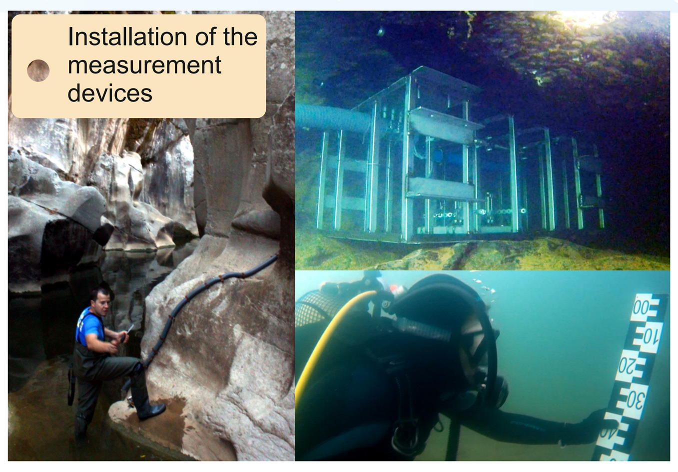

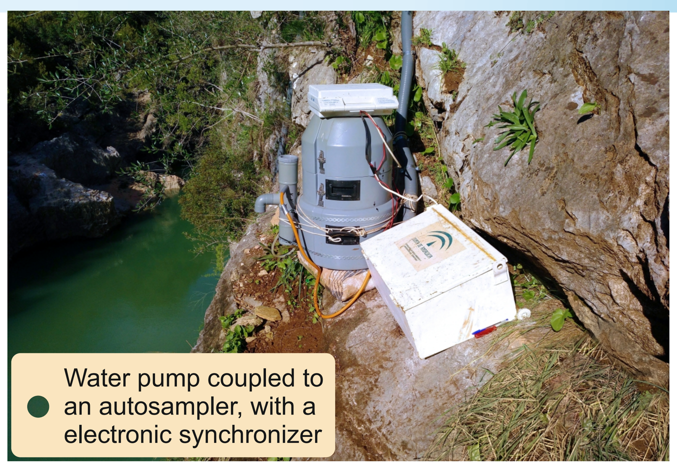

Introduction & Objetives

- In carbonate aquifers, analysis of natural responses of springs provides direct information on the hydrogeological functioning of karst aquifers.
- Poorly accesible sites require an adecuate and inventive combination of electronic datalogger/probes and supplementary facilities for acceptable monitoring results
- In this work, joint analysis of the data recorded in Charco del Moro spring (one hydrological year) has meant a significant improvement in understanding the behavior of the this site.

Site description

- Charco del Moro spring is located 85 km WSW from the city of Málaga, in the SW edge of Ronda Mountain (**Fig. 1**).
- The pilot site consists of ~ 500 m thick Jurassic dolostones and limestones, which present Triassic clays, and evaporite rocks at the bottom, and Cretaceous marly-limestones at the top (Martín-Algarra, 1987) (**Fig. 2**).
- This spring is an outflowing cave (Vauclusian type), at the bottom of a partially flooded gorge (Las Buitreras Gorge), eroded by the Guadiaro river streamflow (**Fig. 3**).
- The outlet is fed by a karst conduit with at least 120 m lenght of development determined by speleological explorations (Millán et al., 2006).

