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Dr. Robert J. Varga, Editor
Director, Keck Geology Consortium
Pomona College

Dr. Holli Frey
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Union College

Carol Morgan
Keck Geology Consortium Administrative Assistant

Diane Kadyk
Symposium Proceedings Layout & Design
Department of Earth & Environment
Franklin & Marshall College

Keck Geology Consortium
Geology Department, Pomona College
185 E. 6th St., Claremont, CA 91711
(909) 607-0651, keckgeology@pomona.edu, keckgeology.org

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LATE PLEISTOCENE EDIFICE FAILURE AND SECTOR COLLAPSE OF VOLCÁN BARÚ, PANAMA
Project Faculty: THOMAS GARDNER, Trinity University, KRISTIN MORELL, Penn State University

PETROLOGIC EVIDENCE FOR MAFIC RECHARGE AT VOLCÁN BARÚ, PANAMA
SHANNON BRADY, Union College
Research Advisor: Holli Frey

VOLUME CONSTRAINT AND POTENTIAL SECONDARY VOLUME INPUTS OF LATE PLEISTOCENE AGE SECTOR COLLAPSE, VOLCÁN BARÚ, PANAMA
LOGAN SCHUMACHER, Pomona College
Research Advisor: Eric Grosfils

VOLCÁN BARÚ DEBRIS AVALANCHE FACIES AND AGES
HANNAH ZELLNER, Trinity University
Research Advisor: Thomas Gardner
Panama is not normally associated with impressively large, active volcanoes, perhaps because no historic eruptions have occurred in the Panamanian section of the Central American Volcanic Arc. There are no newsworthy images of Panamanian eruptions as are common from other volcanoes within the “Pacific Ring of Fire”. Despite this fact, we demonstrate in this project that Panama played host to one of the largest edifice and sector collapses in Central America during the Late Pleistocene. We hypothesized that Volcán Barú, a 3374 m high active volcano in westernmost Panama, experienced an early Holocene or Late Pleistocene sector collapse with estimates of displaced material ranging from ~25 km$^3$ to ~100 km$^3$ (Mt Saint Helen’s was ~3 km$^3$ for comparison). Hummocky debris-avalanche deposits and lahars, the most volumetrically significant facies associated with this sector collapse, extend over 60 km away from the collapsed edifice, extending into the Gulf of Chiriqui.

A window of opportunity existed last year to explore, in detail, the debris avalanche deposits on the southern flank of Volcán Barú. Most importantly, construction of hydroelectric plants and the supporting road, dam and tunnel network on the Rio Chiriqui Veijo which drains the southern flank of Volcán Barú provided unprecedented exposures and access to these deposits; deposits which are normally inaccessible and poorly exposed in the jungle setting. Our research goals were to 1) describe and map the facies, composition, internal relationships, and extent of the debris avalanche deposits; 2) undertake an extensive radiometric dating campaign to determine the age and number of sector collapse “events”; 3) complete extensive petrographic and geochemical analyses of the sector collapse deposits to help reconstruct the edifice failure and shed light on possible causes; and 4) calculate minimum and maximum volume estimates of the sector collapse.

**GEOLOGIC SETTING**

The evolution of the Central American volcanic arc through Costa Rica and Panama is, to the first order, controlled by interaction of three plates; the Caribbean, Cocos and Nazca plates and especially the subduction of the Cocos and Nazca plates under the Panama block at the Middle America Trench (MAT, Fig. 1). Volcán Barú lies along this complex plate boundary inboard of the Panama Triple Junction (Fig.1). The long-term evolution of Volcán Barú is very much dependent upon the position of the Panama Triple Junction (PTJ) throughout the last ~3 Ma because it determines the nature of the subducting plate under Volcán Barú (Fig. 1 inset, Bird, 2003; DeMets et al., 1990; Gardner et al., 1992; Silver et al., 1990). The subducting Panama Fracture Zone juxtaposes Cocos subduction to its west against Nazca subduction to its east (Fig. 1), and creates an abrupt boundary for drastic along-strike variations in lower plate properties and behavior.

**ERUPTIVE HISTORY OF VOLCÁN BARÚ**

The eastern rim of the “Pacific Ring of Fire” extends from Alaska to Terra del Fuego. As part of this “Ring of Fire”, the active volcanic arc of Central America continues unbroken from Guatemala to central Costa Rica. However, the last active volcano in Costa Rica is Volcán Turrialba, which lies along the western edge of the Panama block. Southeast of Volcán Turrialba and inboard of the Cocos Ridge, the arc is extinct and ~8-10 Ma granitic plutons that formed the core of the old volcanic arc [de Boer et al., 1995; Grafe, et al., 2002] are exposed in the highest range on the Central
American isthmus, the Cordillera de Talamanca (Fig 2). Southeast of the Cordillera de Talamanca volcanic edifices are again recognized along the Costa Rica-Panama border (Fabrega and Tisingal in Fig. 2), but those volcanoes are extinct, having last erupted in the late Neogene (de Boer et al., 1995, Tournon and Alvarado, 1997; Drummond et al., 1995; MacMillan et al., 2004). Southeast of the PFZ and the PTJ, active volcanism resumes at Volcán Barú in western Panama (Fig. 2). Volcán Barú (Fig. 3) has not erupted in historic times, but it is an active volcano. There have been 4 eruptive episodes within the last 1600 years (Sherrod et al., 2007) consisting of small lapilli and ash eruptions with accompanying pyroclastic surges. Compositionally these eruptions are andesite to basaltic andesite with minor dacite. The most recent eruptive episode occurred between 420 and 540 cal yr BP (Sherrod et al., 2007). There was an earthquake swarm under the volcano several years ago.

