COUPLING HYDRO-GEO-CHEMICAL AND ISOTOPIC APPROACHES TO ASSESS THE MAIN FACTORS CONTROLLING KARST DEVELOPMENT IN A FISSURE-DOMINATED CARBONATE AQUIFER SYSTEM (S SPAIN)

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UNIVERSIDAD DE MÁLAGA
CEHIUMA
CENTER OF HYDROGEOLOGY OF UNIVERSITY OF MALAGA

J. Prieto-Mera (1), J.A. Barberá(1) and B. Andreo (1)

Introduction and site description

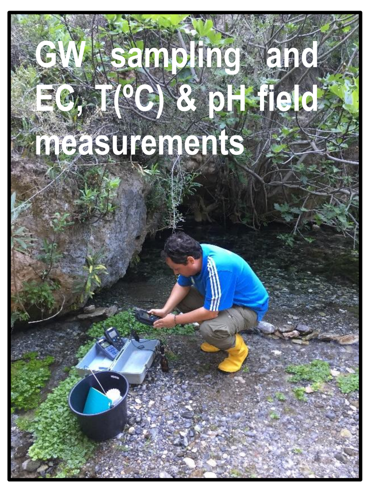
Study area: Sierra Tejeda, Almijara, Guájares and Albuñuelas mountains comprise a large outcrop (750 km² CA) of Triassic marbles in between of Málaga and Granada provinces at southern Spain. They constitute a large entity carbonate aquifer system providing strategic groundwater resources for drinking water supply in sparse urban settlements and crops irrigation.

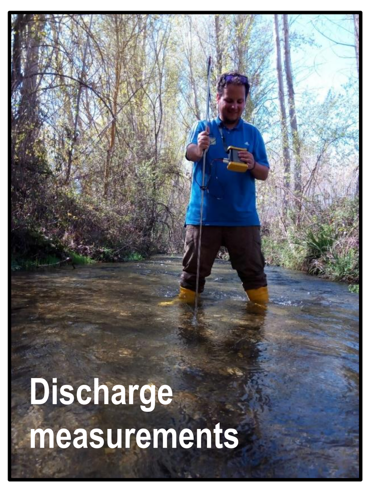
Hydrogeological settings: The aquifer geometry is strongly conditioned by the tectonic deformation of metamorphic rocks sequence (Paleozoic metapelites and Triassic calcareous and dolomitic marbles)

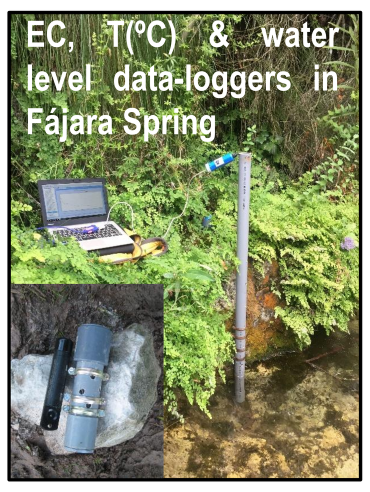
- **Recharge:** diffuse infiltration (rain and snow melting) much bigger than preferential infiltration (little exokarst development)
- **Discharge:** mainly in natural regime through karst springs and permanent groundwater (GW) outputs towards dug valleys. In addition, GW transference must exists toward northern porous aquifers.

Objective: The present research aims to refine the current hydrogeological knowledge of large-scale fissure-dominated carbonate aquifers regarding flow mechanisms and geochemical processes defining observed groundwater chemistry.

Methodology: Two-year monitoring program (regular measurements of EC, temperature, discharge, major ions and *$\delta^{13}C$ data*) from three selected discharge points (Fájara, Cijancos and Maro springs), which are representative of different aquifer functioning.