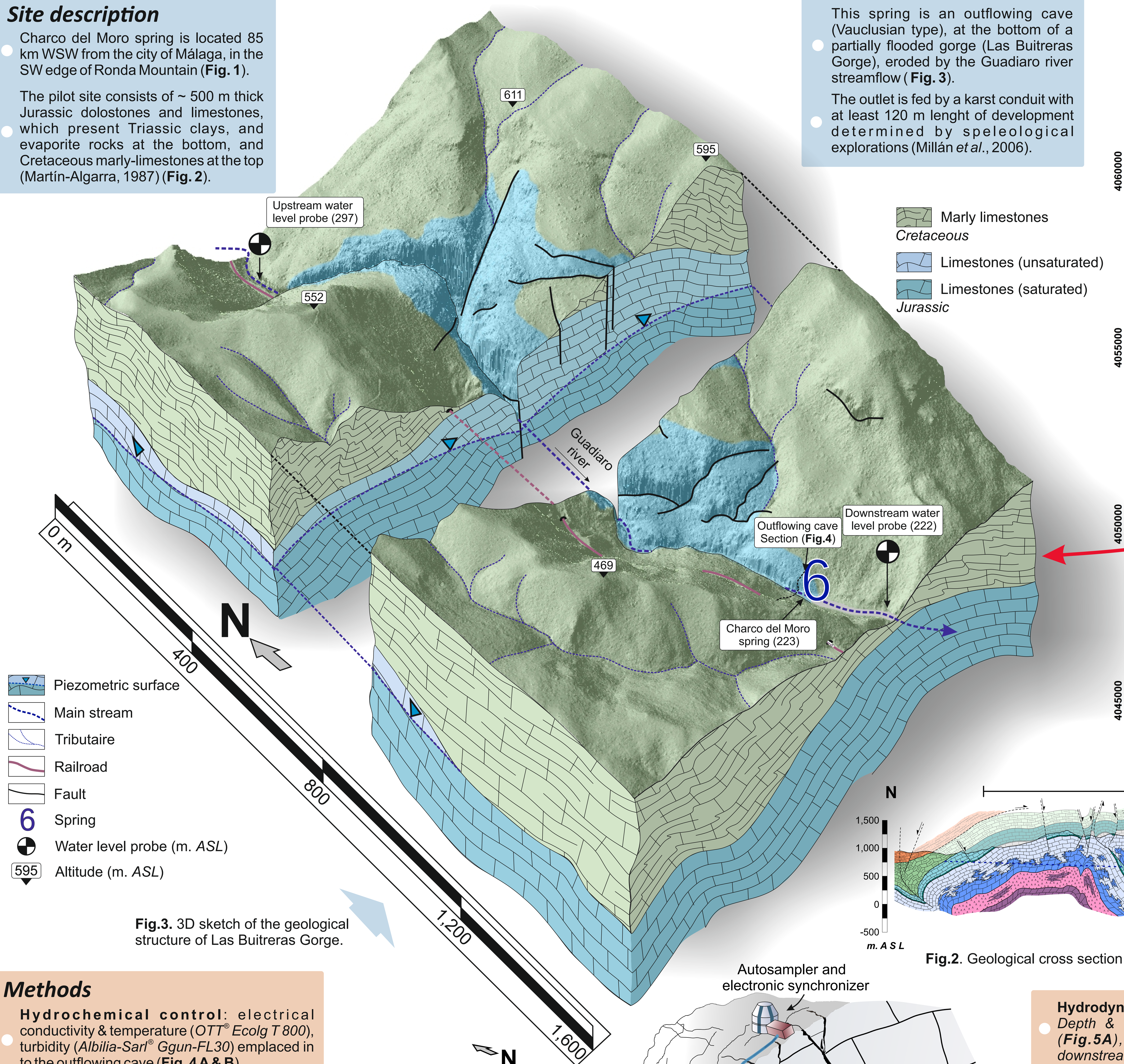

Fig.3. 3D sketch of the geological structure of Las Buitreras Gorge.

