

**PROBLEMS WITH A LOW-PRESSURE THOLEIITIC MAGMATIC HISTORY FOR THE CHASSIGNY DUNITE** J. Filiberto<sup>1</sup>, H. Nekvasil<sup>1</sup>, and D. H. Lindsley<sup>1</sup>, <sup>1</sup>Department of Geosciences, SUNY, Stony Brook, NY 11794-2100, jfiliber@ic.sunysb.edu, Hanna.Nekvasil@sunysb.edu.

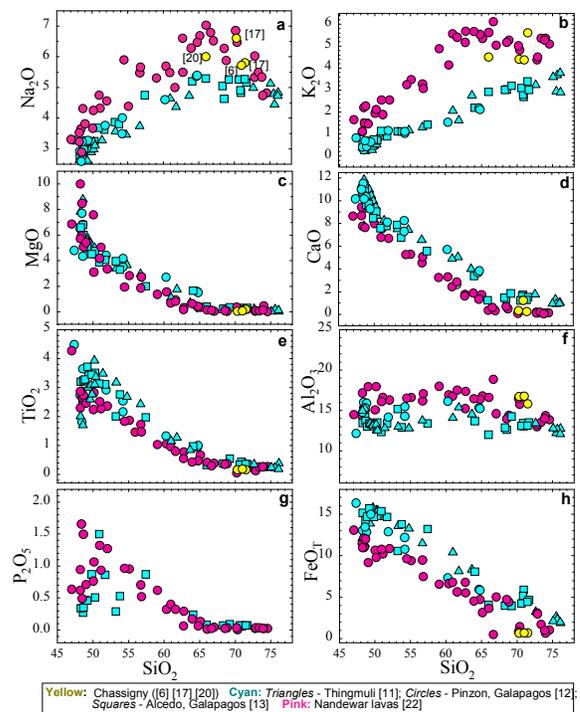
**Introduction:** A variety of workers have proposed low-Al, high-Fe parental liquids for the SNC meteorites. This conclusion arose from the results of rock melting experiments and computational work on Shergotty and Zagami [1-4], and bulk melt inclusion approximations [5,6] of the Chassigny and nakhlite cumulates. In spite of the general acceptance of these proposed parental liquid characteristics, to-date, no phase equilibrium experiments on high-Fe, low-Al melt have produced the cumulate and melt inclusions assemblages of the SNC meteorites. For Chassigny and the nakhlites even the phases themselves have not been produced experimentally, much less their compositions. The strong deviations of natural assemblages for the Chassigny, for example, from those produced by postulated low-Al, high-Fe parental liquids under "dry" and water-saturated conditions can be clearly seen by the experimental data of [7].

Doubts about the accepted parental compositions have been raised by several workers using different approaches [8-10]. It was proposed by [8, 9] that instead of a low-Al, high-Fe parental liquid, the parental liquid for the Chassigny was a silica-saturated hawaiite. Their conclusions were based on the similarities between the polyphase melt inclusion assemblages of the Chassigny and the fractionation assemblages of silica-saturated hawaiite above 4.3 kbar and with >0.4 wt% bulk water. They showed that Al:Ti cation ratios in melt-inclusion pyroxene support such pressures and the alumina contents of this pyroxene supports a high-alumina, rather than low-alumina melt (at least by the stage that the inclusion pyroxenes formed).

A third possible martian magma type was proposed by [10]. This was based on their observation that the computed Pathfinder sulfur-free rock lies compositionally along the low-pressure fractionation path of a typical terrestrial intra-plate olivine tholeiite. Although this conclusion was not based on the SNC meteorites, it does lead to the question of whether such a model could be extended to the parental magma(s) of SNC meteorites. If so, it would indicate a lack of uniqueness in the conclusion of [8,9] regarding a hawaiitic parental magma. To assess the possibility that low-pressure fractionation of olivine tholeiite rather than higher pressure fractionation of a hawaiitic parent could lead to formation of the SNC meteorites we have compared experimental phase equilibria for the two trends, focusing specifically on the Chassigny.