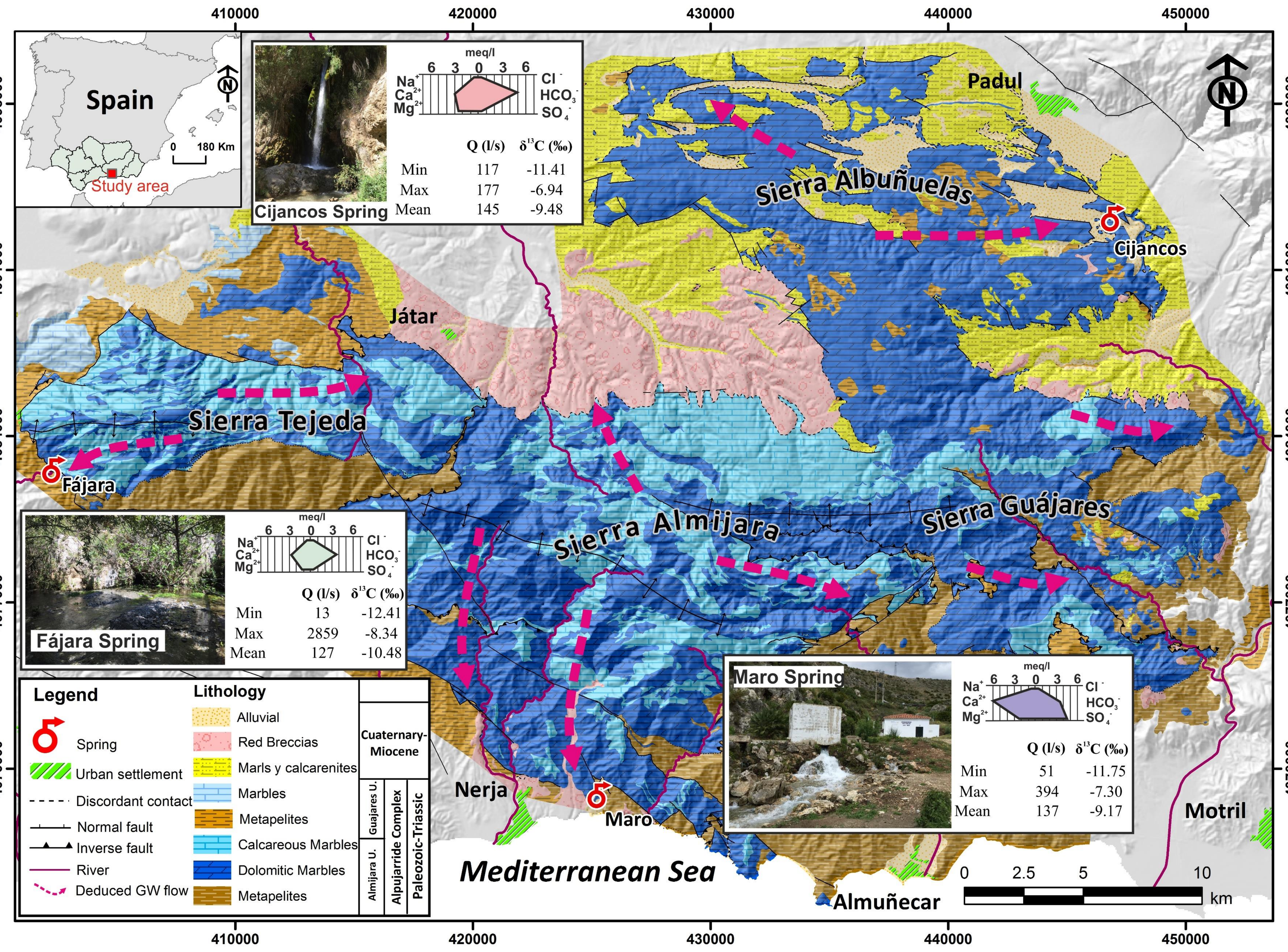


Figure 1. Location, hydrogeological features and hydrochemical and isotopic information (major ion concentrations and statistics of discharge and $\delta^{13}C$ data)

