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# Sector-zoned Augite Megacrysts in High Alumina Basalts with Implications for the Conditions of Basalt Crystallization and the Generation of Calc-Alkaline Series Magmas

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Understanding the nature and location of calc-alkaline differentiation is important to understanding the characteristics of crustal structure and composition. High Alumina Basalt (HAB) is thought to be parental to calc-alkaline series magmas. Thus, understanding the nature of HAB crystallization is fundamental to understanding the entire process of calc-alkaline differentiation and its role defining the structure of continental crust. Two important features that distinguish HAB from other types of basalt are very high initial $H_2O$ contents (up to 3wt% $H_2O$) and very high phenocryst contents (up to 60 volume%). These two features, coupled with the knowledge that: (1) dissolved $H_2O$ suppresses the crystallization temperatures of all silicate minerals; and (2) the solubility of $H_2O$ decreases with decreasing pressure, has led to the suggestion that HAB crystallization is due to decompression-induced volatile exsolution and accompanying rapid crystallization. If correct, this implies that HAB magmas spend much of their life in a superheated state, which places significant constraints on the subsequent differentiation of HAB magmas. Until now, there has been no direct evidence to support this suggestion.

A potentially important feature of HAB lavas is the presence of sector-zoned augite phenocrysts. Lavas containing such crystals have been reported from the Aleutian, Japanese, Mariana, Kurile, and Lesser Antilles arcs, suggesting that it could be a common but largely overlooked phenomena. Sector zoning in pyroxenes is significant as it is suggestive of rapid crystal growth which, in turn, could support the notion of rapid, volatile exsolution-induced crystallization. Before such a connection can be established, however, several important criteria must be satisfied. These include: (1) that the observed sector zonation is indeed a reflection of rapid crystal growth; (2) that significant volatile exsolution occurred in the host HAB magmas prior to eruption; and (3) that augite growth occurred during the process of volatile exsolution. To address these criteria, several sector-zoned augite megacrysts in HAB lavas from the Aleutian arc have been studied in detail. The megacrysts are invariably euhedral with well developed {001}, {010} and {111} forms. All crystals display concentric bands that are rich in mineral and glass inclusions. The sector zonation typically occurs as well developed (010), (100), (111) and (110) sectors. Different widths of synchronous growth bands indicate relative growth rates of (111)> (100)~(110)>(010). $SiO_2$ and MgO abundances decrease and $TiO_2$, $Al_2O_3$, FeO and $Na_2O$ abundances increase in the different sectors in the same order, implying that growth rate clearly had a role in the development of the sector zonation. Calculated pre-eruption $H_2O$ contents of the host basalts range from 1 to 3 wt% but measured post eruption $H_2O$ contents range from 0.01 to 0.3 wt%. Deuterium isotopic values are heavily depleted and range from -110 to -141% Together, these indicate significant vapour ($H_2O$) exsolution prior to eruption. $H_2O$ abundances in glass inclusions systematically decrease from the core to rim of one augite megacryst studied in particular detail, indicating that augite crystallization occurred during a period of on-going vapour ($H_2O$) exsolution.

On the basis of these results, it is concluded that the presence of sector-zoned augite is indeed a reflection of augite super-saturation and rapid crystallization brought about by magma decompression and volatile ($H_2O$) exsolution. The calculated pre-eruption $H_2O$ contents of 1-3wt% limit vapour exsolution and HAB crystallization to depths of less than 3km and more likely 1.5km. Very rapid crystallization at very shallow depths makes it unlikely that the time scales between initial crystallization and final eruption are sufficient to permit appreciable amounts of fractional crystallization. If HAB fractionation is the dominant process for generating more evolved calc-alkaline series magmas, the inability of parental HAB to yield such derivative magmas in the low pressure environment places the likely site of fractionation in the high pressure environment, at or near the base of the crust.