### Low pressure fractionation of olivine tholeiite vs. fractionation of hawaiite at elevated pressure:

(a) *Differences in mineral assemblage.* The liquid line-of-descent of olivine tholeiite at low pressure is shown by lavas of a variety of ocean islands and exemplified in Figure 1 by lavas from Thingmuli, Iceland [11] and the Galapagos Islands [12,13]. A variety of experimental data exist that describe the phase equilibria that lead to this liquid line-of-descent [14-16].



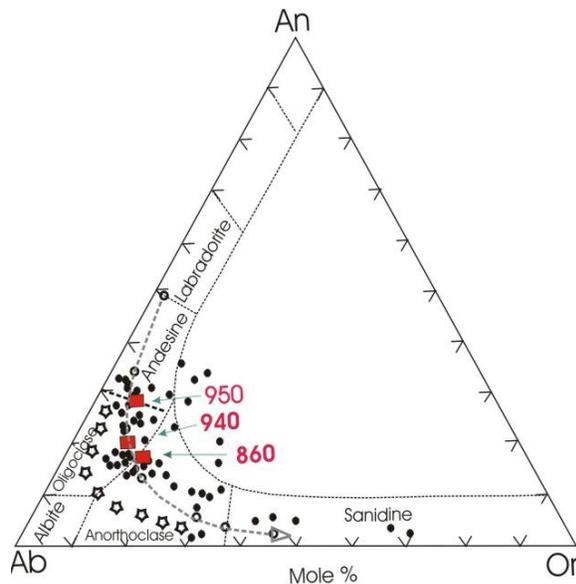
**Figure 1.** Bulk lava compositions of intra-plate tholeiitic suites (cyan), the silica-saturated alkalic Nandewar suite (pink), and non-feldspathic melt inclusion glass from the Chassigny meteorite.

The crystallizing assemblages along this liquid trend consist of combinations of olivine, plagioclase, low-alumina clinopyroxene, magnetite and ilmenite, until highly silicic liquid compositions are reached. These assemblages are inconsistent with the olivine - high-Al clinopyroxene - orthopyroxene - kaersutite, - (Ti-biotite) - apatite - ilmenite assemblages of the Chassigny polyphase inclusions that lead to the silica saturated alkalic trend (Fig. 1).

(b) *Differences in rhyolite composition.* The rhyolitic glass of the polyphase inclusions also sheds light

on whether liquid evolution in the Chassigny polyphase melt inclusions followed the low pressure tholeiitic differentiation trend or a higher pressure silica-saturated alkalic trend. Rhyolites from both trends are similar but nonetheless show significant differences (Fig. 1). Residual glass in polyphase melt inclusions from the Chassigny [6] and non-feldspathic rhyolite glass from holohyaline inclusions [17] are shown for comparison. It is clear that the Chassigny rhyolite shows better agreement with the rhyolite from the alkalic trend than with that from the tholeiitic trend.

(c.) *Differences in feldspar evolution.* The Chassigny dunite contains interstitial feldspars which may have preserved compositional information on the late-stage liquids with which the dunite was in contact. Figure 2 shows the normative feldspar constituents of the Chassigny interstitial feldspars [18] compared with those from the experiments of [19] on hawaiite at 9.3 kbar and 2 wt % water. Also shown is the evolutionary path of feldspars from Nandewar lavas compared to those from the typical low-pressure tholeiitic differentiation path. The feldspars are more consistent with those from the alkalic sequence.



**Figure 2.** Interstitial feldspars from the Chassigny cumulate (black dots) [18], experimental feldspars (red) [19], feldspars from the silica-saturated alkalic Nandewar suite (open circles) [22], feldspars from Thingmuli lavas (open stars) [11].