Results

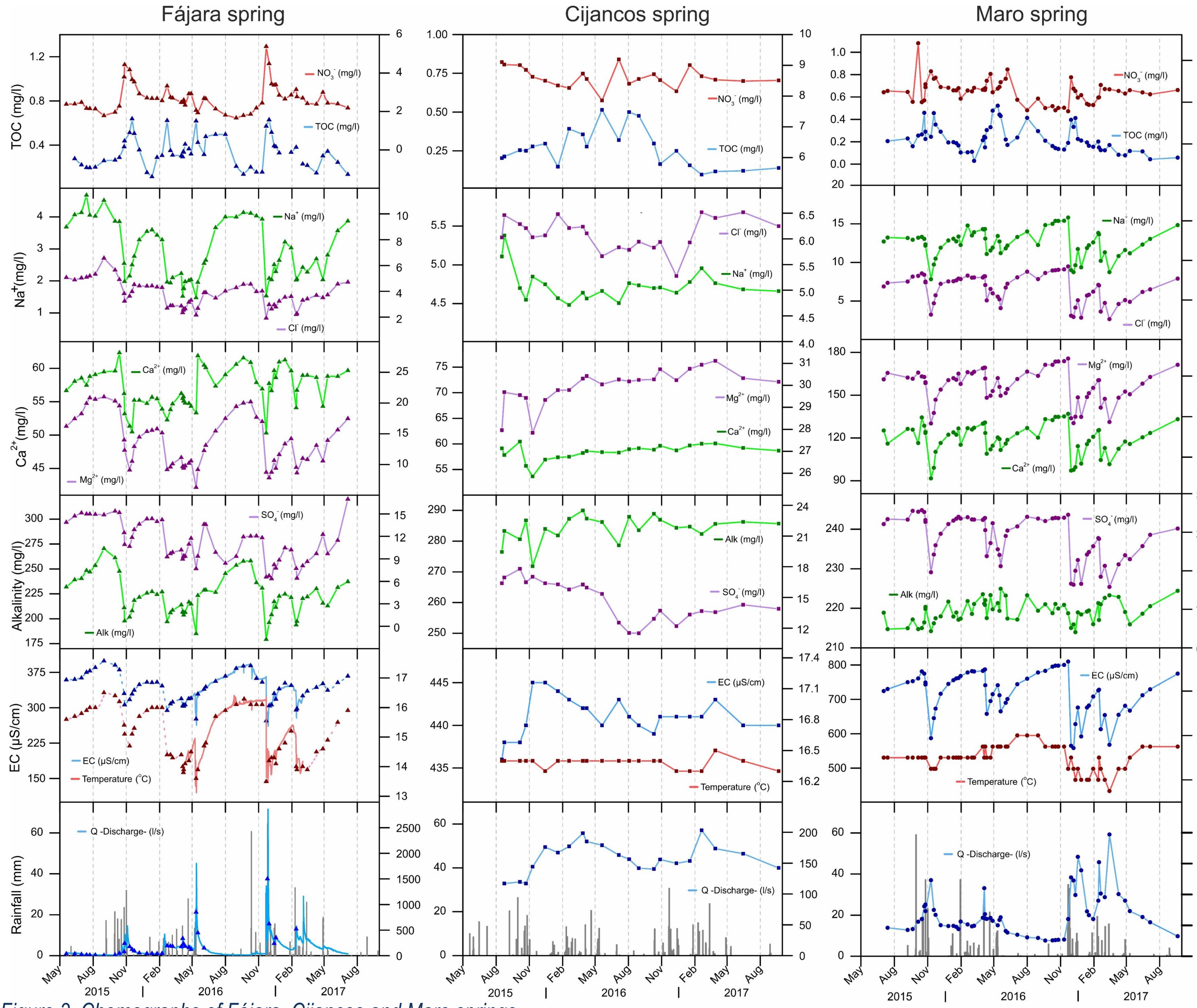
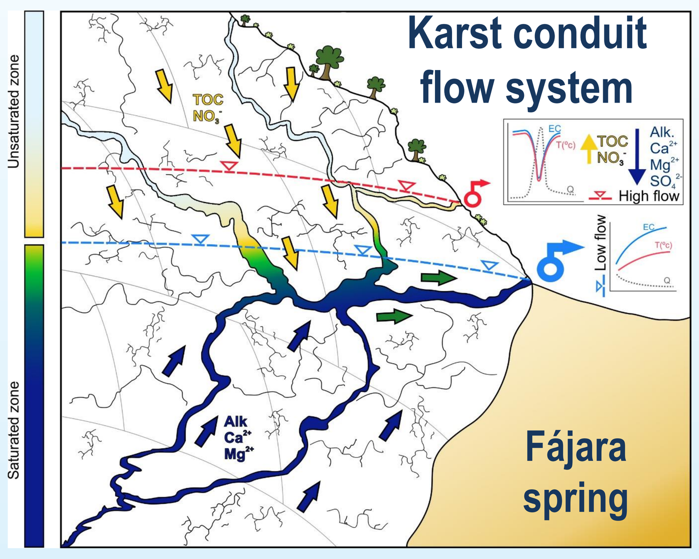


