

INTRODUCTION

The combination of hydrodynamic responses with physico-chemical parameters and the quantitative analysis of the relief allows a better understanding of the groundwater (GW) - surface water (SW) interaction along the rivers. This is particularly relevant in high mountain karst environments, as Sierra de Segura (SE Spain).

OBJECTIVES

- 1) Better understanding of karst GW - SW interaction processes.
- 2) Improve the comprehension of hydrological and hydrogeological processes occurring in alpine karst massifs.

A study of 3 years has been carried out to achieve this purpose (June 2021 to May 2024).

METHODS

A) Geomorphological analysis: calculation of morphological parameters as indicators of catchment genetic evolution (concavity $-C_{max}$ and θ , distance from the source $-\Delta L/l$ and channel steepness $-K_{SN}$), knick-points (KPS) and its gradients (α -KPS) from GIS treatment of a 2x2 DEM (IGN, 2019) and LSDTopoTools software (Mudd *et al.*, 2014).

B) Hydrodynamic data: direct measurements of flow-rate (SalinoMadd® and OTT C2® flow-meter).

C) Physico-chemical parameters: electrical conductivity and temperature (WTW Cond. 3310®/315®); dissolved O₂ and ²²²Rn (HQ40D multi-parameter and AlphaGUARD α -particle counter); major ions determinations (METROHM® 930 Compact IC Flex and 881 Compact IC Pro); Total Organic Carbon -TOC- (SHIMAZDU® V-TOC).

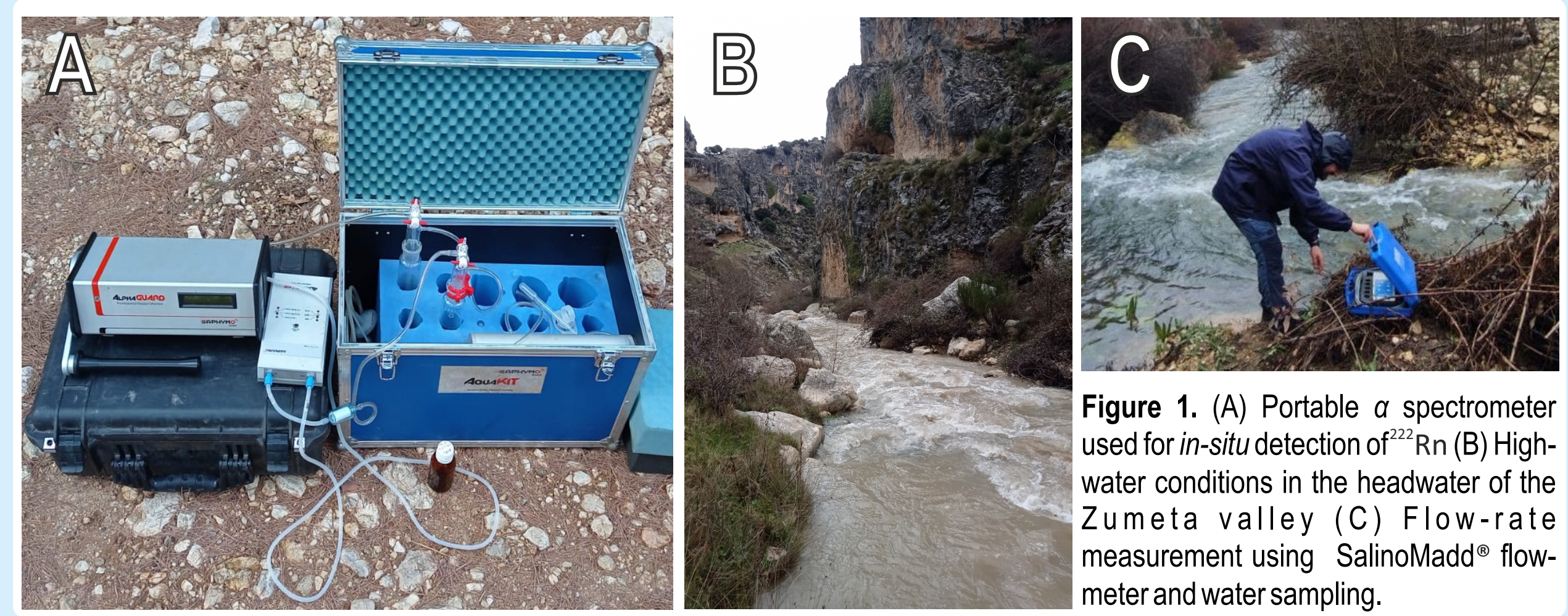


Figure 1. (A) Portable α spectrometer used for *in-situ* detection of ²²²Rn (B) High-water conditions in the headwater of the Zumeta valley (C) Flow-rate measurement using SalinoMadd® flow-meter and water sampling.

