

# Assessing deep gas fluxes in a volcanic island with no recent volcanism by using noble gases and isotopes – Portugal

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**KEY WORDS** deep mantle gases, noble gases and isotopes, water ages and recharge temperature, old volcanism

## ABSTRACT

To assess whether a volcanic island whose last eruption took place ~6000 years ago, still showed any evidence of ongoing connection to deep geological structures, the origin of several groundwater compounds was investigated. This was done by the use of noble gases and stable isotopes (H, C, O and S) that allowed to identify deep gas fluxes albeit the documented volcanic inactivity of the island.

Groundwater samples were collected throughout the island, and all chemical and environmental tracers could distinguish three groundwater end-members named according to type of sampling place: i) wells and ii) *outer* galleries, all near the island's border, and iii) *inner* tunnels, to the interior of the island.

All tracers applied, proved to be useful in tracing different processes affecting groundwater. Hence, whereas the compositions of  $\delta^{18}\text{O}$  and  $\delta^2\text{H}$  indicated a meteoric origin for all water samples, with a slight influence of silicate hydrolysis and/or exchange with  $\text{CO}_2$  at low temperatures, the  $\delta^{13}\text{C}$  of the dissolved inorganic carbon indicated equilibrium with  $\text{CO}_2$  of mantle origin, in waters of the *inner* tunnels. These same waters also showed  $\delta^{34}\text{S}\text{-SO}_4^{-2}$  compositions typical of volcanic sulphur, even if the  $\delta^{18}\text{O}\text{-SO}_4^{-2}$  points to mixture with atmospheric sources and evaporitic minerals.

The evidence of a non-atmospheric gas flux into the *inner* tunnels of the island, was also put in evidence by the very high concentrations of the noble gas He, and the consequent Ne/He ratio, which was thus much lower than the water-atmosphere equilibrium. Furthermore, the very high  $^3\text{He}/^4\text{He}$  ratios in the order of  $10\text{E-}05$  are typical of mantle origin, implying the presence of mantle-derived helium which must rise to the surface of the island by deep geological structures. In fact, a deep water circulation is probable for those waters whose ages go up to 200 years, as determined by the  $^3\text{H}\text{-}^3\text{He}$  method. Such long water residence times under an heterogeneous geothermal gradient within the island, justifies the warming of the waters of the *inner* tunnels by 7-12°C (as opposed to the 0-4°C observed in the wells and outer galleries), as indicated by the groundwater recharge temperatures determined by the noble gases (Ne, Ar, Kr and Xe) concentrations.

Such sole joint-application of environmental tracers in groundwater could distinguish groundwater bodies and verify that those in the inner part of the island are affected by an influx of non-atmospheric gas rising through deep geological structures, that probably connect to the magma.