Despite decades of research, the origin of arc magmas remains somewhat of a mystery. Cold material is advected into the earth’s interior at subduction zones, yet melting occurs. The trigger for that melting probably relates to the flux of fluids originating from metamorphic devolatilization within the descending plate, or perhaps the advection of hot material upward by corner flow within the wedge. A variety of slab-derived fluids appear in arc magmas, indicating great variation between and within arcs in both the extent of melting and the contribution from slab-derived fluids. This processing of materials input at the trench to form arc magmas has been termed the Subduction Factory, and is the basis of one of the NSF MARGINS Initiatives. Central America is a critical place for testing theories of arc melting, because nearly the global range is observed in geochemical proxies for slab-derived fluids. In central Nicaragua, the global maximums are achieved in $^{10}$Be, a short-lived isotopic tracer of the shallowest subducted sediments, and a variety of other elements enriched in subducted sediments and altered oceanic crust such as Ba. Within 300 km along strike to the southeast, in central Costa Rica, nearly all of these tracers are absent from primitive arc lavas, and geochemical indicators of the maximum extent of melting also appear to be lower [e.g. Carr et al., 2003]. Recent direct measurements of water contents within arc basalts show a systematic decrease from Nicaragua to Costa Rica [Wade et al., 2006]. Thus the Subduction Factory operates very differently over a short distance in a single arc. For that reason, Central America was chosen as a MARGINS Focus Site, leading to a great deal of work there in the past decade.

Seismology could hold the key to understanding the causes for these variations in melting process, and hence the origins of arc volcanism. Geochemistry describes the inputs and outputs of the Subduction Factory, but seismic imaging lets us look inside. The potential for discovery comes from the varying sensitivity of commonly observed seismic parameters (Vp, Vp/Vs, Qs, anisotropy, etc.) to temperature, melt, and composition, as well as the ability of seismic waves to image the interfaces that define the geometry of subduction.

**THE TUCAN EXPERIMENT**

To that end, we designed and carried out a broadband field experiment across Nicaragua and Costa Rica, TUCAN (Tomography and other things Under Costa Rica And Nicaragua). We deployed 48 PASSCAL broadband seismographs across Nicaragua and Costa Rica, starting in July 2004, with the main phase ending in March 2006 and final instrument recovery in November 2006. The experiment

Circles show broadband seismographs with TUCAN stations in yellow. Blue lines show depth to slab at 50 km intervals. Triangles show volcanoes, color-coded by the element ratio Ba/La in lavas. This ratio is often used to represent the contribution of slab-derived fluids to arc lavas (Carr et al. 2003), and varies over its global range from a high in central Nicaragua to near-MORB background in Costa Rica.

Volcanoes Momotombo and Momotombito, Nicaragua.
features two dense arc-crossing lines optimized for teleseismic P-coda imaging across two sections that best show the contrast in arc geochemistry, and following older refraction surveys; additional stations provided sparse along-arc coverage.

The deployment is almost equally divided between two countries, Costa Rica and Nicaragua, which speak a common language but have many differences in culture, politics, and customs laws. In Costa Rica, our partners are Marino Protti and Victor Gonzalez from OVSICORI (Observatorio Vulcanológico y Sismológico de Costa Rica), a research institute affiliated with Universidad Nacional. The facilities at OVSICORI, in Heredia, served as a base for the deployment in July, 2004 and subsequent servicing by Protti and Gonzalez. Sites were mostly located on private lands, typically in a farm or ranch. In Nicaragua, we collaborate with Wilfried Strauch and the Geophysics group at INETER (Instituto Nicaragüense de Estudios Territoriales), the agency that monitors earthquakes nationally. The August, 2004 deployment built on the lessons in Costa Rica, and proceeded efficiently despite greater difficulty with customs and transport. Between the two countries, we were able to import, test, deploy and recover initial data from all 48 instruments within about 5 weeks of fieldwork.

