Healed microfractures and mineral or fluid inclusions in olivine xenocrysts and in xenoliths from Tatara San Pedro complex, Central Chile: Evidence for subsolidus and remobilisation history.

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Phenocryst proportions in many mafic lavas of the Quaternary Tatara-San Pedro complex (TSPC; 36ES, Chilean Andes) are minor compared to modal abundances of coarse olivine, clinopyroxene, and plagioclase xenocrysts derived from disaggregated mafic-ultramafic xenoliths. The xenocrystic nature of the olivine crystals is indicated by the presence of embayments, melt channels with mineral composition different from the groundmass, and an abundance of healed microfractures (HMF, Dungan & Davidson, 2004). Modelling of iron diffusion in olivine shows that the residence time of these crystals in the basalt is on the order of a few years (Costa & Dungan, 2005).

Other units, in particular a Holocene dacite flow from Volcan San Pedro contain abundant xenoliths of amphibole- and phlogopite-bearing gabbros (Costa et al., 2002.). Most minerals in these xenoliths, and in particular the olivines, also contain abundant HMF. The dacitic composition of the host lava implies moderate temperatures (<980°C), and therefore less thermal impact following incorporation in the host magma on the observed features. This is consistent with observations suggesting limited reaction / melting of the xenoliths with the host magma.

We are investigating these HMF and their inclusions in both types of rocks. Because these features are found in volcanic rocks but originally formed in plutonic rocks, they provide two types of information: 1) The original fractures are remnants from a subsolidus history, indicating the extent of remobilisation of plutonic roots of the arc. 2) The history of remobilisation has reheated the xenocrysts in a basaltic and dacitic environment for various amounts of time.

The HMF's are show two types of characteristic features: 1) many of the HMF's are marked by thin linear low-Fo zones (ΔFo = 1 to 5; width= 3 to 10 µm) along the healed microfracture. 2) various kinds of fluid and mineral inclusions were trapped after healing of the fracture. We have investigate the chemical variations in olivine adjacent to the HMF using back scattered electron images and electron microprobe In order to assess the extent of modification that the HMF have undergone following incorporation of host in magma. Some of the HMF partially retain subsolidus histories in the form of fluid and or mineral inclusions. We use Raman spectrometry to identify these phases.

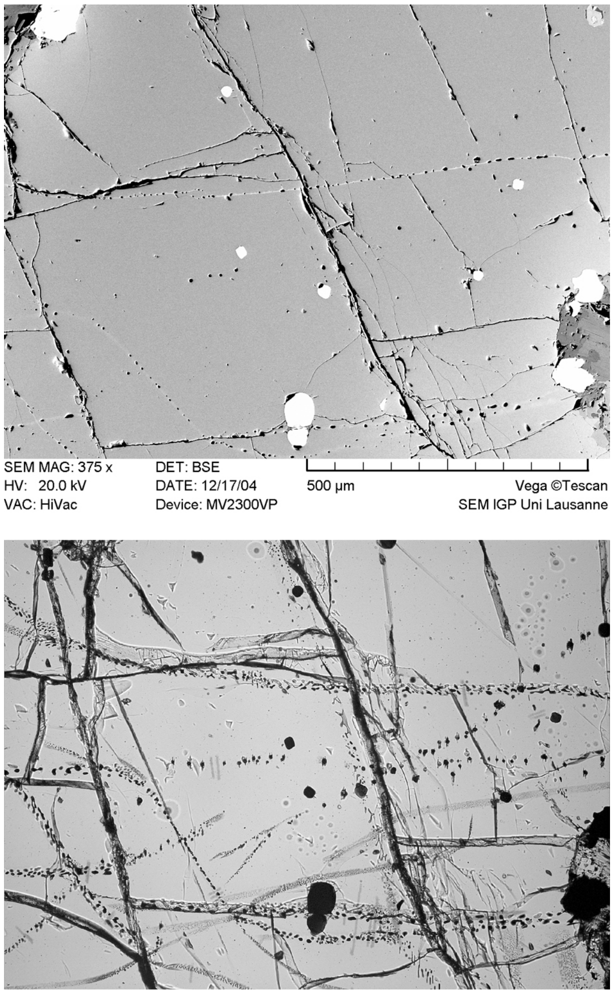

Figure 1. HMF in olivine xenocrysts from TSPC basalt. a) Backscattered electron image showing Fe rich zone (lighter grey); b) Transmitted light microscopy.