SITE SETTING

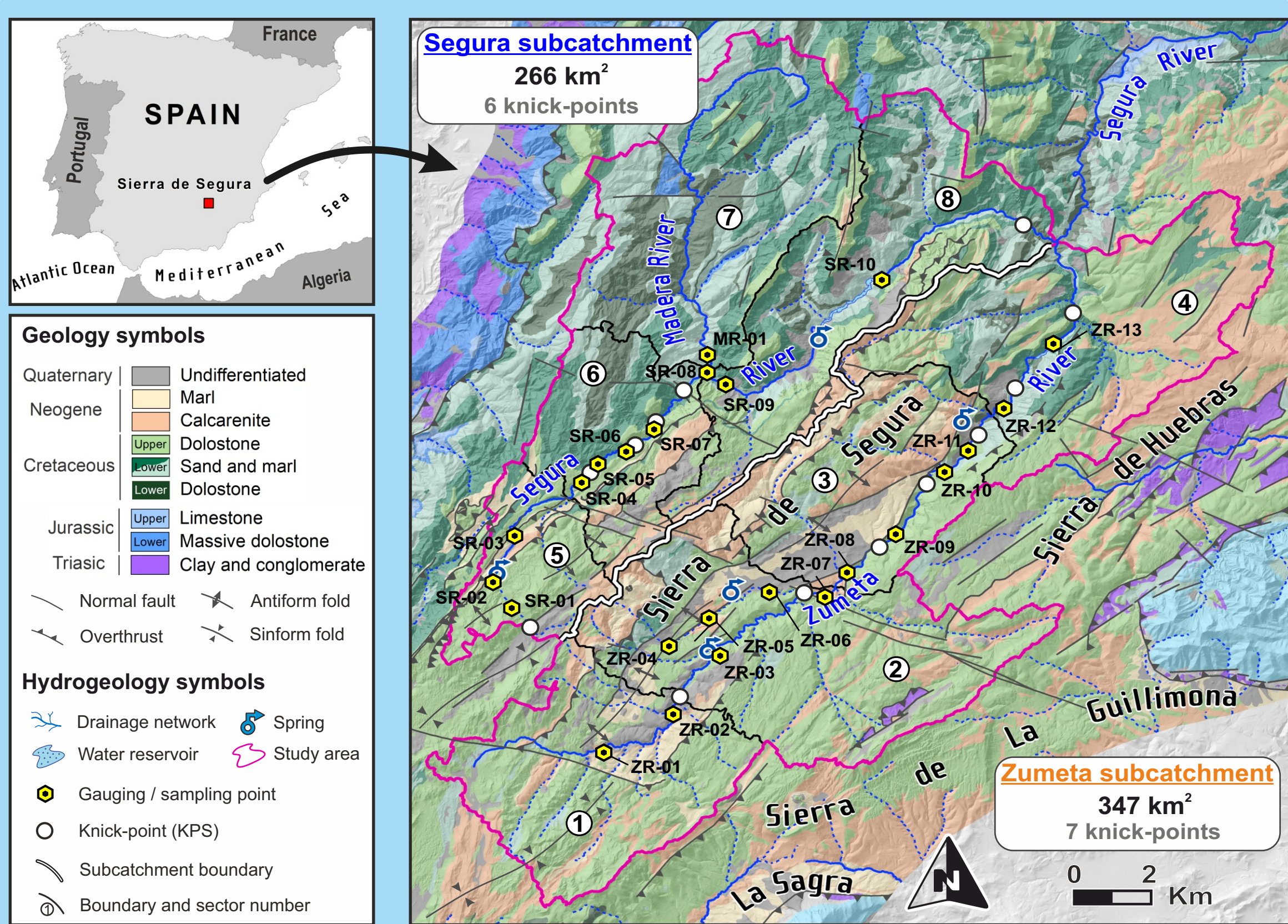


Figure 2. Situation and geological map of the research area of the Sierra de Segura outcrop.