With the hard work and 4-8 week visits by the INETER and OVSICORI groups, the TUCAN stations enjoyed exceptional reliability. After 12 months we estimated 96% successful data recovery, somewhat higher than the GSN. Reliability dropped after the second wet season, in September-October 2005, but we were able to recover well over 90% of all possible data, lost only one sensor to flooding, and encountered virtually no problems with theft or vandalism. All data were processed at Boston University, and delivered via PASSCAL to the IRIS DMC.

INITIAL IMAGING

In the first round of analysis, these data are being run through the gamut of seismological tools, including joint inversions of P and S travel times for velocities and hypocenters (E. Syarce, BU), inversion for attenuation structure (C. Rychert, Brown), receiver-function imaging of interfaces (L. Auger, BU), 3D inversion of shear-wave splitting for anisotropy (D. Abt, Brown), search for anomalous low-frequency events (J. Brewer, BU), surface-wave imaging for anisotropy (D. Abt, Brown), search for anomalous low-frequency events (J. Brewer, BU), surface-wave imaging

of km below the Moho behind the volcanic front, unusually low. In receiver functions, the Nicaragua Moho itself is sharp behind the volcanic front and in the backarc but becomes faint or complicated beneath the arc and forearc. The along-strike line and Costa Rica transect both show a similarly complicated conversion structure, with low back-arc mantle velocities. Sub-solidus temperature variations cannot produce the low velocities seen behind the arc, indicating likely contributions from melt, although the presence of residua from magmatic differentiation cannot be ruled out. The forearc wedge, or region trenchward of the volcanoes and above the Wadati-Benioff zone, shows relatively elevated velocities and sharply higher Q. Similar patterns are seen in many subduction zones [e.g. Stachnik et al., 2004], and indicate that the forearc is quite cold, probably isolated from the main mantle flow. The pattern of velocity anomalies beneath Costa Rica is more complicated, but velocities are generally higher than in the Nicaragua mantle wedge. Similarly, the mantle wedge beneath Costa Rica exhibits significantly less shear attenuation. These results are consistent with cooler temperatures or less hydrated mantle beneath Costa Rica, thus correlating with the geochemical data that suggest less water and lower extents of melting. A rigorous comparison of Vp, Vp/Vs, and Q may allow some assessment of where in the system melt is forming.

Within the downgoing plate, the seismic zone itself is only a few km wide, < 10 km wide where hypocentral uncertainties are lowest. Even though the starting model

P-wave velocities and receiver functions beneath the arc-normal line of stations in Nicaragua.
Shear-wave attenuation beneath the arc-normal line of stations in Nicaragua. Events and stations within 50 km in the along-arc direction are shown by yellow stars and red triangles, respectively. Green contours correspond to a resolution matrix diagonal of 0.4.

for the inversions include fast slabs, lower velocities are recovered in the region of the slab just below the Wadati-Benioff zone seismicity. While the thickness of this lower-velocity zone within the slab is poorly constrained, these observations are consistent with hydration of the subducted crust and underlying mantle forming low-velocity minerals such as serpentine that carry water to the deep Earth.

Resolving the geometry of flow in subduction zones is essential to understanding mantle wedge thermal structure and melting processes. Shear-wave splitting measurements from local events recorded by the TUCAN array are dense and fairly complex, but subsets of the data reveal arc-normal fast directions in the fore-arc, where waves sample the shallow wedge corner, while arc-parallel fast directions dominate large regions beneath the arc and back-arc. Using an iterative, damped, least-squares inversion to solve for crystallographic orientation and fabric strength, we find a 3D model of anisotropy in which olivine a-axes vary in the mantle wedge beneath the arc and back-arc cannot be explained by simple 2D arc-normal corner flow, even allowing for the presence of B-type olivine LPO in the shallow wedge corner [e.g. Kneller et al., 2004]. The anisotropy could be explained by 3D flow with a significant arc-parallel component in the mantle wedge. Thorough modeling is still required to evaluate the plausibility of such flow and its implications for melting processes, but potential drivers include flow around the slab edge beneath southeast Costa Rica, steepening of the slab to the northwest beneath Nicaragua, and slightly oblique subduction of the Cocos Plate.

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