(d.) *Bulk melt inclusion compositions.* Bulk melt inclusion data also suggest an alkalic melt for at least part of the Chassigny crystallization history. These data include the alkalic potassium contents of rehomogenized polyphase inclusions [17], the alkalic nature of liquid of the Chassigny melt inclusion predicted to be in equilibrium with kaersutite (composition B of

[6]), alkalic widebeam analyses of polyphase inclusions [18], and alkalic silica-poor rhyolite inclusions [20].

**Further considerations:** Even if the Chassigny melt inclusion assemblages support an alkalic composition, could the parental liquid of the *cumulate* be tholeiitic? That is, could olivine tholeiite be parental to silica-saturated hawaiite? Recent work [21] has shown that between 4.3 and 12.3 kbar an olivine tholeiite from the Snake River Plain with water content >0.4 wt% evolves to silica-saturated hawaiite. Because of this, there is no need to invoke a primitive alkalic magma from the martian mantle.

Could alkalic magma at near-surface pressures yield the Chassigny assemblages? It has been shown [21] that at low pressure conditions, silica-saturated alkalic magmas crystallize the same assemblage as tholeiite. For this reason, the Chassigny assemblages could not be produced at low pressures from a hawaiite.

**Summary:** Many lines of evidence suggest that the Chassigny polyphase melt inclusion assemblage formed from a typical terrestrial silica-saturated hawaiite at elevated pressure. They further indicate that even if the magma parental to the sulfur-free Pathfinder rock arose from low-pressure fractionation of olivine tholeiite, this process cannot be extended to the Chassigny meteorite (or the nakhlites).

**References:** [1] Stolper E. and McSween H. (1979) *Geochim. Cosmochim. Acta*, 43, 1475-1498. [2] McCoy T. J. et al. (1992) *Geochim. Cosmochim. Acta*, 56, 3571-3582. [3] Hale V. P. S. et al. (1999) *Geochim. Cosmochim. Acta*, 63, 1459-1470. [4] Dann J.C. et al. (2000) *Met. Planet. Sci.*, 36, 793-806. [5] Treiman A. H. (1993) *Geochim. Cosmochim. Acta*, 57, 4753-4767. [6] Johnson M. C. (1991) *Geochim. Cosmochim. Acta*, 55, 349-366. [7] Minitti M. E. and Rutherford M. J. (2000) *Geochim. Cosmochim. Acta*, 64, 2535-2547. [8] Nekvasil H. et al. (2003) *Mars VI*, Abstract #3041. [9] Nekvasil H. et al., LPSC 35. [10] McSween H. Y. Jr. et al. (1999) *J. Geophys. Res.*, 104, 8679-8715. [11] Carmichael I. S. E. (1964) *J. Petrol.*, 5, 435-460. [12] Baitis . H. W. and Lindstrom, M. M. (1980) *Contrib. Mineral. Petrol.*, 72, 367-386. [13] Geist D. (1995) *J. Petrol.*, 36, 965-982. [14] Spulber S. D. and Rutherford M. J. (1983) *J. Petrol.*, 24, 1-25. [15] Juster T. C. et al. (1989) *J. Geophys. Res.*, 94, 9251-9274. [16] DiFrancesco N. J. et al. (2003) *GSA Abstr. w. Prog.*, 34, Abstract # 258-14. [17] Varella M.E. et al. (2000) *Meteor. Planet. Sci.*, 35, 39-52. [18] Floran R. J. et al. (1978) *Geochim. Cosmochim. Acta*, 42, 1213-1229. [19] Nekvasil H. (in press) *J. Petrol.* [20] Monkawa A. et al. (2003) *Nat. Inst. Polar Res*, 88-89. [21] Nekvasil H. et al. (2003) *GSA Abstr. w. Prog.*, 34, Abstract # 161-14. [22] Stolz A. J. (1985) *J. Petrol.*, 26, 1002-1026.