

13 SPAIN: LA FÁJARA SPRING

13.1 Overview

The la Fájara spring is located in the South of Spain, in the autonomous region of Andalucía, in the province of Málaga, 34 km to the North-East of the city of Málaga. The source is located in the area of the Sierra Tejeda-Sierra Almijara-Sierra de los Guájares Triassic marble karst (*Figure 51*). The spring of la Fájara drains the south-western part of Sierra Tejeda (*Figure 52*) and the area is characterised by a pronounced relief but with an absence of typical karst dissolution morphology. La Fájara is a famous site because it is the origin of the local Bermuza river and because 30 m above the spring the entrance to la Fájara cave forms a trop plein (overflow) after heavy rainfall events.

The la Fájara spring is formed at the contact between Triassic marbles and Paleozoic schists, at an altitude of 470 m above sea level. The catchment area is estimated to be about 17 km². The spring data have been provided by the Centro de Hidrogeología de la Universidad de Málaga (Spain), the director is Professor Bartolomé Andreo.



Figure 51: The geographic location of the “la Fajara” spring (blue solid dot) in Southern Spain. The underground catchment area is the blue polygon in the figure.

13.2 Geology

The catchment area of the “La Fájara” spring is mainly within the Triassic carbonate marbles which unconformably overlie Paleozoic schists which form the impermeable base to the aquifer. From a geological point of view the aquifer is inside the Internal Zone of the Betic Cordillera as part of the Apujarride Complex (Sanz de Galdeano et al., 2019). These materials are affected by regional Alpine metamorphism. The lithology is marble (from limestones and dolostones) of Triassic age. The general structure of the area (*Figure 52*) are large folds of approximately E-W orientation. The catchment of la Fájara spring forms one flank of an anticline (*Figure 52*).

13.3 Geomorphology

Exokarst

The landscape of the catchment basin presents few forms of dissolution like karren and closed depressions (dolines). However there are many potholes developed at the intersection of fractures.

Endokarst

A few meters above la Fájara spring there is a cave known as la Fájara cave (*Figure 54*). La Fájara cave has been explored for 1500 m and it comprises a labyrinthine system of karst conduits. The cave functions as a trop plein (overflow) after heavy rainfall events. Thus, la Fájara spring (*Figure 55*) is a siphon of the lower parts of the network of karst conduits forming the phreatic part of the network.

13.4 Climate

The catchment area of la Fájara spring has a typical Mediterranean climate with hot summers and mild winters as well as a bimodal rainfall in winter and spring. The mean annual rainfall is 573 mm and the mean annual temperature is 18° C. Spectral analysis of time series of precipitation data (Pérez and Andreo, 2006) have shown that apart from the annual periodicity there are climatic cycles with periods of 2-2.8 years, 3.5-4.5 years, 7 years, 14.6 years and 25 years. These cycles seem to be related to the quasi-biennial oscillation, the North Atlantic Oscillation and solar activity.

13.5 Hydrogeology

Autogenic recharge

The recharge of the aquifer is autogenic, that is, it comes from the rainfall that falls over the aquifer catchment. There are no closed karst depressions (dolines) in the landscape but there are potholes. The recharge is mainly along fissures, fractures and bedding planes that have an E-W direction and define the E-W flow direction. Recharge is concentrated along large fractures and potholes. The catchment area of la Fájara is largely comprised of permeable Triassic marbles, and the impermeable base of the aquifer is formed by Paleozoic schists. The mean annual infiltration has been estimated as 379 mm/year (IGME, 2001) which implies 66% of the rainfall. Thus the mean recharge is estimated to be around 6.5 hm³/year.

