

## Oxygen and hydrogen stable isotope composition of precipitation in Friuli-Venezia Giulia (Northeastern Italy)

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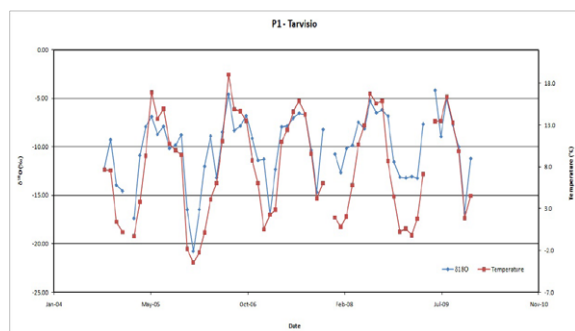
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### Introduction

Oxygen and hydrogen stable isotopes, being natural tracers of the hydrological cycle, have been extensively used as tools to characterize regional aquifers. In particular, the knowledge of the mean annual-weighted isotopic composition of precipitation is a very important tool to determine the origin of the waters that feed aquifers and rivers, their recharge area and its mean altitude, thanks to the definition of the vertical isotope gradient. The knowledge of the relationship between isotopic composition of local precipitation and local environmental conditions is also essential for hydrological studies. In order to provide an overview of the isotopic composition of the precipitation in Friuli-Venezia Giulia region a monitoring of the regional rain gauge network has been carried out at the University of Trieste from 2004 to 2010.

### Results and Discussion

Here we present  $\delta^{18}\text{O}$  data obtained from monthly precipitation collected by rain gauges; where possible the  $\delta^{18}\text{O}$  data were compared with temperature data weighted for precipitation (fig. 1) showing generally a good correlation. Vertical  $\delta^{18}\text{O}$  gradients for homogeneous areas and an average gradient for the region as a whole were also calculated. Finally the local meteoric water line was calculated using  $\delta^{18}\text{O}$  and  $\delta\text{D}$  long-term weighted values for all the sampling sites.



**Figure 1:** Monthly trends of  $\delta^{18}\text{O}$  and temperature for the Tarvisio sampling site.

## Metastable accessory phases in high heat-producing felsic igneous rocks

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High heat-producing felsic igneous rocks are characterised by enriched values of U, Th and K relative to upper continental crust, and are of specific interest when seeking to exploit geothermal energy through enhanced geothermal systems. The elevated values reflect the evolved nature of the felsic rock; common examples include granites and rhyolites. The current study focuses on famous HHP systems of Soultz-sous-Forêts, France, Cornwall, UK, and the novel HHP rhyolite of central Queensland, Australia.

Samples from Soultz and central Queensland show evidence that metasomatised titanite can form rutile + calcite + quartz with accessory hydrothermal zircon and Ca (REE, Y)CO<sub>3</sub> (OH, F)<sub>7</sub> or cheralite, respectively. The accessory phases reflect how Zr, Th, Y and REE can substitute into titanite's structure in an evolved system. EPMA of the anhydrous hydroxyl-, fluoro-carbonate phase found elevated values of both Ca and Ce with variable LREE, Y and Th. The occurrence of Ca (REE, Y)CO<sub>3</sub> (OH, F)<sub>7</sub> in place of cheralite may result from elevated [CO<sub>2</sub>] and [F<sup>-</sup>] as opposed to [PO<sub>4</sub><sup>3-</sup>] and [CO<sub>2</sub>]; as indicated by cogenetic chloritisation of F-bearing biotite and intercleavage-grown ankerite. Mobilisation of incompatible elements as fluoro-carbonate ligand complexes was minimised by the presence of Ca<sup>2+</sup>, resulting in precipitation within or proximal to the titanite void. By contrast, SEM analyses of the F-dominated Cornish metasomatic system shows monazite solid-solution phases along cleavage planes of chloritised biotite, implicating the uncommon mobilisation of Th<sup>4+</sup>. Further EMPA will better define these phases and constrain their palaeometasomatic conditions.

Analysed primary accessory phases such as titanite were relatively enriched in incompatible elements that formed polymineralic assemblages following metasomatism. The volatile content of metasomatising fluids played a significant role in the production of these metastable phases. Titanite specifically, destabilised in the presence of CO<sub>2</sub> or F<sup>-</sup> [1, 2]. Volatiles not only helped destabilise the primary phases but also mobilised constituent elements; as seen when halide ligands drastically increase the mobility of incompatible elements such as REE and HFSE [3]. By analysing metastable accessory phases, this study will further constrain under which conditions HHP systems undergo metasomatism as well as better understand the extent of metasomatic incompatible element immobility.

[1] Markl & Piazzolo (1991) *Am. Min.* **84**, 37–47. [2] Hunt & Kerrick (1977) *G&C Acta* **41**, 279–288. [3] Wood (1990) *Chem. Geo.* **88**, 99–125.