

## A two-component mantle below Mt Etna volcano: Evidences from noble gas and trace element geochemistry of primitive products

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A geochemical study comprehensive of major elements, trace elements and Sr-Nd isotopes in the bulk rock, coupled to noble gases analyses from fluid inclusions retained in minerals, was performed. The studied samples (basalts, trachybasalts and basanites) represent some among the most primitive products of Etnan history. The variable composition measured in trace elements (i.e. Zr/Nb=2.81–4.98, Ce/Yb=35.02–66.90, La/Yb=15.36–35.52, Th/Y=0.17–0.43) was modeled as due to varying degrees of melting of a common mantle source. We numerically simulated the process by MELTS code to calculate a melting percentage for each product and we accordingly estimated the pristine trace-elements content of their mantle source. This latter resulted to be common to all of the investigated samples and evidenced a close affinity between Etnan and Hyblean mantle. The observed coupling between trace elements and noble gases allowed us to better define the Etnan mantle, which resulted compatible with a peridotitic matrix veined by 10% of clinopyroxenites. The geochemistry of the Sr-Nd-He isotopes ( $^{87}\text{Sr}/^{86}\text{Sr}=0.703321\text{--}0.703910$ ,  $^{143}\text{Nd}/^{144}\text{Nd}=0.512836\text{--}0.512913$  and  $^3\text{He}/^4\text{He}=6.7\text{--}7.6$  Ra) confirmed the relation existing between Etnan and Hyblean mantle and evidenced that mantle contamination by crustal-like fluids occurred at a variable extent in our products. The  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio appears correlated to the estimated degree of melting for each product, therefore the metasomatic fluids probably refertilized some portions of the mantle and promoted partial melting. In contrast, the observed decoupling between  $^3\text{He}/^4\text{He}$  and  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios could be related to shallower processes, as magma aging or a contribution of shallow fluids, able to decrease the primitive  $^3\text{He}/^4\text{He}$  of some samples.

## Modeling water-gas-rock interactions using CHESSE/HYTEC

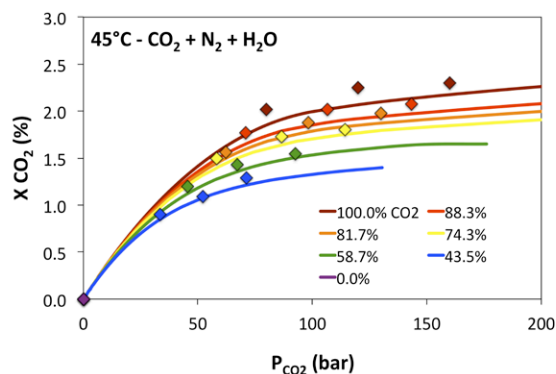
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Numerous applications of reactive-transport codes within the field of Geosciences require handling water-gas-rock interactions. Some strong but convenient assumptions could be made to simplify the problem: infinite gas source, dissolved gases, perfect gas approximation... Nevertheless, in many cases, such approaches lead to significant errors and the gaseous phase has to be more accurately represented in models.

Specific gas modules incorporating classical cubic equations of state (Redlich-Kwong, Peng-Robinson...) and their appropriate analytic solver have been developed [1,2] and implemented in the geochemical code CHESSE [3] and the coupled reactive-transport code HYTEC [4].

These improvements allow the modeling of complex water-salt-gas-rock systems in various conditions. CHESSE can, for example, be used to study the geochemical impact of impurities captured and possibly co-injected along with CO<sub>2</sub> for its geological storage. As an illustration, the code is able to reproduce the measured solubility and co-solubility of gases including gas mixtures such as CO<sub>2</sub>-N<sub>2</sub> mixtures.



**Figure** Aqueous CO<sub>2</sub> molar fraction vs. pressure for CO<sub>2</sub>-N<sub>2</sub>-H<sub>2</sub>O system (symbols correspond to measurements [5] and solid lines to CHESSE simulations).

[1] Corvisier *et al.* (2012) *Geofluids VII Rueil-Malmaison (France)*, 67-70. [2] Corvisier *et al.* (2013) *Energy Procedia*, in press. [3] van der Lee (2009) *Technical report, MINES ParisTech RT-20093103-JVDL*. [4] van der Lee *et al.* (2003) *Comput. Geosci.* **29**, 265-275. [5] Liu *et al.* (2012) *J. Chem. Eng. Data* **57**, 1928-1932.