RESULTS

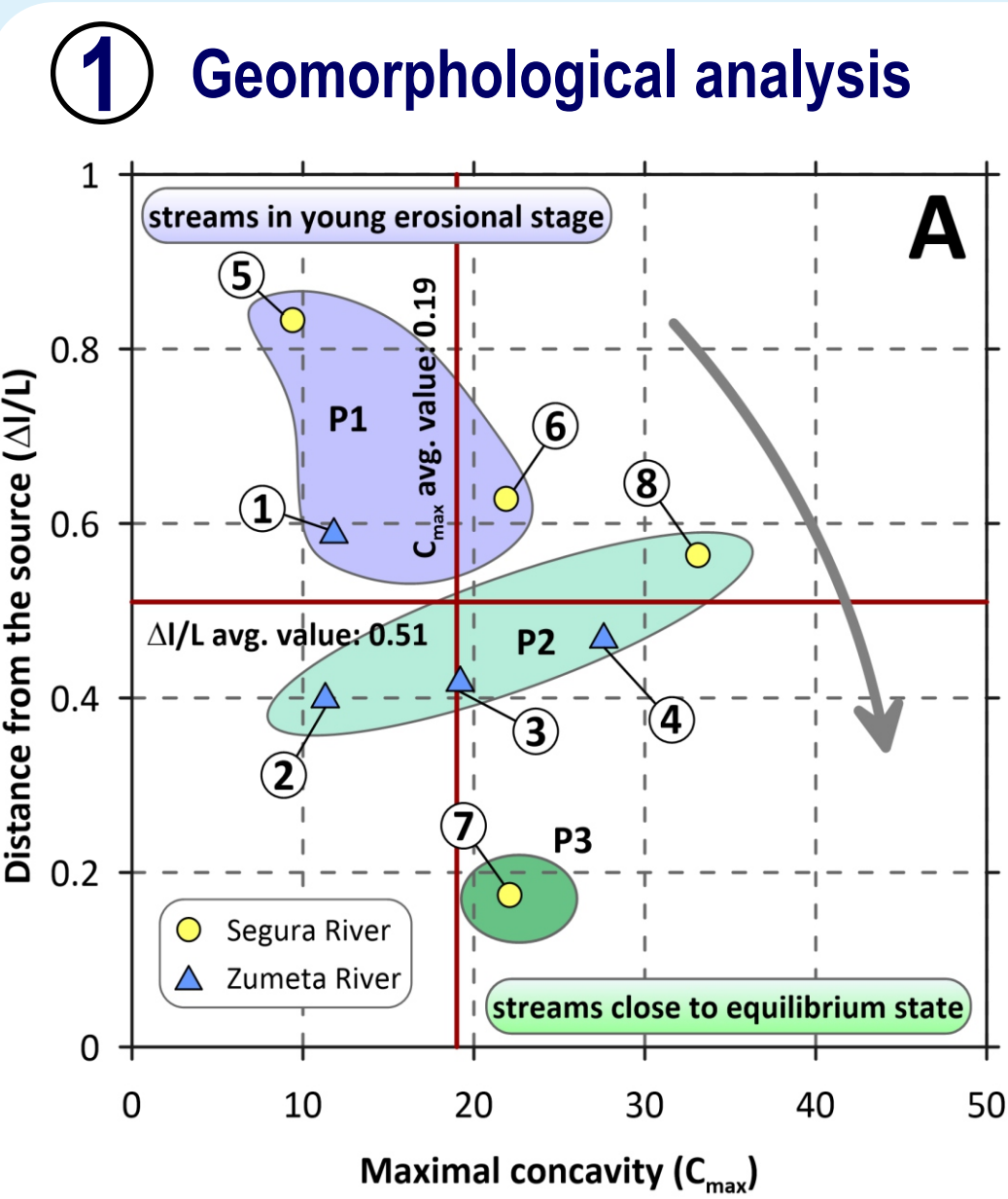


Figure 3. Scatter plot of (A) C_{max} vs $\Delta l/l$ of normalised stream profiles; (B) K_{SN} vs θ of computed stream channel steepness and concavity index. Average values are indicated with red lines, and numbers in circles refer to the sectors. Grey arrow indicates the genetic evolution of the subcatchments.

