

EFFECT OF WATER ON CRYSTALLIZATION OF MAFIC ARC HIGH-ALUMINA BASALT FROM THE SOUTH SANDWICH ISLANDS: STILL NO LIQUIDUS OLIVINE. David S. Draper, Institute of Meteoritics, 1 University of New Mexico MSC03-2050, Albuquerque NM 87131. david@draper.name

Introduction: During the late 1980s and early 1990s, a consensus view emerged from ongoing debate regarding whether island-arc tholeiites were derived from melting the subducted slab or the overlying mantle wedge. Trace-element, isotopic, and petrologic data have been cited to infer that most arc basalts originate in the mantle wedge and that wedge melting is either caused or facilitated by fluxing from fluids derived from devolatilization of the upper reaches of the subducting slab. Alumina-rich arc tholeiites (termed HAB for high-alumina basalt), the dominant lithology in most such settings, are thus held to be differentiates of more primitive, magnesian parents such as volumetrically less extensive high-magnesia basalts (HMB), and the more evolved lithologies such as andesites and dacites are, in turn, likely to be differentiates of HAB. Only in specialized settings is significant slab melting thought to occur, and then mostly to produce comparatively uncommon compositions such as the so-called adakites (magnesian andesites).

Yet one important feature of arc HAB phase equilibria that is not compatible with this model remains unaccounted for. Under anhydrous conditions, a typical primitive arc HAB, SSS.1.4 from the South Sandwich Islands in the Scotia arc (red star on Fig. 1), is not saturated with olivine at any pressure; instead, its liquidus phases are plagioclase, clinopyroxene, and garnet at increasingly elevated pressures; olivine does not appear until $\sim 100^\circ\text{C}$ beneath the liquidus [1]. But SSS.1.4 is not far in composition from some liquids coexisting with olivine \pm clinopyroxene formed in melting experiments on arc HMB by [2], who argued (p. 16) that liquidus plagioclase was not expected for those HMB-derived melts because, in a clinopyroxene-olivine-plagioclase-quartz projection, those liquid compositions plot along "an extrapolated intermediate pressure Plg-Ol-Cpx cotectic while SSS.1.4 plots comfortably in the plagioclase field." The question then becomes, if HABs like SSS.1.4 are indeed the product of olivine-dominated fractionation from more primitive precursors, why would the parental melts to SSS.1.4 fractionate to that cotectic and then jump across it into the plagioclase field, rather than following it down-temperature?

Two possible explanations for these anhydrous results are that SSS.1.4 suffered plagioclase accumulation in a process like that described by Crawford et al [3], or that SSS.1.4 liquid could be in reaction relationship with olivine. Draper and Johnston [4] tested the latter notion experimentally under anhydrous condi-

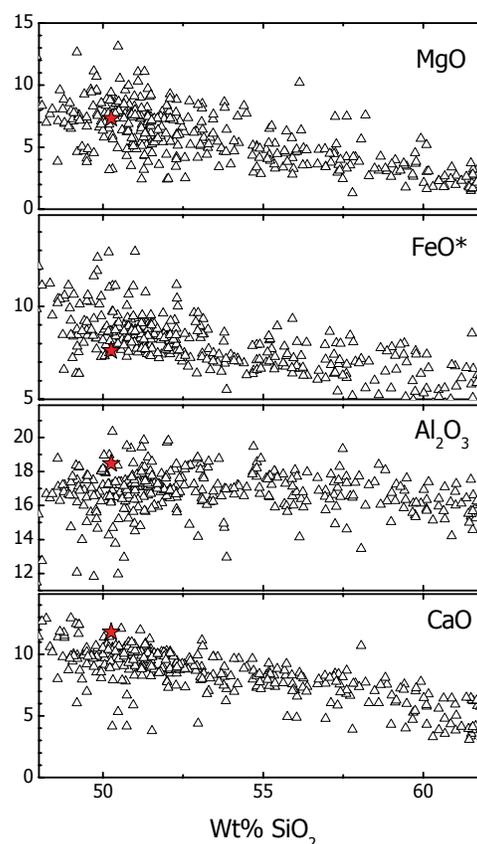


Figure 1 Oxide variation diagrams for arc volcanic compositions. SSS.1.4 (red star) typifies primitive end of spectrum

tions, finding that such a process is feasible only for a few, comparatively Ca-poor arc HABs and does not account for typical HAB like SSS.1.4. They also calculated that plagioclase accumulation is unlikely to account for the nearly aphyric SSS.1.4 lava, and concluded that the most likely explanation was that if the parent magma to SSS.1.4 were hydrous, small amounts of water could expand the primary phase volume of olivine at the expense of that for plagioclase, removing the final hurdle for deriving SSS.1.4 from mantle-wedge-derived magnesian parental magmas. In this contribution, this process was tested experimentally by performing near-liquidus experiments on SSS.1.4 with several percent water added. Surprisingly, however, results thus far show that olivine is still not a near-liquidus phase for SSS.1.4 at 2-3 wt% H_2O , and probably even at 5 wt% H_2O .