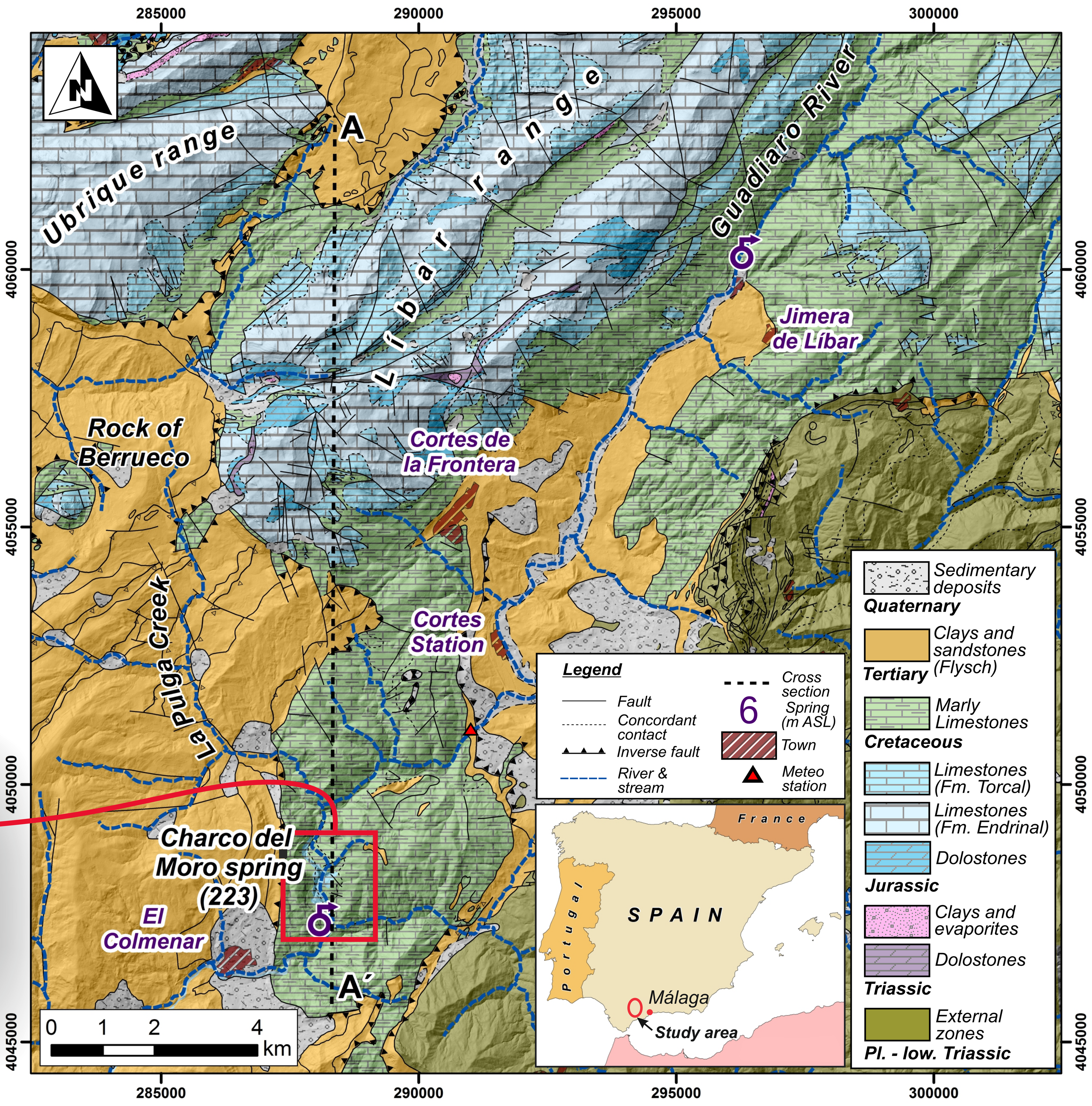

Fig.1. Geographical location and simplified geology of the test site in the Southern Spain.

