Central America’s most active volcanoes

How does the slab variability influence trace elements?

There are probably sedimentary and igneous components to this influence.

Walker, Patino, Cameron & Carr, 2000, J Geophys Res 105: 18949-18963

Santiaguito SW Guatemala

From A J L Harris
A “child” of Santa Maria, Santiaguito is an active dacite dome, which has erupted every day since 1922. It has killed hundreds of people and causes millions of dollars of damage to infrastructure each year.

Santa Maria/Santiaguito, 20 km³, 40 ka

- Growth of basaltic-andesitic composite cone: 75-34 ka
- Repose (with rare andesitic lava eruptions?): 34 ka-1902
- Dacite explosive eruption: 1902
- Continual dome extrusion: 1922-2001
• 1902 crater of Santa Maria exposes a remarkable composite sequence of andesitic flows that were erupted during ~34-75 ka and which record a paleomagnetic and geochemical variation.

Santiaguito is a long-lived continuously active, volcanic dome complex, which has been growing since 1922. It has a total volume of about 1.1 km³ and is the residual of a much larger (>10 km³) magma chamber that formed within Santa Maria during several millenia and erupted in 1902.

Santiaguito has grown in spurts of extrusion, which has created several dome units that abut each other.
Prime remote sensing site:
- excellent cloud free archive -- pathfinder site
- heavy vegetation enhances recent activity

**Improved Volumetric Constraint using Landsat TM**
(Harris, Flynn & Rose, Bulletin of Volcanology, 2002)

Time series of 30 TM images 1987-2001

- Flow surface temperature & Area
- Heat loss
- Extrusion Rate

Santiaguito’s long eruption continues to be episodic. In recent years we can get more precise data from satellite IR measurements.
Current (Jan 2002) activity consists of a long merapi-type lava flow with prominent levees which terminates in the valley of the Rio Nima II. Erosion of a new canyon east of the 1996-9 flow and breaching the 1902 crater rim is dumping lots of sediment into Rio Nima I.

2004 extrusion is at the "slow" rate, to the south of Caliente, and bifurcating into two 200m lobes.

Direct observations of active block lava extrusions and associated phenomena.

Harris et al, 2002, Bull GSA 114: 533-546
Dacite lava extrusion for 45 years, now becoming more mafic, and more exogenous.

Maurice Krafft

Dacite magma of Santiaguito has 64% SiO₂ and about 35% phenocrysts and makes a highly viscous morphology.

Large volumes of hot viscous magma are found at substantial elevations, representing substantial hazards to nearby populations.

October 2003, Caliente Vent, Santiaguito Guatemala—after the collapse

Collapse scar

Borde sur del cendid del Domo Caliente, Oct., 2003
Dome or flow front collapses with block and ash flows occur about once a year.

July 1989, photo by Mike Conway, from 10 km S of Caliente Vent. This block and ash flow travelled 4 km.

October 7, 2003 Collapse event caused a pyroclastic surge that burned a dense cloud forest.

Vertical explosions of ash and bombs occur every 20-100 minutes from a vertical conduit of viscous dacite magma. This has been true for decades and it happens during both slow and rapid conduit flow.

Conduit Flow Modeling

Melnik et al, in prep
Observation point: 3770 m

Active vent, 2500 m

• Accessibility to prime observation points,
• Dependable weather in dry season mornings,
• Daily diverse activity

Access to Study areas at Santiaguito is good--access to prime observational areas is “safe”

Active dome

Climbing route

Summit vantage for eruption observations

Some have reported visual and auditory hallucinations
Schematic view of Santiaguito’s conduit, as inferred from observations of activity. Incremental plug flow of conduit occurs with an overall rate of about 0.2 m$^3$/s, generating ash eruptions from sheared margins.

Analysis
(Harris, Vallance, Kimberly, Rose, Matias, Flynn & Garbeil, Bulletin of Volcanology, 2003)

Change analysis using 21 Landsat TM images and ground measurements

Proximal drainage zone

Medial drainage zone
Current generation of volcanic centers in Guatemala and El Salvador are <200ka and their morphology is strikingly more constructional than older erosional features.