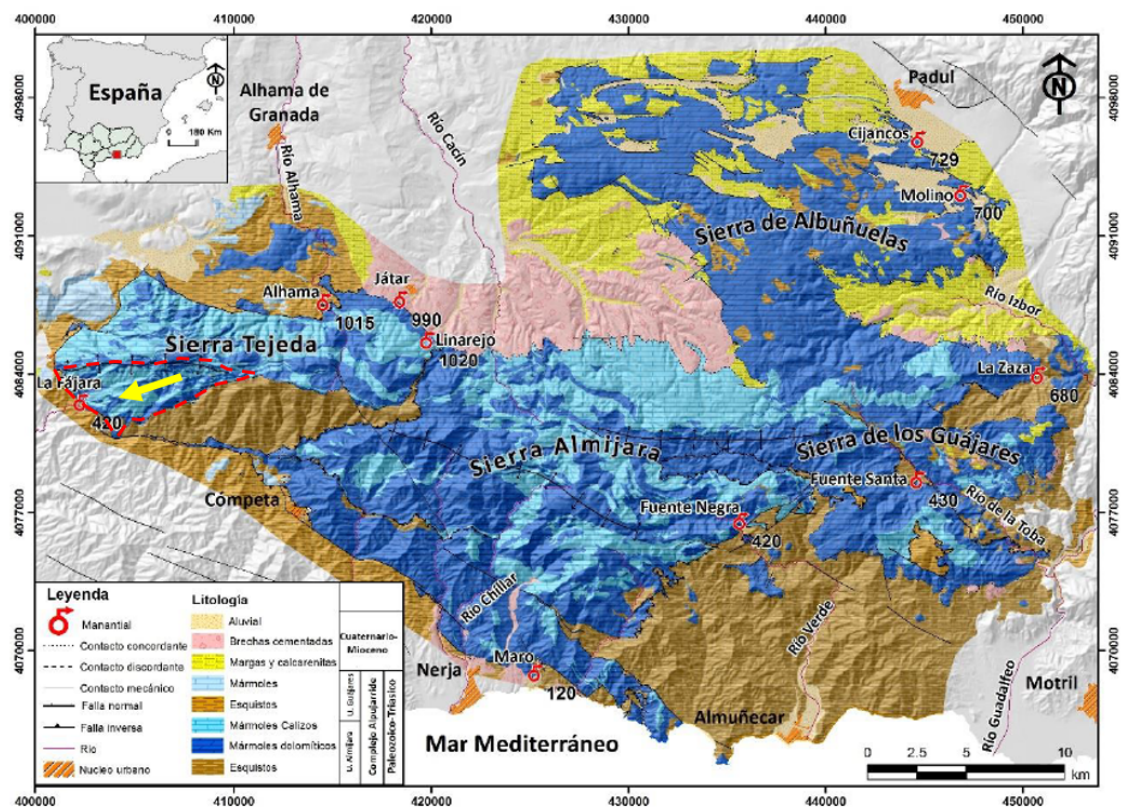


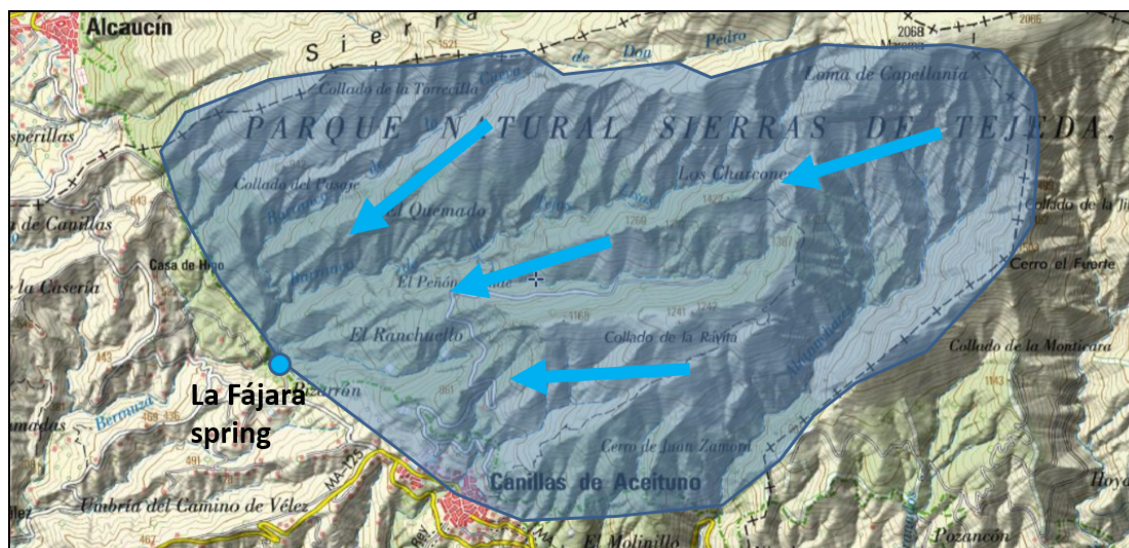
Figure 52: Hydrogeological map of the catchment area of the “la Fajara” spring. Figure taken from Prieto and Andreo (2017).

Groundwater flow system

The groundwater flow follows the stratification of the flank of the anticline and the E-W direction of the fold as seen in Figure 53. The mean discharge of la Fájara spring is 100 l/s.