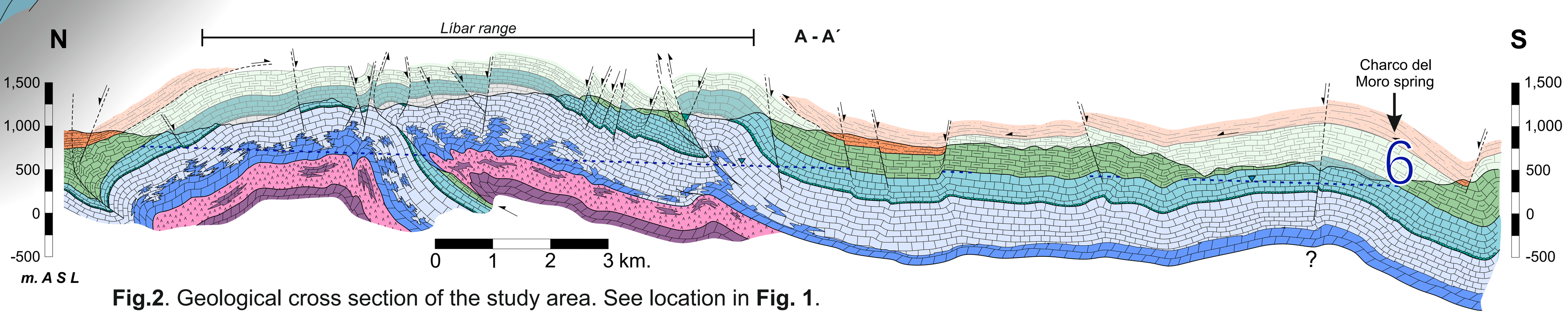

Fig.2. Geological cross section of the study area. See location in **Fig. 1**.

Methods

- **Hydrochemical control**: electrical conductivity & temperature (*OTT® Ecolg T 800*), turbidity (*Albilia-Sarl® Ggun-FL30*) emplaced in to the outflowing cave (**Fig. 4 A & B**).
- Groundwater sampling (*HACH® Sigma SD 900*) coupled with a water pump, with electronic synchronizer located over the spring.

