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Hydrochemical regime of the fractured rock aquifer of Simonos Petra Monastery, Holy Mountain

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Research highlights

- The fractured rock aquifer of Simonos Petra Monastery in Holy Mountain discharges from a fracture zone artesian spring.
- The spring water is characterized by low electrical conductivity (127 μS/cm), and the absence of anthropogenic pollution such as nitrogen species and potentially toxic elements.

The Athos peninsula is located in Northern Greece and constitute one of the last unexplored areas of Greece regarding hydrogeological conditions (Figure 1). This study is focused on the Hydrosystem of the Holy Monastery of Simonos Petra with the aim of determining the hydrochemical regime of the fracture zone aquifer. The Territory of the Holy Monastery of Simonos Petra covers an area of 13 km^2, has a coastline of 5.9 km, the mean elevation is 473 m, and the maximum is 892 m in Tsamantara peak. The study area is located at the boundary of the Hellenic Hinterland and the Internal Hellenides and consists of granitoid rocks, of the Eocene age (Christofides *et al.,* 1990). It constitutes facies of extensive magmatism, which geotectonically belongs to the late-Alpine stage of the Hellenic Hinterland and the Innermost Hellenides deformation and is characterized by such granitic bodies. The Gregoriou type granite is, according to Kockel *et al.,* (1977), a mainly biotitic granite, rich in quartz, perthitic orthoclase, microcline, plagioclase with a 30% anorthite, biotite, and hornblende. Frequently enough veins of leucocratic aplitic muscovite granite occur rich in quartz, perthite and orthoclase, microcline, and plagioclase with a 15-20% anorthite, muscovite and secondary minerals. The main aquifer of the Simonos Petra spring stretches in an area of 0.87 km^2 and is developed within the fractured formation of the Granodiorite, Gabbro, and Diorite (Figure 1). The aquifer discharge from a fracture zone artesian spring (Busico *et al.,* 2022). The gush points of the spring are more than 15, however**,** five gushes are the main discharge points that we focused this hydrochemical research. The water demands of the study area are exclusively covered by the spring water.

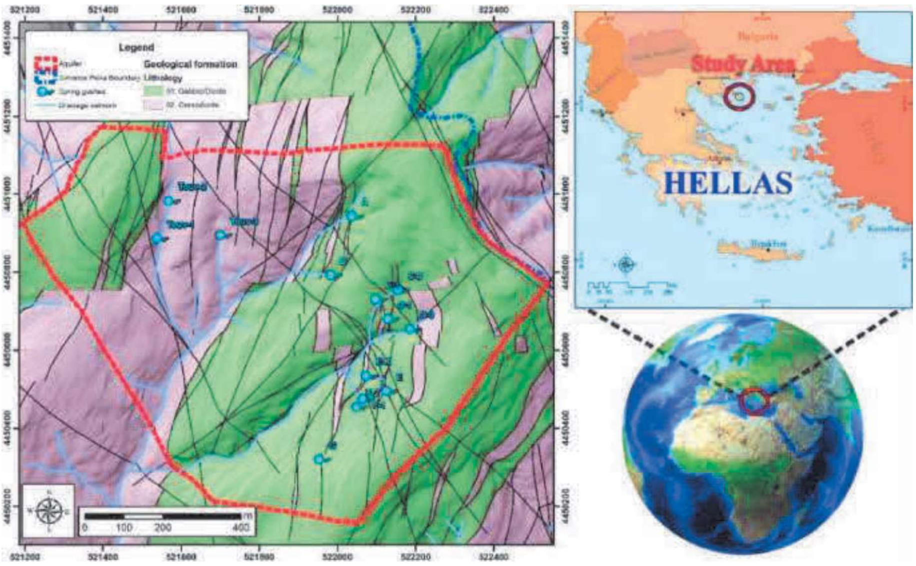

Figure 1. Geological map of the study area.

Water samples were collected from 5 gushes from the Simonos Petra aquifer in November 2020 for hydrochemical, isotope and tritium analysis. The physicochemical parameters of temperature (T), pH, and electrical conductivity (EC) were measured in situ using a multi-parametric probe, HANNA (HI98194). All water samples were filtered using a 0.45

μm millipore filter and stored in two 50 mL PE bottles (one acidified with ultrapure HNO_3) for laboratory analysis (ICP-MS) according to standard methods (Lenore *et al.* 1998). According to the hydrochemical data all gushes have similar water quality verifying the spring mechanism. The spring pH is 7.1, the electrical conductivity 126.8 μS/cm and the temperature 9.6 °C, with the absence of potentially toxic elements, nitrate, nitrite, and ammonium ions (Table 1). Based on the sample classification in the Piper (Piper, 1944) and Durov (Durov, 1948) diagrams in Figure 2, the water type of the spring is $Mg\text{-}HCO_3$.

Table 1. Results from the underground water isotope analyses from the spring systems of Mount Athos Simonopetra spring for the sampling period of November 2020.