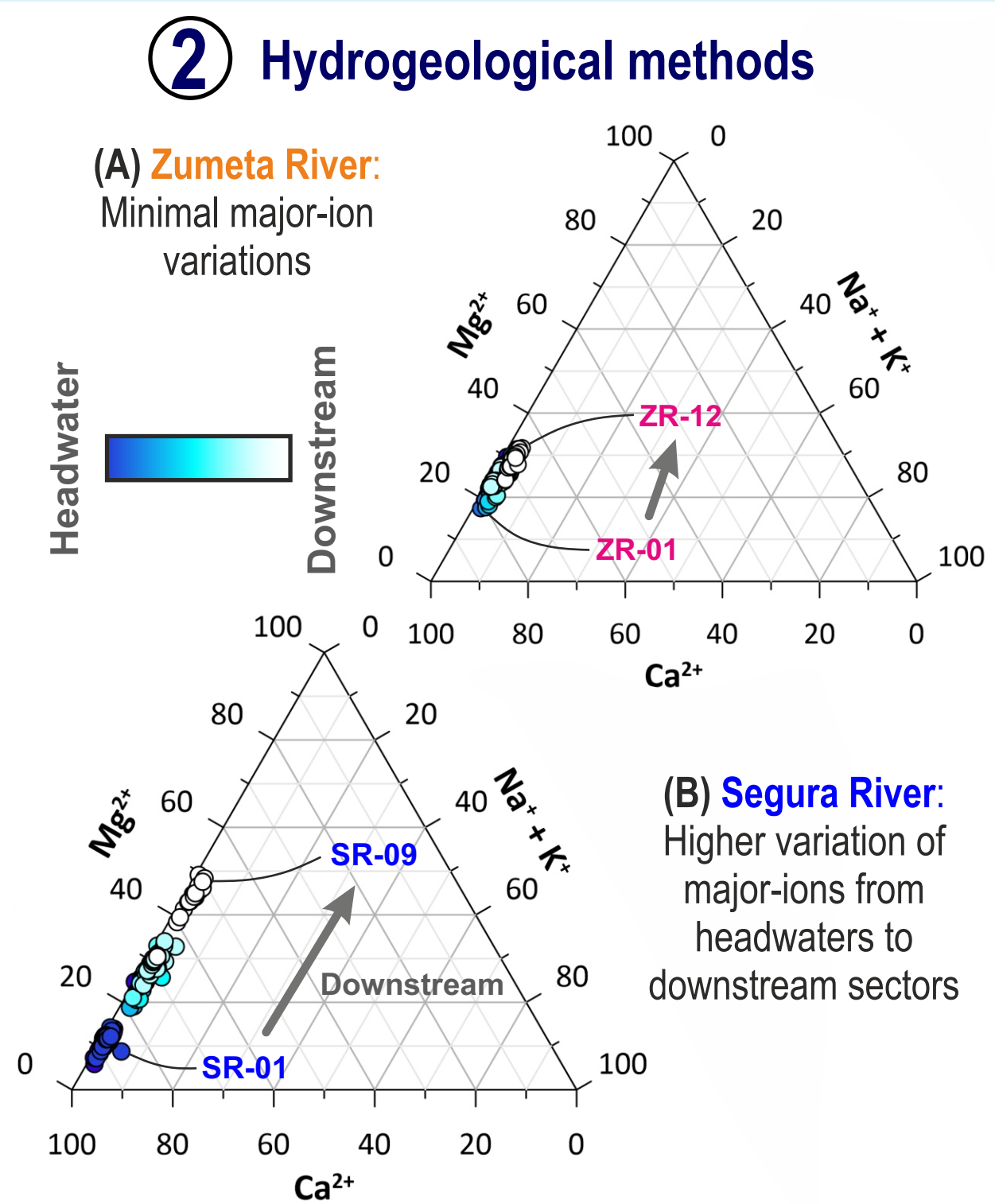


Figure 4. Simplified piper diagrams showing the water samples of the Segura and Zumeta rivers.

3 Hydrodynamic data and spatial distribution of physico-chemical parameters

Segura River: 3 discharge areas where physico-chemical parameters and major ion decrease. ²²²Rn increase up to 700 Bq/m³
Zumeta River: 4 discharge areas. Inertial pattern of physico-chemical parameters, major ion and TOC increase downstream