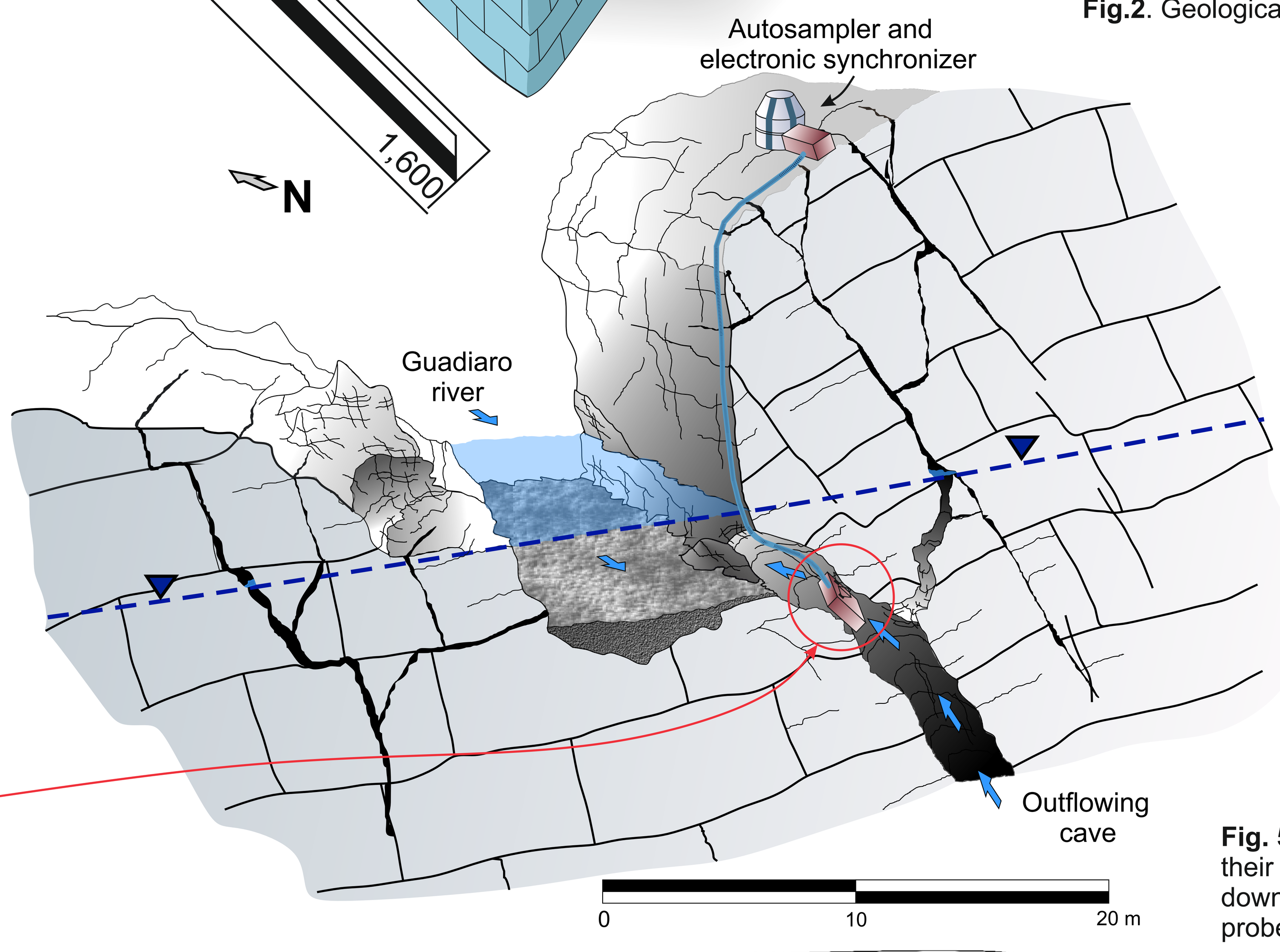

Fig.4A. Schematic section of spring and outflowing cave.

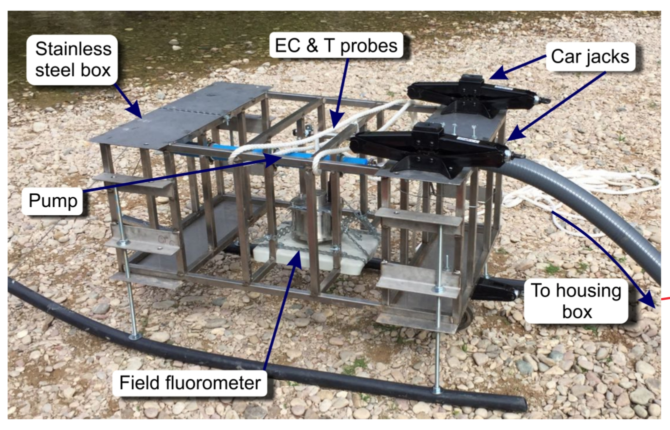

Fig.4 B. Photograph of different devices installed inside steel box.

- **Hydrodynamic control**: 2 *Odyssey® Depth & Temperature Loggers* (**Fig. 5A**), *installed upstream and downstream from spring* (**Fig. 5B & 5C**).
- Water-level variations were afterwards transformed into continuous records of discharge by applying the corresponding rating curve, whose accuracy was checked from single discharge flow measurements (**Fig. 5D**).