The earliest eruptive history of Volcán Barú is not well constrained. De Boer et al. (1988) describe a phase of calc-alkaline volcanism that is undated but generally assigned to the Quaternary. There is a well-dated swarm of adakitic eruptions in the vicinity of Volcán Barú at 1-3 Ma (MacMillian et al., 2004. Johnson et al., 1996, 1997).

Previous field mapping on the southern flank of Barú identified an eruption that produced debris avalanche and lahar deposits (Siebert et al., 2006, Sherrod et al., 2007, Frels, 2009) that are spectacular in their estimated volumes and extent. Volume estimates range from ~25 – ~30 km³ for the debris avalanche deposits (Siebert et al., 2006; Sherrod et al., 2007) to as much as 60 – 100 km³ for the combined debris – avalanche and lahar deposits (Sherrod et al., 2007; Frels, 2009). The age of the debris - avalanche deposits has been only poorly constrained to greater than~2.9 ka and less than ~12 ka (Siebert et al., 2006, IRHE, 1987, although the upper limit was just an estimate by IRHE), to greater that ~8.7 ka (Sherrod et al., 2007), to between 8.7 -9.2 ka from organic material lahars and reworked lahar in fluvial terraces (Frels, 2009).
house (and yoga studio) in Cerro Punta, on the northeast flank of Volcán Barú (Fig 4.). One of the most significant contributions by the group was the creation of a new geologic map (Fig. 5) for the area around Volcán Barú.

Shannon Brady (Union College) conducted geochemical and petrographic analyses of 26 samples from intact edifice and hummocks in the debris avalanche from Volcán Barú. She found reaction rims on hornblende phenocrysts and dusty sieve-textured plagioclase which suggest disequilibrium, possibly from injection of a hotter mafic magma into the andesitic storage chamber of Volcán Barú. Opacitization of hornblende phenocrysts further suggested to her that hornblende was raised out of its stability field by decompression during ascent. This lead Shannon to conclude that mafic recharge of the magma chamber under Volcán Barú may have lead to an eruption that triggered edifice collapse.

Hannah Zellner (Trinity University) described stratigraphic sections from dam and road exposures in the sector collapse deposits. She constructed stratigraphic cross-sections for merged photographic, collected sample for radiometric dating, and created a facies map of the Late Pleistocene debris avalanche

Figure 3. Photograph of the edifice of Volcán Barú. View is to the northeast.

Figure 4. Our Panama group from left: Logan Schumacher (Pomona College), Hannah Zellner (Trinity University), Shannon Brady (Union College), Tom Gardner (Trinity University) and Kristin Morell (Penn State University).

Figure 5. Surficial geologic and structural map for region surrounding Volcán Barú draped over slope map (DEM combined from data courtesy of Arkin Tapia, and SRTMv4), with data from this study, Sherrod et al. (2007), Morell et al. (2008) and Herrick et al (2011). DA1, DA2 and DA3 are debris avalanches associated with sector collapses from Volcán Barú. DA3 is the Late Pleistocene debris avalanche that was the focus of this project.
deposit. She discovered outcrops of lacustrine-filled closed depressions on lahar of the sector collapse (her extra-marginal facies). The lacustrine deposits contained well-preserved organic materials. From her work she could tightly constrain the age of the most recent sector collapse to 12900 - 9920 YBP. This age constraint is much improved over previously published constraints. Using stereo aerial photographs, field observations and previously published maps, she constructed a facies map of the Late Pleistocene debris avalanche. Additional radiometric dating of other debris avalanche deposits indicate that there are at least 3 collapses of Volcán Barú over the last several hundred thousand years. Hannah concludes that the sector collapse resulted from gravitational failure of a weakened and deeply incised southwestern flank of Volcán Barú.

Logan Schumacher (Pomona College) use ArcGIS tools, field observations and stratigraphic sections to estimate the volume of the Late Pleistocene sector collapse. Previous estimates range from a minimum of ~20 km$^3$ to a maximum of ~100 km$^3$. Logan reconstructed the upper paleo-topographic surface of the debris avalanche, the underlying land surface onto which the debris avalanche flowed and the areal extent of the debris avalanche. From those parameters he estimated a volume and adjusting for expansion during emplacement, estimates that the debris flow was between ~65 km$^3$ and 70 km$^3$.

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