Back-scattered electron images (Fig 1a) and electron microprobe analyses delineate narrow zones of high Fe contents along the HMF. Because of the rapid diffusion of iron in olivine, the fact that these features have not been erased shows that they are relatively late and the shape of the Fe profile can be modelled in terms of residence time, assuming the temperature known.

In the olivine xenocrysts from the basalts, the iron-rich zone is usually narrow (<5 µm) with a sharp boundary, and (isothermal) iron diffusion modelling gives time since crystallisation of a few hours at magmatic temperatures, indicating that these fractures were probably open upon eruption and that the crystallisation of the iron rich zone is mainly post-eruptive. Some longer diffusion times (a few days) suggest possible crystallisation during ascent. In both cases most information (fluids) from the subsolidus stage will have been lost. The large effect of remobilisation is consistent with the high temperature of the host lavas and seems to be correlated with the residence time of the olivine in the lava.
In contrast the olivines from the xenoliths entrained in the Holocene dacite, rarely show the iron rich zone along the HMF axis, although such healed fractures are especially abundant. When present, the iron-rich zones have a much more diffuse profile similar to those near olivine rims. The time given by iron diffusion at temperatures between 925 and 525°C is a few years to over 1 Myrs. This seems too long for post-eruptive crystallisation event at magmatic temperatures. Therefore, these iron variations probably represent either a crystallisation in the re-opened HMF immediately after xenolith incorporation or a low temperature subsolidus history.

First results of Raman spectroscopy analyses for the identification of fluid and mineral inclusions show following features :
Whereas most of the HMF's that show recent re-opening, in the form of Fe-rich zones, seem, as expected, to have lost their trapped fluids (or contain low pressure fluids), some others still retain some of the original fluids / minerals, modified to an unknown extent following incorporation.

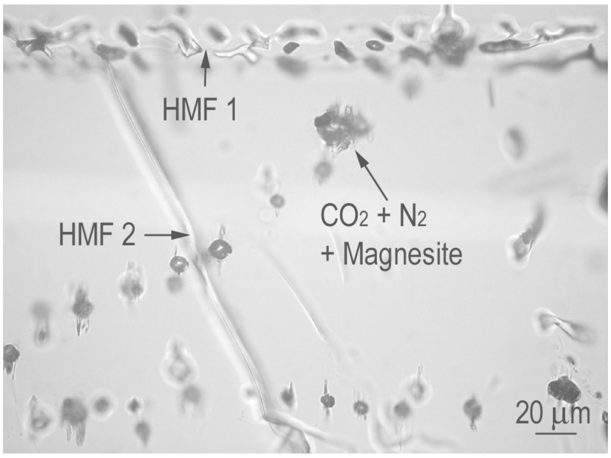

Figure 2. HMF in olivine: HMF1 (showing Fe rich line in BSE image) is empty whereas HMF2 inclusions, partially decripitated, still contain CO_2, and N_2 as well as magnesite.

The moist common fluid inclusions are rich in CO_2 (gaseous state) with or without significant amount of N_2. (Fig 2). The inclusions exhibit partial decrepitation features, and, in some cases, magnesite as a reaction product of the CO_2 with olivine. No fluid water was observed, but a few inclusions seem to contain antigorite, a reaction product of water with olivine. We also found anhydrite crystals in some inclusions suggesting very oxidizing conditions.

A more detailed Raman study is under way, in order to characterise the fluids phases. The xenoliths and xenocrysts are thought to come from the plutonic root of the arc at relatively shallow depth. The inclusions present in the olivines have, therefore, recorded fluids flowing through the crust. Although modified by the post incorporation heating, the inclusions contained in xenocysts and xenoliths have the potential to reveal the nature of the crust sampled and assimilated by the magma, especially in terms of volatile elements and fluid phases.

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