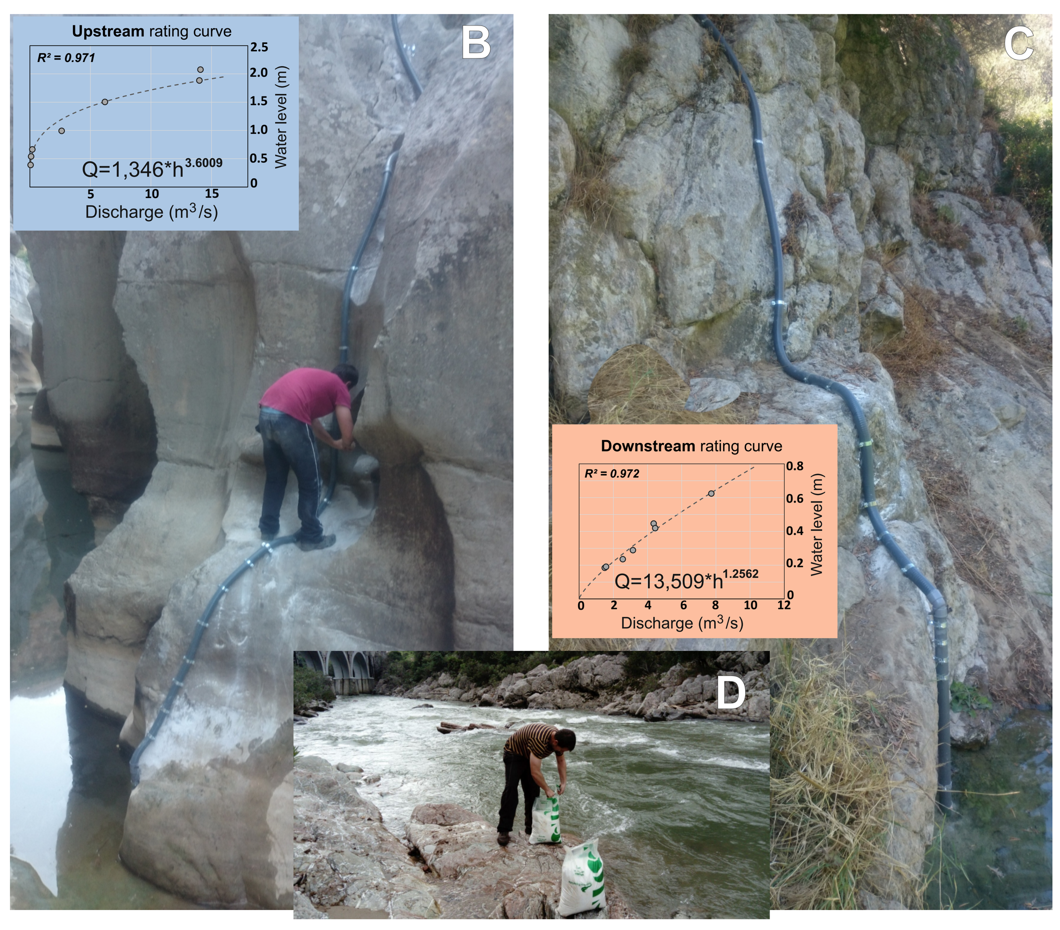

Fig. 5. Water level data loggers emplacement and their respective rating curves, upstream (**A**) and downstream (**B**). Odyssey Depth & Temperature probe (**C**). Upstream discharge measurement (**D**).

Results

- Quick flow variations in response to the main recharge events (from 1.2 to 8.3 m³/s); about 3 days between the center of gravity of precipitation and the discharge peaks.
- Falls of up to 200 µS/cm in EC during each recharge event. The magnitude depending on the quantity and intensity of rainfall.
- Water temperature falls (up to 0.7 ºC) following main rainfall episodes, within a general seasonal pattern influenced by air temperature.
- When rainfalls were intense, EC and water T decreases were preceded by more mineralized and slightly warmer groundwater.
- The turbidity values shows quick rises during all recharge events, proportionally to the intensity of precipitation episodes.

