

**DO MAGMATIC CLAYS EXIST? THE IMPORTANCE OF TERRESTRIAL ANALOGUES.** A. Meunier<sup>1</sup>, A. Mas<sup>1</sup>, D. Beaufort<sup>1</sup>, P. Patrier<sup>1</sup> and P. Dudoignon<sup>1</sup>. University of Poitiers, HYDRASA INSU-CNRS, 40 avenue Recteur Pineau, 86022 Poitiers Cedex, France. [Alain.meunier@univ-poitiers.fr](mailto:Alain.meunier@univ-poitiers.fr)

**Introduction:** Mars' crust in the southern hemisphere is mainly composed of basalt-like rocks. The discovery of nontronite in Syrtis Major, Nili Fossae and Mawrth Vallis regions [1] has been attributed to long-term contact of these rocks with liquid water. The conditions in which nontronite has been formed at the surface of Mars were discussed assuming a low-temperature alteration process [2]. However, the question is: do clay minerals in basaltic rocks form exclusively through alteration? To address this question we studied terrestrial analogues in order to compare the petrography, mineralogy and geochemistry of clay minerals formed in altered glassy chilled or brecciated margins with those composing the mesostasis in the massive inner crystallized parts of three basalt-hawaiite bodies from Mururoa atoll (French Polynesia).

**Analytical methods:** X-ray diffraction (XRD) has been performed from randomly oriented powders and oriented preparations using a Philips PW 1730 diffractometer (Cu K $\alpha$  radiation, 40 kV, 40 mA), equipped with a stepping motor drive (SOCABIM DACO system) and a KEVEX solid state detector. A JEOL 6400 scanning electron microscope (SEM) equipped with a KEVEX energy dispersive X-ray fluorescence analysis system (Si-Li diode – EDS) was used. Observations were performed both in the secondary (SE) and back-scattered electron (BSE) modes on small slabs of rocks (several mm<sup>3</sup>) and petrographical thin sections previously coated with carbon.

Electron microprobe analyses were performed using a CAMECA SX50 electron microprobe (CAMPARIS service, Paris VI) equipped with wavelength dispersive spectrometers (4 nA, 15 kV, spot size 4 $\mu$ m, counting time 10s per element). The quantitative analyses have been obtained by comparison with natural silicate standards using a CAMECA PAP matrix correction.

The chemical analyses of the bulk rocks and the clay fractions were performed from <5 $\mu$ m and <0.2  $\mu$ m powders respectively at the Service d'Analyse des Roches et des Minéraux (SARM), Nancy France (<http://www.cprg.cnrs-nancy.fr/SARM/>). Major elements and Rare Earth Elements (REE) were analyzed using atomic absorption spectrometry (AA), ICP-AES and ICP-MS respectively. Stable and radiogenic isotopes (O, Sr, Rb) were analyzed using mass spectrometry. The loss on ignition (LOI) was measured

using a Netzsch apparatus for simultaneous thermal analyses (STA 409 EP).

**Results:** The clay minerals form polyphased assemblages either in the veins crosscutting the glassy chilled margins or in the mesostasis. All assemblages are composed of di- and trioctahedral phases which are formed of expandable (nontronite, saponite types) and non expandable layers (chlorite, celadonite types) either in discrete phases or interstratified in mixed layered minerals. These assemblages are different from that formed in hydrothermal systems or low grade metamorphic conditions which are characterized by the saponite  $\rightarrow$  randomly ordered chlorite/smectite mixed layered minerals  $\rightarrow$  corrensite  $\rightarrow$  chlorite sequence (no plagioclase albitisation; no corrensite). Nontronite is systematically present. It is high-charge in the massive inner crystallized part.

Clay minerals formed in the chilled margins and the massive crystallized inner parts of three basalt-hawaiite bodies of Mururoa atoll (French Polynesia) exhibit contrasted textures. Glass alteration textures are observed around fractures crosscutting the quenched margins: Fe-rich clays grow inward the glass (retreating surface on which Ti-oxides accumulate) while Mg-rich ones grow outward (Fig. 1).

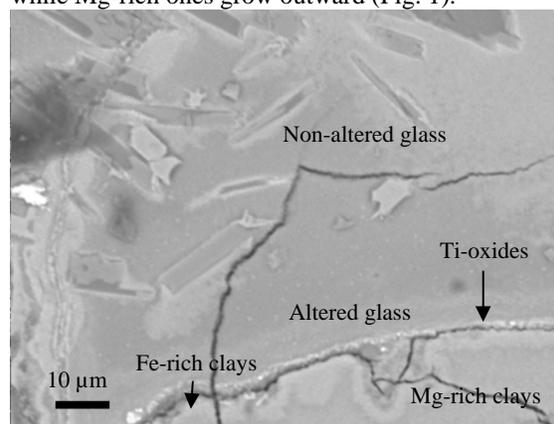


Figure 1: Submarine flow. BSE picture of the chilled margin.

The textures of clay deposits filling the diktytactic voids (mesostasis) in the massive inner parts of the three volcanic bodies are different: non-oriented clay matrix (submarine flow) embedding euhedral apatite and pyroxene microcrysts; palissadic clays (subaerial flow) coating the void walls and the crystal surfaces of apatite and K-feldspar microcrysts. In the

dyke, the central part of the void remain empty (Fig. 2A). Clay muffs (dyke) cover all the apatite needles (Fig. 2B).

The non-oriented texture could result from the alteration of a glass precursor concomitantly to the olivine phenocrysts (clay pseudomorphs). The palisadic and muff textures form through heterogeneous nucleation on the solid surfaces and crystal growth from a saline solution. No glass precursor has existed before. The centre of the diktytaxitic voids in the dyke being empty, it is probable that the residual liquid was boiling.

