The volcanic-plutonic connection at subduction zones

JON BLUNDY

Department of Earth Sciences, University of Bristol, Bristol, BS8 1RJ, UK. (jon.blundy@bris.ac.uk)

The vast majority of arc andesites and dacites are not primary magmas. Instead they form by the processing of primitive magmas, derived from fluid-modified mantle wedge, at or close to the base of the arc crust. A deep crustal “hot zone” evolves by incremental intrusion of primitive magmas, typically Mg-rich hydrous basalt. Evolved andesite and dacite melts in the hot zone come primarily from basalt crystallisation, with contributions from melting of old arc crust and/or earlier basalt intrusions. Magma composition is controlled by the initial geotherm and the relative maturity of the hot zone. Where the crust is greater than ~35 km thick (1.1 GPa), basalt crystallisation involves garnet at temperatures <1000°C, imparting a distinctive trace element signature to residual melts.

Hot zone melts can contain ≤ 10 wt% H_2O, depending on the H_2O content of the parental basalt. Once liberated from their source these buoyant, inviscid magmas ascend rapidly. They become superheated en route, enabling them to corrode both entrained residual phases and wall rocks. Experiments on Mount St. Helens dacites show that the net cooling from melt generation at 1.1-1.3 GPa to surface eruption is only 90°C. Crystallisation does not begin until magmas intersect their H_2O-saturated liquidus at shallow depth. Because it is driven by decompression, rather than cooling, crystallisation is rapid, resulting in a huge viscosity increase over a small depth range. Most magmas stall at ~6 km, a typical pluton emplacement depth. Pluton construction involves incremental addition of chemically related melts derived from the hot zone. Each successive addition mingles with earlier additions, reheating them and generating a wealth of complex crystal zoning textures. Such “proto-plutons” can retain a rhyolitic residual melt fraction for sustained periods. Residual rhyolite may be periodically extracted, as evidenced by aplite veins in many granite plutons, leading to linear variation in the chemistry of plutonic rocks. This is an alternative explanation to the restite-unmixing hypothesis. In some cases the residual rhyolitic melt may accumulate sufficiently above the proto-pluton to erupt. Major crystal-poor rhyolitic eruptions, such as the Bishop Tuff, probably formed in this way. Proto-plutons may also be remobilised by injections of hotter magma from below, leading to wholesale eruption, such as the voluminous Fish Canyon Tuff or the current Soufriére Hills andesite.

Partial assimilative recycling of the plutonic roots of a continental arc

M.A. DUNGAN[1], W.P. LEEMAN[2], S. GOLDSTEIN[3], C.H. LANGMUIR[4], J.P. DAVIDSON[5] AND A. PIATROWSKI[3]

[1]University of Geneva, Earth Sciences Section, Geneva 1205, Switzerland (michael.dungan@terre.unige.ch)
[2]Rice University, Department of Geology & Geophysics, Houston, TX 77005, USA (leeman@rice.edu)
[3]Columbia University, Lamont-Doherty Earth Observatory, Palisades, NY 10964, USA (steveg@LDEO.columbia.edu)
[4]Harvard University, Department of Earth and Planetary Sci., Cambridge, MA 02138, USA (langmuir@eps.harvard.edu)
[5]University of Durham, Department of Earth Sciences, Durham, DH1 3LE, UK (j.p.davidson@durham.ac.uk)

If most evolved continental arc basalts are the products of open-system differentiation, resolving their mantle and crustal components requires integration of whole-rock chemistry with constraints from solid phases for many samples from an eruptive episode. This increases the probability that least modified compositions as well as intracrustal contributions, which commonly impose heterogeneity on magma batches, will be identified. A basaltic volcanic sequence of the Andean Tatara-San Pedro complex is characterized by poorly correlated variations among compatible and incompatible elements. Textural and mineral chemistry evidence support partial recycling of mafic-ultramafic cumulates. Low boron concentrations (1 ppm) in the least contaminated magma and higher B in contaminated lavas (5-9 ppm B) imply that B was fixed by hydrous phases in plutonic residues of magma evolution and then was passed on to magmas as a consequence of partial assimilation. Assimilation-related ranges in trace element concentrations and ratios are not correlated with isotopic variations. Two subunits distinguished only by contrasting $^{87}Sr/^{86}Sr$ (0.70405-0.70411 & 0.70390-0.70396) lack systematic isotopic variations as a function of elemental variations. This is explained by recycling of isotopically unevolved Neogene plutonic material by two voluminous pulses of Sr-rich parental magma with subtly different isotopic compositions.