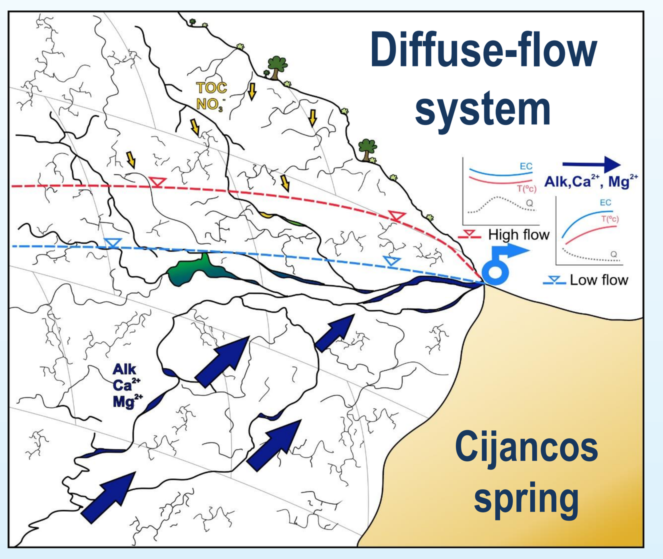
Figure 3. Chemographs of Fájara, Cijancos and Maro springs

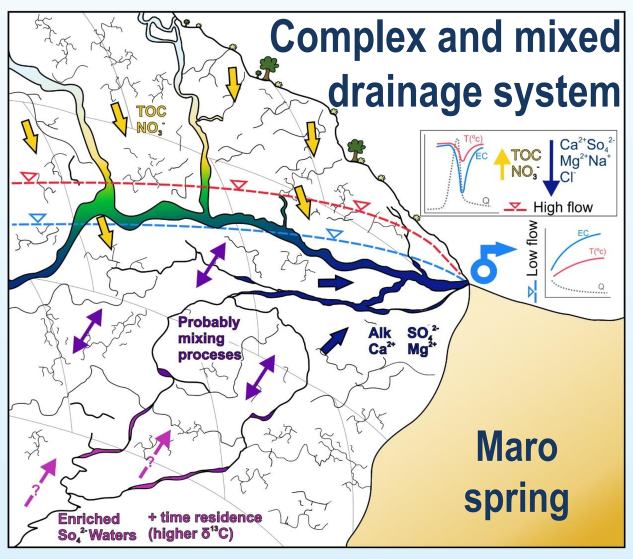
Hydrodynamic response: < 1day
Fast and marked falls in GW mineralization and water temperature per hydrodynamic pulse. Most solutes evolve as EC, except TOC and NO_3^-, which maximun values are reached during first flooding of water year, coinciding with generalized dilutions. This is consequent with fast infiltration through karst conduits.

Hydrodynamic response: seasonal
The narrowest variations of Cijancos spring in almost all parameters (hydrodynamic, water temperature and hydrochemistry) of the examined outlets denotes a diffuse type dominant flow system due to the presence of fissured dolomitic marbles in its catchment area.

Hydrodynamic Response: > 1day
Synchronous evolution of EC, water temp., SO_4^{2-}, Ca^{+2} and Mg^{+2}, Na^+ and Cl^- which are opposite to TOC and NO_3^-. Chemograph shape seems indicate fast flow by relatively well develop karst conduit through the unsaturated zone.