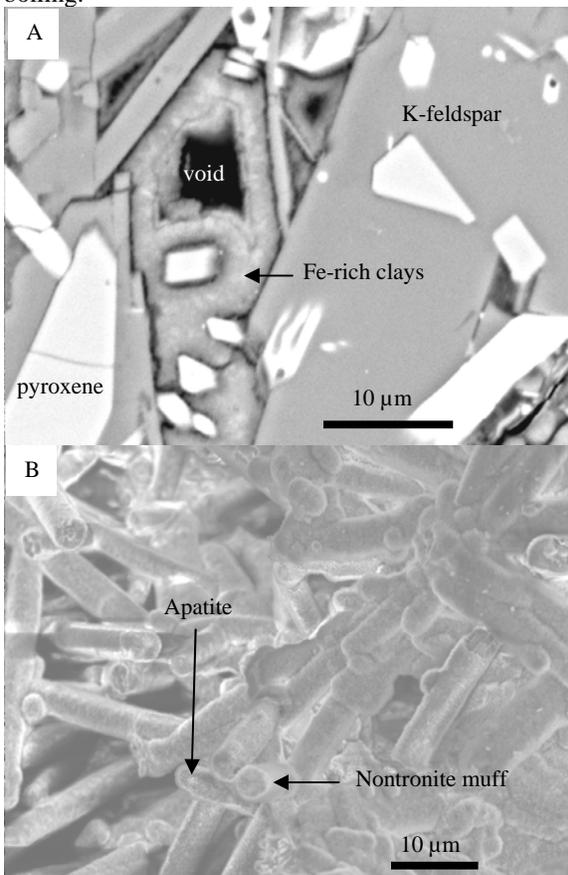


Figure 2: Dyke. A) BSE picture of small sized diktytaxitic voids. B) SE picture showing nontronite-like muffs coating apatite needles in a micro-geoda.

The amounts of LREE, Sr and the most incompatible elements are systematically higher in clays from diktytaxitic voids relatively to that formed in the altered glass of the chilled margins (Fig. 3). Thus, diktytaxitic clays formed from a residual liquid which gave either a glass or a saline solution after cooling (fractionation process). On the contrary, clays in quenched margins result from glass-solution interactions (alteration process). The  $\delta^{18}\text{O}$  variation versus LOI indicates that sea water was involved either in rock alteration or magma contamination (Fig. 4). This

is confirmed by the  $^{87}\text{Rb}/^{86}\text{Sr}$  ratio of bulk rocks and clay fractions from the quenched and massive inner parts of the three volcanic bodies which do not fit with the 11.5 Ma isochron indicating that the Rb-Sr system was never closed during the magmatic history.

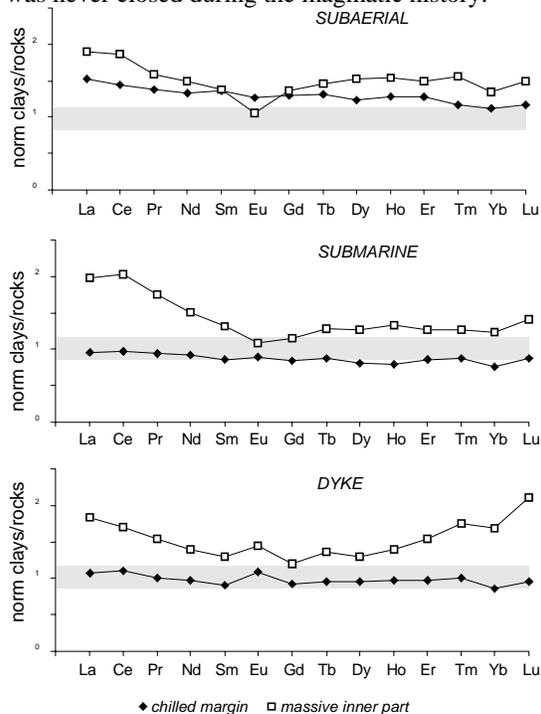


Figure 3: REE amounts normalized to the parent rock composition of the < 2µm fraction of the chilled margins (black diamonds) and the massive inner parts (square) of the three volcanic bodies. Grey zone: experimental error domain for the bulk rock composition.

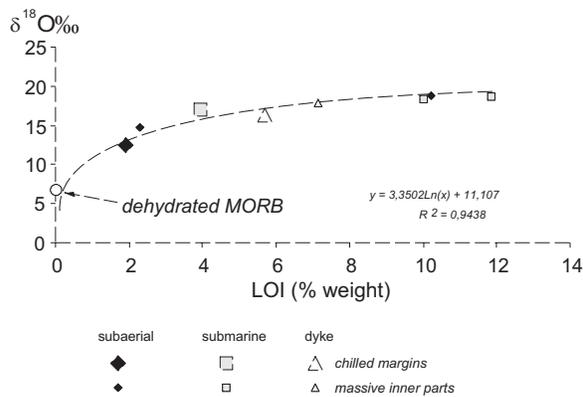


Figure 4: Relation between the loss on ignition (LOI) and  $^{18}\text{O}/^{16}\text{O}$  isotopic ratio of the clay fractions .

**References:** [1] Poulet, F., Bibring, J.P., Mustard, J.F., Gendrin, A., Mangold, N., Langevin, Y., Arvidson, R.E., Gondet, B., Gomez, C. and the Omega Team (2005) *Nature*, **438**, 623-627. [2] Chevrier, V., Poulet, F. and Bibring, J.P. (2007) *Nature*, **448**, 60-63.