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High water contents in basaltic magmas from Irazú Volcano, Costa Rica

Ezra R. Benjamin [a,1], Terry Plank [a,*], Jennifer A. Wade [a,2], Katherine A. Kelley [b,3], Erik H. Hauri [b], Guillermo E. Alvarado [c]

[a] *Department of Earth Sciences, Boston University, Boston, MA 02215, USA*
[b] *Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015, USA*
[c] *Universidad de Costa Rica and Instituto Costarricense de Electricidad, San José, Costa Rica*

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Abstract

Irazú volcano, in Costa Rica, erupts magmas unusually enriched in incompatible trace elements (e.g., K, REE) relative to most other arc volcanoes worldwide. Previous studies place this enrichment in the mantle, with minimal inputs from the subducting slab. In order to test the subduction vs. mantle hypotheses, we present here the first published measurements of the pre-eruptive volatile content of Irazú magmas. Olivine-hosted melt inclusions from basaltic–andesite scoria from the 1723 eruption are volatile-rich, containing >3 wt.% H_2O, >200 ppm CO_2, >2500 ppm S, >2200 ppm Cl and >1800 ppm F. The average composition of the 1723 melt inclusions is very similar to that of the host scoria (SiO_2=54% SiO_2), although inclusions include more mafic (48% SiO_2) and felsic (57% SiO_2) compositions. The 1723 melt inclusions have the same trace element characteristics (e.g., Ba/La) as the host scoria, ruling out exotic crustal or mantle sources. Together, the melt inclusions and their host olivines ($Fo_{87–79}$) define a closed-system ascent path (150–20 MPa) of coupled degassing, crystallization, and cooling (1075–1045 °C). The maximum H_2O measured in the melt inclusions and the shape of the degassing path together constrain the pre-eruptive H_2O content to 3.2–3.5 wt. %, significantly higher than in ocean island basalts, but typical of arc magmas. The high H_2O in Irazú melts, coupled with their high Cl/K_2O, are inconsistent with enriched mantle with minimal slab fluid addition. We propose instead that subducting input is the dominant contributor to Irazú's geochemical compositions. Galapagos-derived seamounts and volcaniclastics are currently entering the trench near Irazú, and provide to the Irazú source both volatiles (from seafloor hydration and chlorination) and ocean–island-type trace elements and isotopes. A few percent of subducted Galapagos volcanics added to MORB mantle can create Irazú compositions quantitatively, provided elements are further fractionated according to solute-rich liquid or melt–eclogite partition coefficients. Subduction of seamount chains may create high-K arc volcanism elsewhere, such as in the northern Marianas.

Keywords: volatiles; arc; subduction; geochemistry; mantle

* Corresponding author. Tel.: +1 617 353 4213; fax: +1 617 353 3290.
E-mail address: tplank@bu.edu (T. Plank).
[1] Now at: Environmental Resources Management, Boston, MA 02116 USA.
[2] Now at: Library of Congress, Preservation Research and Testing, Washington, DC 20540, USA.
[3] Now at: University of Rhode Island, Graduate School of Oceanography, Narragansett, RI 02882 USA.

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1. Introduction

Irazú Volcano is an active arc volcano at the southeastern terminus of the Central American Volcanic arc (CAVA) in Costa Rica (Fig. 1). The geochemical composition of volcanic rocks from Irazú and neighboring volcanoes are unusual both within the CAVA and within the spectrum of global arc compositions. For example, the CAVA records systematic along-strike variations in many geochemical tracers of the slab (Fig. 2), including Ba/La (Carr et al., 1990), $^{238}U/^{230}Th$ (Herrstrom et al., 1995), U/Th (Patino et al., 2000), $^{10}Be/^{9}Be$ (Morris et al., 1990), B/Be (Leeman et al., 1994), and $\delta^{18}O$ (Eiler et al., 2005). For most of these tracers, the peak in inferred slab flux occurs in the central portion of the CAVA, in Nicaragua, and falls to nearly the global minimum to the southeast, at the terminal sector of volcanoes that includes Irazú. At the same time, the concentrations of many trace elements are highly enriched in Irazú magmas relative to the CAVA or arcs worldwide. Irazú magmas possess among the highest La/Sm of any arc volcano (Fig. 3a), and their REE patterns (Fig. 3b) resemble those of ocean island basalts (OIB).

