Rapid genesis of large "supervolcanic" volumes of silicic magmas in the upper crust based on microanalytical isotope investigation of crystals in eruptive products and numerical modeling of melting and segregation processes

Быстрая генерация больших "супервулканических" объёмов кислой магмы в верхней коре на основании микроаналитического изотопного изучения кристаллов в продуктах извержений и численного моделирования процессов плавления

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We present new results of *in-situ* geochronologic and isotopic investigation of zircons using SHRIMP and Cameca 1270-1280 large radius ion microprobes. We investigated isotopic variations of oxygen and determined U-Pb and U-Th geochronologic ages of Holocene and Pleistocene zircons from a variety of settings: intraplate high-silica rhyolites from Yellowstone, many older low and high-silica rhyolites from the Snake River Plain, dacites and rhyolites from Timber Mt Caldera, Nevada, silicic rocks from Iceland's largest silicic centers, and a silicic rocks from Kamchatka. Many of these units are additionally fingerprinted by low-$\delta^{18}O$ values, characteristic of meteoric waters. The origin of such isotopically-fingerprinted large-volume ignimbrites and smaller volume intra-caldera lavas requires shallow remelting of large volumes of variably ^{18}O-depleted volcanic and sub-volcanic rocks altered by hydrothermal activity. Zircons provide probes of these processes as they preserve older ages and inherited $\delta^{18}O$ values. In total we have a database exceeding 1000 $\delta^{18}O$ analyses of cores and rims of zircons coupled with their U-Pb and U-Th ages.

The results of this work provide the following new observations.
(1) Most zircons from post-caldera low-$\delta^{18}O$ lavas are zoned, with higher $\delta^{18}O$ values and highly variable U-Pb ages in the cores that suggest inheritance from pre-caldera rocks often exposed on the surface. (2) Many of the higher-$\delta^{18}O$ zircon cores in these lavas have U-Pb zircon crystallization ages that postdate caldera formation, but pre-date the eruption age by 10-20 kyr, and represent inheritance of unexposed post-caldera sub-volcanic units that have $\delta^{18}O$ similar to the caldera-forming tuffs. (3) intra-caldera lavas often contain zircons with both high-$\delta^{18}O$ and low $\delta^{18}O$ cores surrounded by an intermediate-$\delta^{18}O$ rim. This implies inheritance of a variety of rocks from high- $\delta^{18}O$ pre-caldera and low-$\delta^{18}O$ post-caldera units, followed by residence in a common intermediate- $\delta^{18}O$ melt prior to eruption. (4) Major ignimbrites also display significant ranges of ages and $\delta^{18}O$, but they diminish with increase in the magma residence time due to progressive annealing. (5) Mineral diffusive timescales estimates based on the initiation of melting to eruptive quench are in a few thousand years suggesting rapid silicic magma production rates of 0.1 to 0.5km^3/yr.

We also present a series of finite element numerical experiments on rhyolitic magma genesis by remelting in shallow crustal conditions using temperature ranges, appropriate phase diagram with defined dynamic eutectic zone, and physical and material parameters appropriate for these environments. The goal is to estimate conditions required and the scale of the remelting in the upper crust, describe the dynamics of the convecting melting, and compare it to the earlier parametric and numerical attempts to model more generic silicic systems by underplating. The proposed model can explain the origin of crystal-poor “recycled” (750-850ºC) rhyolites with inherited crystal cargo. We advocate that the proposed mechanism can adequately explain rapid generation of large, supervolcanic volumes rhyolites through remelting of their erupted and subvolcanic predecessors and this process may proceed via multi-step, incremental batch assembly provided adequate magma supply rates from the mantle to the bottom of the silicic magma reservoir.