Spring gushes	δ18O	δ2H	A(3H)	Mg^{2+}	Ca^{2+}	NO_3^-	NO_2^-	NH_4^+	Cr	As	U
	‰ VSMOW	‰ VSMOW	TU	mg/L	mg/L	mg/L	mg/L	mg/L	μg/L	μg/L	μg/L
E	-8.76	-50.53	3.1	3.2	5.3	ND	ND	ND	ND	ND	ND
C0	-8.55	-49.75	3.2	3.3	5.7	ND	ND	ND	ND	ND	ND
C1	-8.78	-50.34	3.6	3.3	6.5	ND	ND	ND	ND	ND	ND
D0	-8.89	-51.2	3.4	2.8	5.6	ND	ND	ND	ND	ND	ND
D1	-8.73	-51.27	3.5	3.1	6.5	ND	ND	ND	ND	ND	ND

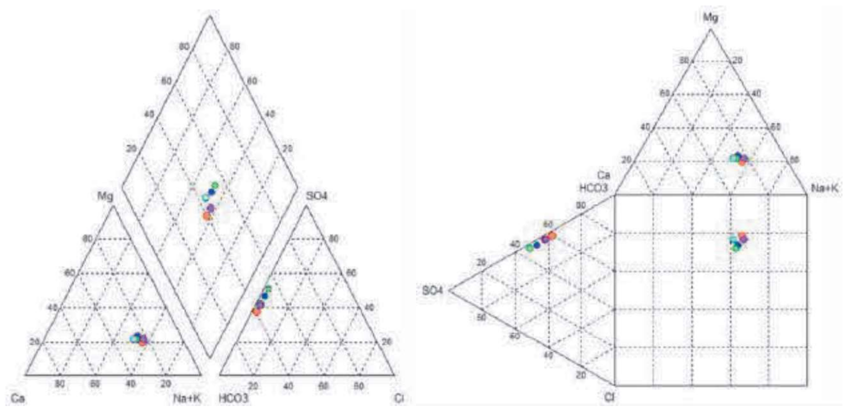

Figure 2. Classification of the water samples from the main spring system in Piper (left) and Durov (right) diagrams for the sampling period of November 2020.

The meteoric water line for Greece was used to characterize the samples, developed by Argiriou and Lykoudis (2006). The relationship of the Greek meteoric water line (HellasMWL) is given by the formula: $\delta^2H = 7.2 \times \delta^{18}O + 8.2‰$. According to the stable isotope analysis, groundwater of the Simonopetra aquifer has meteoric origin and has not been subject to secondary evaporation (Table 1). Additionally, this aquifer recharged from a maximum altitude of 890 m. Regarding the tritium analyses of groundwater of the Simonopetra aquifer, it is characterized as contemporary water, according to classification by Clark and Fritz (1997). The relatively young age of the aquifer's groundwater fortifies the theory of the high flow speed of the aquifer, as well as its direct supply from atmospheric precipitation (meteoric origin).

Conclusions

In the study area, there is an absence of human activity, therefore, the physicochemical characteristics of groundwater solely depend on the interaction and hydrodynamics of water with the geological formations. Groundwater of Simonos Petra aquifer is characterized as potable with the absence of potentially toxic elements, nitrate, nitrite, and ammonium ions. The aquifer recharge occurs from a maximum altitude of 890 meters and is characterized as contemporary water. The next step of this work is the time-series analysis of the hydrochemical data from the Simonos Petra aquifer and its correlation with the hydrodynamic analysis of the Simonos Petra spring.

References

Argiriou, A.A., Lykoudis, S., 2006. Isotopic composition of precipitation in Greece. Journal of Hydrology, 327, 486-495.

Busico G., Ntona M.M., Kazakis N., Mastroccico M., 2022. Simulating historical, actual and future water balance in mountainous watershed. 12th International Hydrogeological Conference, Cyprus, 20-22 March 2022, pp. 172-175.

Clark, I.D., Fritz, P., 1997. Environmental Isotopes in Hydrogeology. Lewis Publishers, New York, p. 328.

Christofides, G., D'Amico, C., Del Moro, A., Eleftheriadis, G., Kyriakopoulos, C., 1990. Rb-Sr-geochronology and geochemical characters of the Sithonia plutonic complex (Greece). European Journal of Mineralogy, 2, 79–87.

Durov, S.A., 1948. Natural water and graphical representation of their composition. Dokl. Akad. Nauk. U.S.S.R., 59, 87-90.

Kockel, F., Mollat, H., Walther, H.W., 1977. Erlauterungenzur Geologischen Karte der Chalkidiki und angrenzender Gebiete 1:100000 (Nord-Griechenland). Bundesanstalt fur Geowisseschaften und Rohstoffe, Hannover, 119.

Lenore, S.C., Arnold, E.G., Andrew, D.E. 1998. Standard Methods for Examination of Water and Wastewater, 20th ed. American Public Health Association, American Water Works Association, World Environment Federation: Washington, DC, USA.

Piper, A.M., 1944. A graphic procedure in the geochemical interpretation of water analyses. American Geophysical Union, Transactions, 25, 914 – 923.