Experiments: The experiments reported here were performed at ~ 2 -3 and ~ 5 wt% H_2O under com-

paratively oxidized conditions relevant to arc magmatism. Powdered SSS.1.4 (a split from the original starting material of Johnston [1]) was run in sealed AuPd capsules with powdered oxalic acid dihydrate (OAD) as the fluid source in a piston-cylinder device at 0.5 to 1.0 GPa, 1075-1250°C for 4-21 hr. OAD breaks down at run conditions to a 50:50 molar mixture of H₂O and CO₂ (29 and 71 % by weight, respectively); solubility of CO₂ at these conditions is less than 200-300 ppm [5], thus OAD provides a very convenient means for controlling water content and the added CO₂ should have virtually no effect on phase relations. Sample capsules were in turn sealed into outer AuPd capsules containing an oxygen buffer assemblage consisting of nickel + nickel oxide (NNO) or fayalite + quartz + magnetite (FMQ). These two buffers are < 0.5 log units apart at the conditions of these experiments and are appropriate for the higher oxygen fugacities held to be prevalent in arc basaltic magmatism. At these fugacities iron loss to the AuPd capsules is minimized [6]. Thus far approximately 10 experiments at ~2-3 wt% H₂O have been completed, with four at ~5 wt% H₂O.

Results: Fig. 2 summarizes the phase relations thus far determined. On the right are curves showing the anhydrous relations found by Johnston [1], showing the liquidus at ~1275° at 1.0 GPa with a broad field of plagioclase crystallization; olivine forms ~100° beneath the liquidus at pressures below ~0.8 GPa. On the left, results from ~10 experiments at 2-3 wt% H₂O are illustrated by the grey field boundaries, and the 4 runs at ~5 wt% are shown by the symbols keyed to the legend. At 2-3 wt% H₂O the liquidus is depressed ~50°, and olivine again does not appear un-

til ~100° cooler at 0.5 GPa (beneath symbol legend). The primary phase volume for plagioclase has indeed contracted, but not enough for olivine to assume the liquidus. The four experiments at ~5 wt%, two above the liquidus and two below, imply the liquidus under these conditions is depressed ~175°. Neither subliquidus run contains olivine; the liquidus phase at ~0.8 GPa is either plagioclase or orthopyroxene, and at ~1.0 GPa is either plagioclase or clinopyroxene. Additional coverage will reveal more detail, but the clear result is that olivine does not assume the liquidus of HAB at ~2-3 wt% water; at 5 wt%, it could do so only at pressures less than 0.8 GPa.

Implications: The conflict described above between anhydrous results on arc HAB and HMB remains unresolved: primitive HAB SSS.1.4 still does not show liquidus olivine even with several percent water in the system, unless it does so at very low pressure and high water contents. With respect to the options listed earlier, could those processes act under hydrous conditions? Clearly plagioclase accumulation is unlikely in hydrous basalts, but it is possible that water-bearing liquids derived from mafic-phase fractionation of a parental HMB could enter into olivine-liquid reaction. A water bearing study similar to the earlier anhydrous work [4] would be required to make such a determination.

References: [1] Johnston, A. D. (1986) *CMP*, 92, 368. [2] Gust, D. A. and Perfit, M. R. (1987) *CMP*, 97, 7. [3] Crawford, A. J., et al. (1987) *CMP*, 97, 417. [4] Draper, D. S. and Johnston, A. D. (1992) *CMP*, 112, 501. [5] Pan, V., et al. (1991) *GCA*, 55, 1587. [6] Hall, L. J., et al. (2004) *Min Mag*, 68, 75

Figure 2 P-T summary diagram comparing anhydrous results on SSS.1.4 with water-bearing results at NNO (~FMQ) reported here. Liquidus depression is ~50 and ~175°C at ~2-3 and ~5 wt% H₂O, respectively. Olivine occurs at 0.5 GPa, 1140°C (~100°C below liquidus) with ~2-3 wt%, does not appear in the two subliquidus runs at ~5 wt% H₂O. *L*, *gl*, glass; *sp*, spinel; *cpx*, clinopyroxene; *Plag*, *pl*, plagioclase; *Ol*, olivine; *opx*, orthopyroxene.