Hydrochemistry

The behavior of electrical conductivity and temperature are similar with a rapid decrease in both parameters when the discharge increases because of heavy rainfall. In the year 2003 this was of the order of 100 μS and 2-3° C respectively (Prieto and Andreo, 2017). This implies a very strong underground connection between la Fájara spring and the recharge area. The mean values of the main ions are (Prieto and Andreo, 2017): Ca^{2+} : 57 mg/l, Mg^{2+} : 14 mg/l, Na^+ : 3 mg/l, K^+ : 1 mg/l, Cl^- : 4 mg/l, SO_4^{2-} : 11 mg/l, NO_3^- : 3 mg/l, F: 0.2 mg/l, pH: 7.7, T 15.1 °C, CE: 338 $\mu\text{S}/\text{cm}$.



The hydrochemical facies are calcium bicarbonate type and calcium-magnesium bicarbonate type and they are of good quality for drinking. The hydrochemical facies are in accordance with the lithology of the catchment. The spring of la Fajara is certainly important for its water resources and for its ecological and environmental importance.



Figure 55: La Fájara spring which is a syphon of the lower conduits connected with la Fájara cave (Figure 53). It has been explored by speleo-diving to -13 m. Photo from the Grupo de Exploraciones Subterráneas de la Sociedad Excursionista de Málaga.

13.6 Hydrodynamic characteristics of the springs

La Fájara spring is characterized by large oscillations of flow. The basic characteristics of the hydrological regime of la Fájara spring are:

- Average flow, $Q_{ave} = 0.183 \text{ m}^3/\text{s}$
- Minimum flow, $Q_{min} = 0.01 \text{ m}^3/\text{s}$
- Maximum flow, $Q_{max} = 20.7 \text{ m}^3/\text{s}$

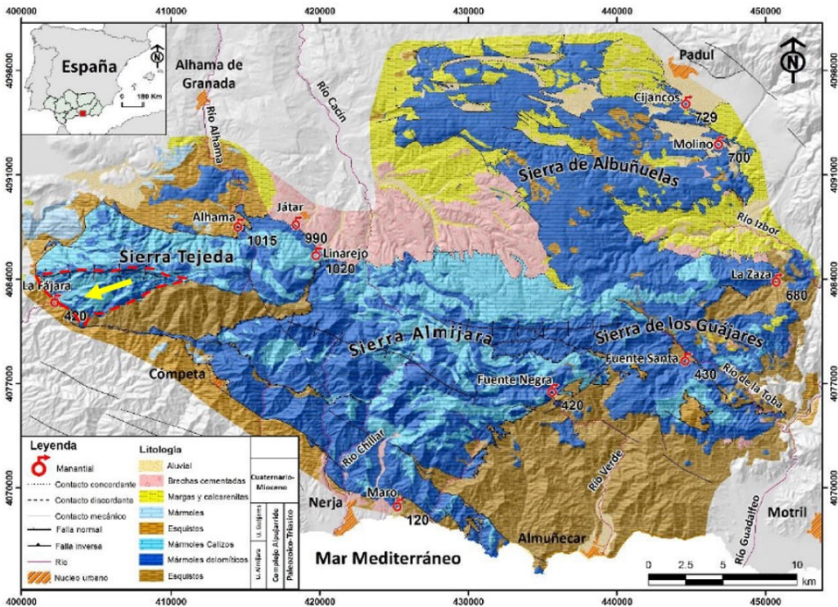
Spectral analysis on time series discharge data from la Fájara (Pérez and Andreo, 2006) have shown that apart from the annual periodicity there is an inter-annual periodicity of around 20 years that seems to be related to a 25 year cycle found in rainfall as described in the climatology section. Based on the discharge curve, the la Fájara recession coefficient has a value $\alpha = 0.021$.

13.7 Data available for the project

1. La Fájara spring			
Data type	Time step	Monitoring period	Time period
Discharge	1 hour	5 year	From 19/05/2015 to 30/09/2017
Electrical conductivity	1 hour	1 year	From 12/04/2016 to 03/03/2017
Temperature	1 hour	1 year	From 12/04/2016 to 03/03/2017

13.8 Summary

Pilot name	LA FÁJARA
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Country	Spain	EU-region	Mountain areas
Area (km ²)	37	Lithology	Carbonatic marbles
Short description:	La Fájara is the origin of the Bermuza river and is of great interest as a spring with a catchment on carbonate marbles. The catchment area is estimated to be around 37 km². The spring has concentrated outflow from the conduit system with a trop plain (La Fájara cave) that “explodes” after heavy rainfall events. The coordinates of the spring in the ETRS89 reference system are X = 402290, Y = 4082358, Z = 470 m. 		
Monitored objects	Spring		
Monitored data	Discharge, temperature, EC,		
Contact person	Eulogio Pardo (e.pardo@igme.es)		

13.9 References

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- <https://doi.org/10.3989/egeol.43395.509>.