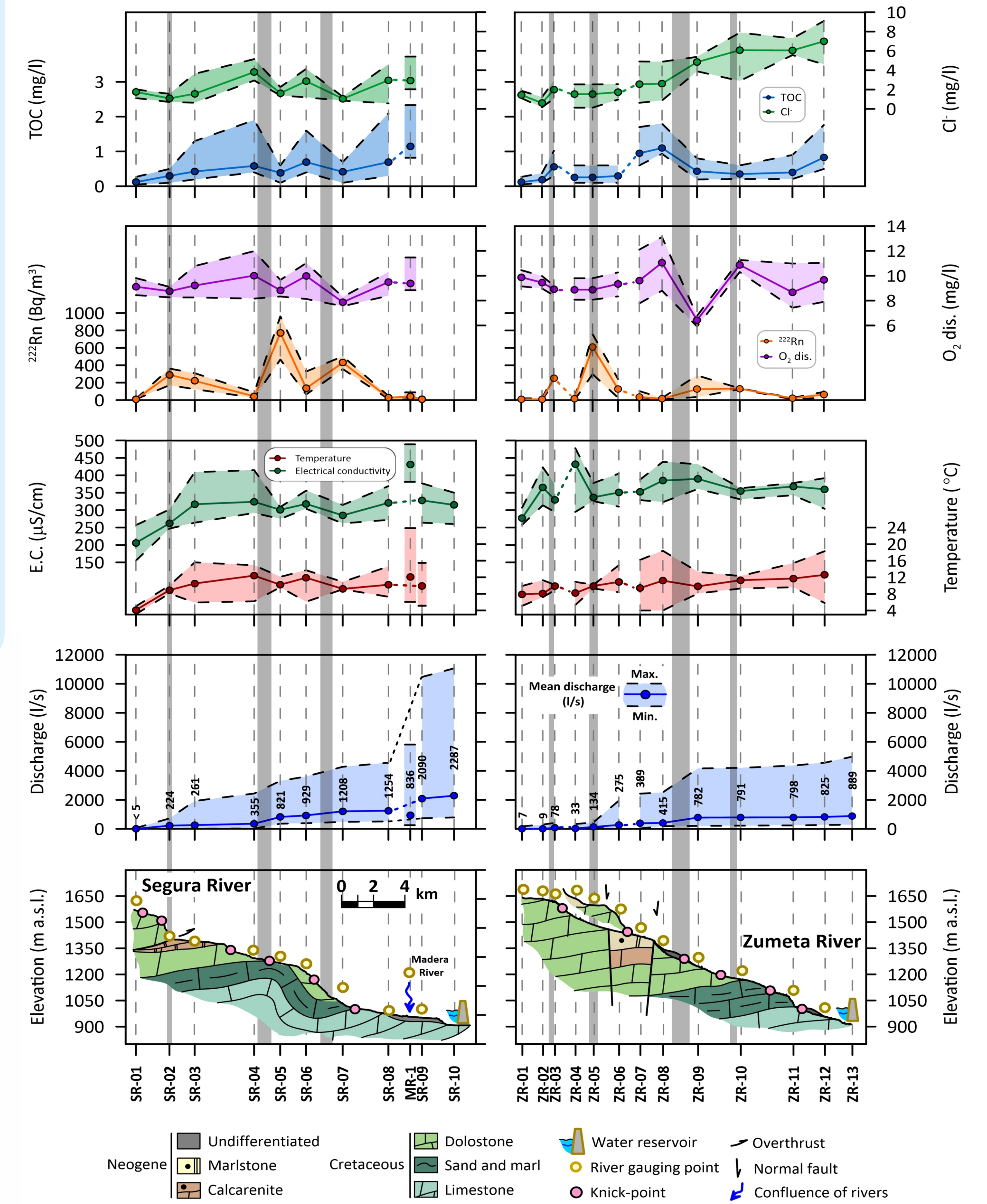


Figure 5. Spatial distribution of flow-rate and main physico-chemical parameters measured in Segura and Zumeta rivers during the control period. From the bottom to the top: mean, maximum and minimum flow-rate, EC, temperature, radon activity, O₂, Cl⁻ and TOC values. Grey polygons identify areas of groundwater discharge into the rivers.

INTERPRETATION AND CONCLUSION

Results from the geomorphological analysis and knick-point methodology (KPS gradient) shows a good correlation ($R^2 = 0.91$ and $R^2 = 0.95$) with the variations of physico-chemical parameters in the rivers, in particular with the