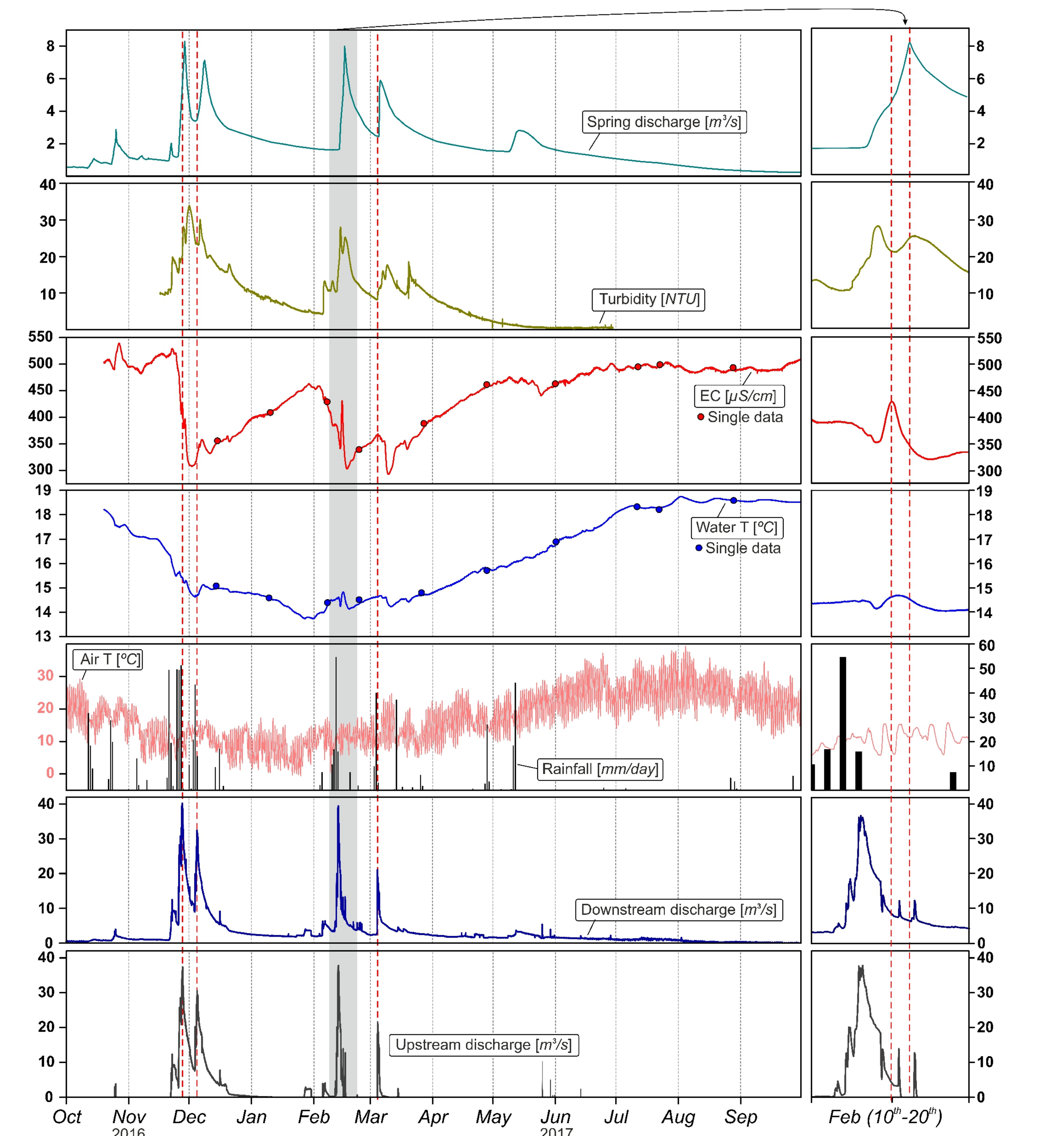

Fig. 6. Continuous records of water level, EC, T and turbidity measured in the water drained by Charco del Moro spring.

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Discussion

- Complex setting or poorly accessible areas where observation points are located, such as the site exemplified in this work, often imposes constraints on reliable field measurements and equipment installation, allowing an adequate and inventive combination of electronic data logger/probes and supplementary facilities for acceptable monitoring results.
- The analysis of the data recorded in Charco del Moro spring during one hydrological year has meant a significant improvement in understanding the behavior of the pilot system, also allowing a preliminary assessment of water resources to be inferred.
- Quick variations in discharge rate following recharge events reflect the existence of a highly developed karst network, which enables fast flows and short transit time of water within the system, from recharge areas to the spring. This is in agreement with the observed changes in EC and T, whose values were generally lower after recharge and higher at recession conditions.
- The high development of karst conduits also favored quick and sharp variations in turbidity during recharge events. Each rainfall episode was always accompanied by increases in turbidity signal, regardless of whether the episode caused "piston-flow" or dilution conditions (Pronk *et al.*, 2006; 2009).

Conclusions

- The adaptation and installation of field equipment for continuously monitoring the natural responses of a poorly accessible streambed spring located at a fluviokarstic gorge in Southern Spain has provided one-year records (2016/17), which allow performing a preliminary assessment of the hydrogeological behavior of the related karst system.
- Charco del Moro spring responds to precipitation events with sharp and fast increases in discharge rate and decreases in water mineralization and temperature; the last one presenting a seasonal pattern influenced by changes in air temperature. This hydrogeological behavior indicates that the system drained by the spring has a well-developed functional karstification, with rapid drainage and a low capacity to attenuate the input signal.
- Further efforts are necessary to determine the hydrogeological functioning of the system, especially in order to precise the hydrodynamic response of the spring, given the significance of this outlet as one of the largest discharge points in Andalusia. This is a crucial aspect that would be considered for the evaluation and management of water resources stored in the nearby carbonate aquifers, since they have direct consequences for water supplying in the region.

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Acknowledgments

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