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Magma chamber processes revealed by silicate melt inclusions hosted by phenocrysts of the Szomolya Ignimbrite, Bükkalja Volcanic Field

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Magma chamber processes are often complex, especially in silicic systems. Rhyolitic volcanic products usually give information only a part of the magma evolution process, however, silicate melt inclusions hosted by various minerals could open a wider window to have an insight into these processes. We studied the silicate melt inclusions along with the juvenile glasses of the Szomolya Ignimbrite occurring in the Bükkalja Volcanic Field, northern part of the Pannonian Basin.

Glass inclusions occur in the phenocrysts both of the host ignimbrite and the enclosed cognate andesitic lithic clasts. We determined the major element composition of these glass inclusions by microprobe, whereas their trace element contents were measured by LA-ICP-MS. The most evolved character was shown by the quartz-hosted glass inclusions, which have the same composition as the glass shards in the ignimbrite. The orthopyroxene- and plagioclase-hosted glass inclusions have wider geochemical variation, but they form linear trends in trace element diagrams. These phenocrysts are embedded in a glassy groundmass of the lithic clast. This glass has fairly similar trace element content as the evolved glasses except for some trace elements such as Zr, Hf, and LREE. Trace element model calculation points to the importance of fractionation of accessory minerals such as zircon and allanite. Following an extensive fractionation of plagioclase and pyroxenes, late-stage crystallization of accessory minerals had a major influence for the trace element content of the most differentiated residual melt represented by the glass shards and quartz-hosted melt inclusions.

Glass inclusions of lithic clast imply that the trapped melt droplets could have evolved in a partially closed system and their compositions were controlled locally by the crystallizing minerals. This can be especially detected in plagioclase-hosted glass inclusions for both major and trace elements. However, strongly incompatible trace elements can be used effectively to reveal the liquid line of descent in the whole magma chamber. We interpret that the lithic clast represents a quenched section of the magma chamber wall.

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Contrasting processes in silicic magma chambers: Evidence from very large volume ignimbrites

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Petrologic studies of silicic ignimbrites suggest that magma chamber processes depend on chamber size and shape as well as the composition, temperature, and crystallinity of the magma filling the chamber.

Several very large (volumes greater than 1000 km^3) crystal-rich dacitic ignimbrites lack the vertical zonation found in many other tuffs (e.g., Fish Canyon Tuff from Colorado and the Cottonwood Wash, Wah Wah Springs, and Lund Tuffs of the Great Basin in western USA). Apparently, their magma chambers were modestly heterogeneous but not systematically zoned from top to bottom. These ignimbrites have 40% to 50% phenocrysts set in a high-silica rhyolite glass. Mineral assemblages and mineral compositions suggest pre-eruption temperatures were 730° to 800°C at relatively high water fugacities. We have speculated that these very large-volume ignimbrites are unzoned because crystallization and convection in slab-shaped magma chambers inhibited separation of crystals from liquids and resulted in a compositionally heterogeneous chambers that lacked systematic chemical zonation.

However, many other very large-volume rhyolitic ignimbrites are vertically zoned (e.g., tuffs related to the Yellowstone hotspot) suggesting that their parent magma chambers were also vertically zoned. And yet these large Yellowstone-type rhyolites must be derived from chambers that are sill-like—their calderas are 40 to as much as 70 km across, implying that the subjacent magma chamber was approximately this size as well. Thus, factors other than chamber shape must be important for establishing the nature of zonation. These zoned rhyolitic tuffs typically have strong imprints of fractional crystallization, few phenocrysts, anhydrous mineral assemblages, and crystallization temperatures of 850° to 950℃. Calculated magma viscosities are several orders of magnitude lower than for the cooler, wet crystal-rich dacites.

Perhaps these water-poor and consequently hot rhyolites had low enough viscoities to allow efficient crystal-liquid separation—probably by sidewall crystallization and rise of fractionated, less dense magma to the top of large chambers. In contrast, crystallization of the water-enriched magmas occurred at lower temperatures where magma viscosity was significantly higher. This inhibited crystal-liquid separation, hindered development of systematic vertical zonation, and promoted quasi-equilibrum crystallization in small domains within large heterogeneous magma chambers.