Magma differentiation rates and processes at Mount Mazama (Crater Lake), a Cascades arc volcano

C.R. BACON AND M.A. LANPHERE

U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025, USA [cbacon, alder@usgs.gov]

We have determined the time needed for silicic magma to repeatedly evolve from andesitic parents by establishing the eruptive history of Mount Mazama through geologic mapping and by K–Ar and $^{40}Ar/^{39}Ar$ geochronology. Eruption of dacite and rhyodacite was associated with episodes of vigorous regional mafic volcanism during Mazama's ~ 400 k.y. history. Andesite and dacite of Applegate Peak, the most voluminous eruptive unit of the edifice, erupted ~250-210 ka, concurrently with peripheral basaltic andesite cones. Andesitic stratocone construction ~80 ka was followed ~70 ka with voluminous dacitic plinian fall and lava from several vents, as well as major andesite cone-building lava and thick flank flows. Commencing ~50 ka was a period of comparatively intense peripheral mafic volcanism that accompanied growth of the rhyodacitic climactic magma chamber, first expressed by plinian fall and lava flows ~30 ka and continuing in several episodes until immediately before the climactic, caldera-forming eruption began 7700 yr B.P. The climactic eruption vented ~50 km^3 of mainly rhyodacitic magma followed by crystal-rich andesitic magma and gabbroic cumulate mush. Many phenocrysts and some zircons in ~30 ka rhyodacites apparently came from ~110 ka granodiorite; new zircons grew during crystallization differentiation within a few k.y. before eruption. Trace element and isotopic compositions of products of the zoned climactic eruption, in conjunction with the order of eruption, suggest incremental growth of the silicic volume of the magma chamber by crystallization differentiation during replenishment. Andesitic to basaltic magmas, whose incompatible element abundances and isotopic compositions varied, are believed to have lodged repeatedly between silicic magma and underlying cumulates. Replenishment magma rapidly crystallized until in thermal equilibrium, at which point buoyant residual melt escaped upward into the growing silicic volume, perhaps aided by gas-driven filter pressing. The minimum silicic magma production rate was ~2 km^3/k.y. The 4 km^3 of crystal-rich postcaldera andesite vented within ~500 yr of caldera formation. A 0.074 km^3 dome of virtually xenocryst-free rhyodacite was emplaced ~2,400 yr later. Presumably, this rhyodacite differentiated from andesitic magma, and this occurred at the low minimum rate of 0.03 km^3/k.y. because of low regional magma input.

Ion microprobe analysis of $^{87}Sr/^{86}Sr$ in $CaCO_3$ and application to otoliths

C.R. BACON[1], P.K. WEBER[2], K.A. LARSEN[3], R. REISENBICHLER[3], I.D. HUTCHEON[4], B.L. INGRAM[2], & J.L. WOODEN[1]

[1]USGS, Menlo Park, CA 94025 USA [cbacon, jwooden@usgs.gov]
[2]Dept. of Geography, Univ. California, Berkeley, CA 94720 USA [pweber, ingram@socrates.berkeley.edu]
[3]USGS Western Fisheries Research Center, Seattle, WA 98115 USA [kim_larsen, reg_reisenbichler@usgs.gov]
[4]Lawrence Livermore National Laboratory, Livermore, CA 94551 USA; [hutcheon1@llnl.gov]

We have determined $^{87}Sr/^{86}Sr$ ratios of calcite and aragonite containing 350 to 1000 ppm Sr *in situ* with the Stanford – USGS SHRIMP RG (1σ~1‰). The method takes advantage of the high transmission at high mass resolving power of the SHRIMP RG (Reverse Geometry: electrostatic analyzer downstream of magnetic sector) to minimize isobaric interferences at 86 to 88 amu. At M/ΔM >6000 (10%), all isobaric interferences are resolved except for Ca dimers (e.g., $^{44}Ca^{42}Ca$, $^{48}Ca^{40}Ca$), $^{48}Ca^{39}K$, and ^{87}Rb. Presently, analyses are performed at M/ΔM=7000. The $^{48}Ca^{39}K$ peak does not contribute to counts at ^{87}Sr in otoliths. A correction is made for ^{87}Rb by measuring ^{85}Rb. A primary beam of ~9 nA $^{16}O_2^-$ produced 25 by 35 μm, flat-bottom craters. Secondary ion intensities at $^{40}Ca^{40}Ca$, $^{40}Ca^{42}Ca$, ^{85}Rb, ^{86}Sr, ^{87}Sr, ^{88}Sr, and $^{48}Ca^{44}Ca$ are measured by peak jumping and pulse counting on an electron multiplier. An analysis consisting of 10 cycles through the mass table requires about 13 minutes. Calibration employs natural calcites, and synthetic calcites and aragonites made at high pressure and temperature. High purity synthetic calcite was used to assess production and instrumental mass fractionation of Ca dimers. Data were processed using (1) peak stripping to correct for all isobaric interferences and (2) using a working curve defined by reference standards. The working curve yields results at least as satisfactory as does peak stripping. A Sr concentration correction to the $^{87}Sr/^{86}Sr$ ratio is necessary.

The chemical and isotopic compositions of fish otoliths track the water (and to a lesser extent, ingested food) chemistry where the animal lived at a time recorded by a particular layer in the aragonitic otolith. Otoliths also preserve a chemical fingerprint of the natal stream or hatchery. The Skagit River of Washington traverses the Cascades, a relatively youthful geologic terrain characterized by low $^{87}Sr/^{86}Sr$ ratios. In contrast, the Idaho streams drain older continental rocks that have higher $^{87}Sr/^{86}Sr$ ratios. Out-migrating juvenile Chinook salmon (*Onchorhynchus tshawytscha*) in these river systems have distinct Sr isotopic signatures. Juvenile fish obtained from Skagit Bay in Puget Sound (Pacific Ocean) have otolith primordia (cores) with marine $^{87}Sr/^{86}Sr$ ratios (0.709) inherited maternally, later growth bands with lower $^{87}Sr/^{86}Sr$ characteristic of the Skagit drainage (≤0.706), and outer growth bands marked by the marine $^{87}Sr/^{86}Sr$ ratio. Otoliths from native juvenile salmon from Idaho streams have distinctly higher $^{87}Sr/^{86}Sr$ ratios (e.g., 0.712).