Taken together, the OIB-type ratios but high concentrations of trace elements have led many workers to propose that Irazú magmas are generated from enriched mantle, like OIB, with little input from the subducting plate. Carr et al. (1990) suggested that enriched mantle preferentially melts beneath Costa Rica due to a spatially diffuse slab fluid flux caused by a shallow slab dip. Leeman et al. (1994) proposed that Costa Rica magmas tap enriched components in the mantle lithosphere. Herrstrom et al. (1995) suggested that trench-parallel flow around the end of the Cocos slab has driven enriched mantle beneath Irazú, citing evidence from seismic anisotropy measurements (Russo and Silver, 1994). Clark et al. (1998) called upon mantle-derived carbonatites in the source of Irazú magmas, while Feigenson et al. (2004) proposed mantle enrichment caused by the Cretaceous passage of the Galapagos hotspot. The implication from many of these studies is that enriched mantle dominates the abundance of most trace elements relative to the slab flux (Reagan and Gill,

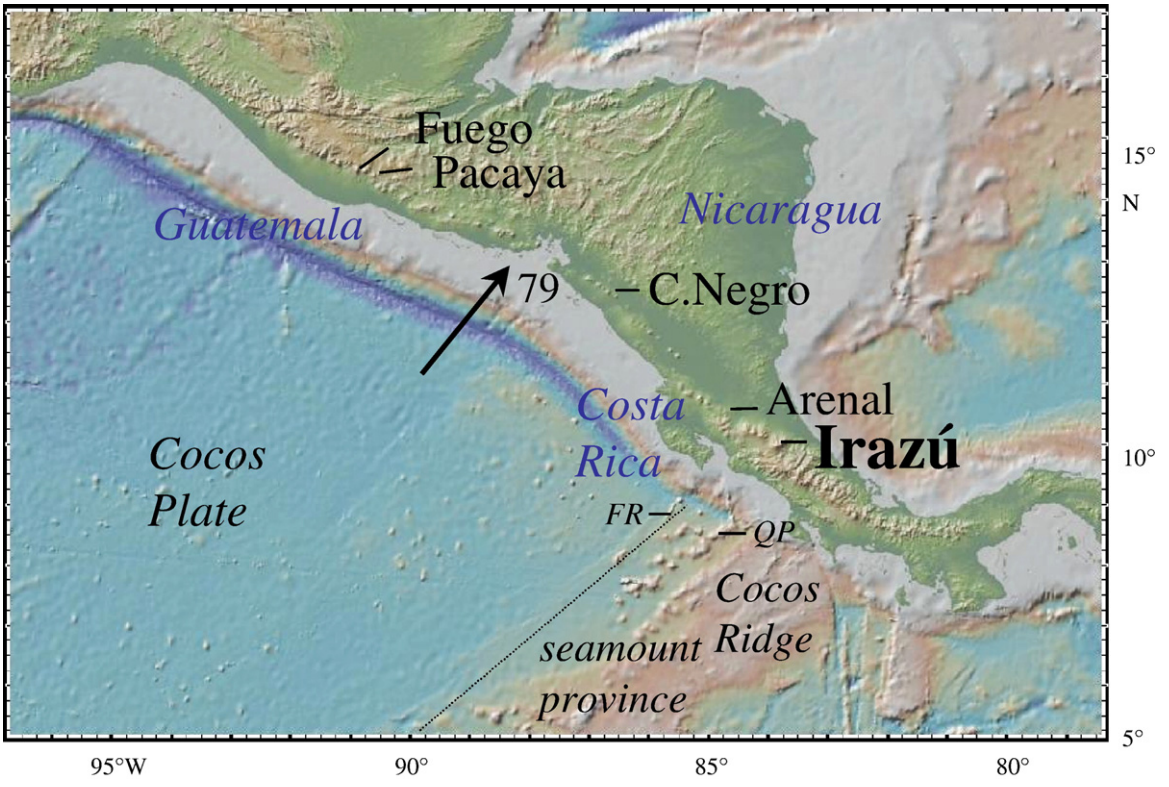

Fig. 1. Location of Irazú volcano within the Central American volcanic arc. Other active volcanoes shown for which H_2O contents have been determined in melt inclusions. Cocos Ridge and seamount province derive from the Galapagos hot spot (Hoernle et al., 2000). FR (Fisher Ridge) and QP (Quepos Plateau). Basemap from GeoMapApp. Plate motion vector, with velocity in mm/yr, calculated from Cocos–Caribbean pole in DeMets (2001).