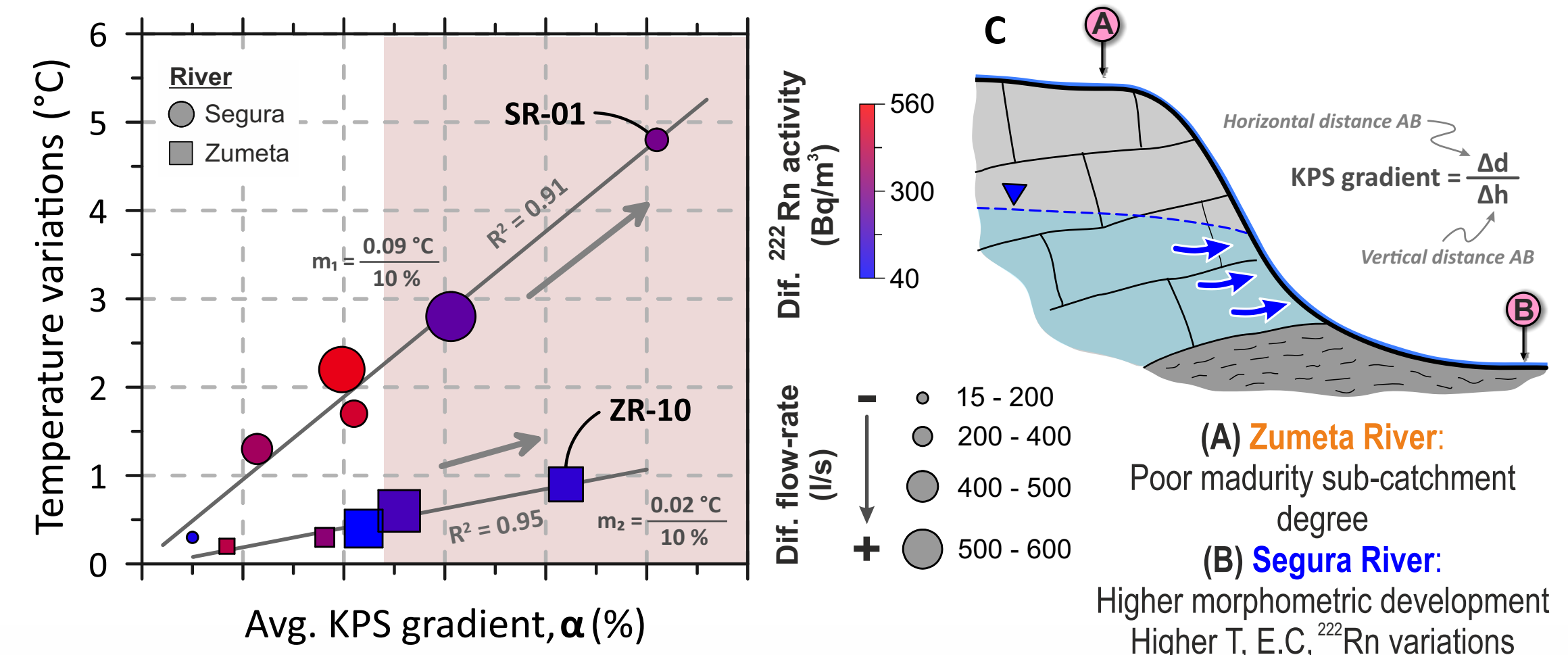


Figure 6. Correlation between knick-points gradient with water temperature, discharge and ²²²Rn measured downstream and upstream the KPS.

- 1) Geomorphological techniques extract up to 13 knick-points (6 in Segura and 7 in Zumeta River; Fig. 1) and numerically confirmed the denudation of the karst relief and its transition to a fluvial modelling landscape (Fig. 3).
- 2) The carbonate substratum and the different incision degrees in the fluvial network (deeper in the Segura River) result in a distinct chemical behaviour for each river (Fig. 4).
- 3) Up to seven stretches were identified differentiated by the increase in flow-rate values and different physico-chemical variations (Fig. 5). All of them coincides with a knick-point location (Fig. 1 and 5)

Hydrodynamic tools combined with the spatial distribution of physical-chemical parameters, including dissolved gases have allowed us to understand the different dynamics of surface water / groundwater interactions (Fig. 6). The data show a good correlation between the landforms and the hydrogeology of the Sierra de Segura (physico-chemical variations downstream and upstream the KPS). The hydrological and chemical spatial distribution is related to the different geomorphological evolution in both subcatchments. Thus, the position of the gaining river stretches (or GW-SW interaction) would be closely influenced by morphometric characteristics and vice-versa.

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• Ortega, L., Manzano, M., Custodio, E., Hornero, J., Rodríguez-Arévalo, J. (2015). Using ²²²Rn to identify and quantify groundwater inflows to the Mundo River (SE Spain). *Chemical Geology* 395, 67–79.

ACKNOWLEDGEMENTS

This communication is a contribution of the RNM 308 Group of the Junta de Andalucía to the Agencia Estatal de Investigaciones Científicas project PID2019-111759RB-I00.