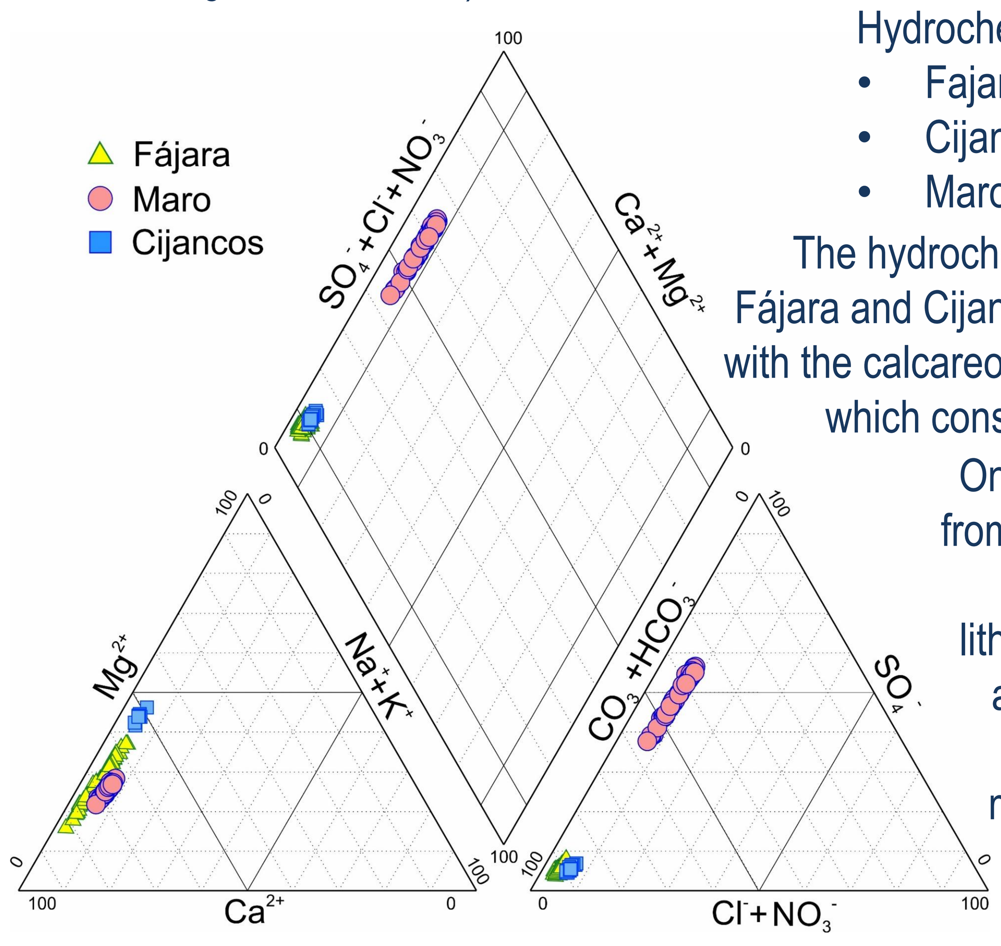


Figure 2. Piper diagram

Hydrochemical facies:
- Fajara: Ca-HCO3
- Cijancos: Ca-Mg-HCO3
- Maro: $Ca-SO_4^{2-}$

The hydrochemical facies of GW from Fájara and Cijancos springs are coherent with the calcareous and dolomitic marbles which constitute the aquifer system. On contrast, high SO_4^{2-} GW from Maro spring seem to be associated with buried lithologies other than that of aquifer materials (Triassic calcareous/dolomitic marbles), likely containing gypsum/sulphide bearing materials.

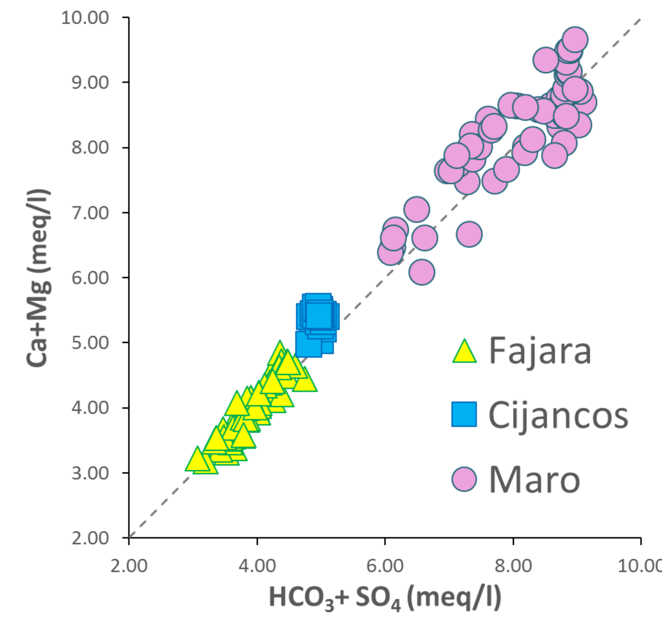


Figure 4. $Ca+Mg$ vs. $HCO_3+SO_4^{2-}$

The chemical reactions deduced from spring water are commonly CO_2 exsolution and calcite-dolomite dissolution, but also gypsum dissolution and/or sulphide oxidation processes in the case of Maro spring.

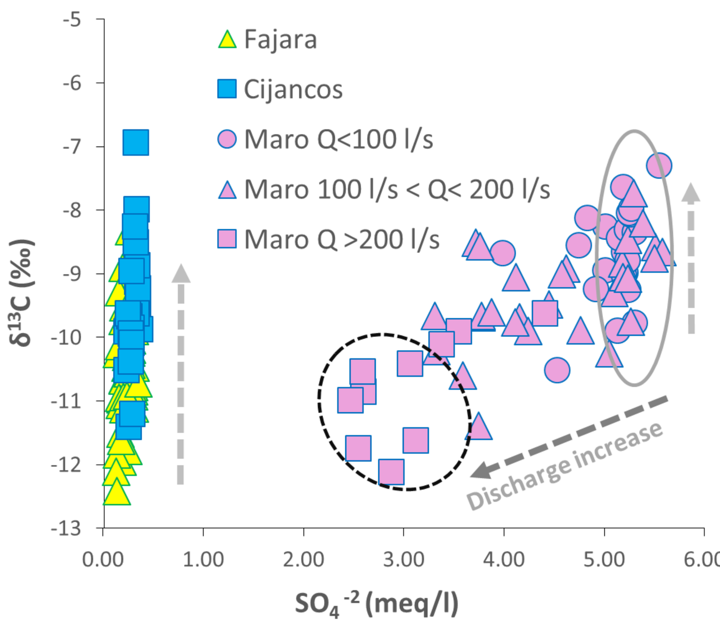


Figure 5. $\delta^{13}C$ vs. SO_4^{2-}

Maro spring waters show lower concentrations of SO_4^{2-} when the values of $\delta^{13}C$ tends toward more negative values. This is consistent with the drainage of high flows. Therefore, the source of SO_4^{2-} is likely more associated with the saturated zone of the aquifer.

Conclusions

The analysis of natural responses of selected springs showing distinctive aquifer behavior and the chemical reactions governing chemical composition of studied GW have permitted to decipher the hydrogeological heterogeneity of the karst functioning in a fissured-dominated karst aquifer at S Spain. The buffered signals observed in the chemograph of Cijancos spring are indicative of a typical diffuse flow system characterizing the global aquifer behaviour. On contrast, fast and large hydrodynamic and hydrochemical variations deduced from Fájara spring record denote a higher development of inner karstification in the aquifer sector that drains, providing a marked karst conduit flow type. Mixed time series describing Maro spring chemograph, along with the existence of SO_4^{2-} enriched GW (up to 200 mg/L), highlight a complex and mixed drainage from a fissured/karst flow system and mixing processes between recently infiltrated waters and old GW from saturated zone.

(1) Department of Geology and Centre of Hydrogeology of the University of Malaga (CEHIUMA), Spain. prieto@uma.es