Atitlán Caldera, Guatemala, 250 km$^3$, 158 ka

- Voluminous brief eruptive events, long reposes, substantial hydrothermal systems

Fuego, Guatemala--180 samples, 17 ka, 135 km$^3$

- Bellweather volcano-->60 explosive historic eruptions
- Excess gas releases
Continuing Eruptions of Fuego Volcano, Guatemala--satellite data can contribute to forecasts

Fuego, Guatemala--17 ka, 135 km$^3$
- >60 explosive historic eruptions
- lahars, ashfalls, pyroclastic flows, lava flows

Fuego’s Historic eruptions cluster--
Clusters may represent magma batches

Fuego Volcano, a high basaltic cone; often in “open vent” condition

Average SO2 emission rate, 1975-2000: ~150 tonnes/day
15 January 2003
USGS photo

“open vent” conditions, with frequent vertical ashy explosions, sometimes generating small pyroclastic flows

Volcanic Processes at Fuego

Vertical ash/bomb explosions
Ashfalls
Spatter ramparts
Lava flows
Block & ash flows
Lahars

Low level activity
On steep slopes
Plinian column and block and ash flows, Fuego 14 October 1974

Monitoring Volcanoes

- a) Volcanic tremor
- b) Expansion
- c) Degassing $SO_2$
- d) Heat

Oct 14, 1974 Tephra Deposit

High-frequency or tectonic earthquake

Low-frequency or long-period earthquake

Volcanic tremor

Tornillo (screw) earthquake
Open vent gas emission variations: Fuego during 04/01-04/02

SO2 flux (tonnes/day)

INSIVUMEH data; Rodriguez et al 2002

Visualizing the subsurface

Fuego during 04/01-04/02

SO2 flux (tonnes/day)
Fuego is known to respond to earth tidal variations during its open vent conditions.

Visualizing the subsurface of volcanoes
Triggers from internal forcing

Triggers from external/internal forcing

Fuego’s open vent activity may change from “vulcanian” to “strombolian”

A strombolian eruption generated a 5 km long spatter fed lava flow.

This change could reflect a widening vent, which affects the eruptive style.
Spatter accumulations form thin lava flows. Lava flows break up, form block & ash flows. Geometry of summit crater important for channeling flows and pyroclastic flows. Accumulation of pyroclastic flow deposits on steep upper flanks of Fuego threatens the barrancas downslope because mudflows will be triggered by heavy rains when the rainy season comes. Accumulation of pyroclastic flow deposits on steep upper flanks of Fuego threatens the barrancas downslope because mudflows will be triggered by heavy rains when the rainy season comes.
Lahars expected from Fuego beginning late April, when rains begin.

Substantial masses of loose materials lie on the steep SW and W slopes of Fuego also.
Accumulation of fragmental materials is more abundant in Las Lajas and El Jute than in Barranca Honda.

15 January 2003
USGS photo

Fuego’s summit crater has a low point to the west, which channels material from the eruptions in that direction.

Otoniel Matias, INSIVUMEH, 11 Jan 2004

Current focus on Zanjon Barranca Seca, west flank of Fuego

Lahar hazards of Fuego Volcano

USGS Open File Report 01-431

Vallance, Schilling, Matias, Rose & Howell, 2001
Pyroclastic flows filled barrancas west of Fuego, July 2003

Rüdiger Escobar, CONRED

Heavy rain on block & ash flow leads to “Lahar” = volcanic mudflow

Channels on west slope of Fuego filled with lava flow 5 km long, Jan 2004

Basalt lava flow

Otoniel Matias, INSIVUMEH, 11 Jan 2004

Fuego future

• ash eruptions and associated ashfalls
• Spatter fed lava flows
• Block & ash flows from ash events and from lava flows on steep slopes
• accumulations of fragmental materials will lead to destructive lahars
• activity is most likely to be at a low level
• regular observations and measurements to detect changes are very important

Zanjon Barranca Seca

Block & ash flow deposit

Effects of pyroclastic surge

Rüdiger Escobar, CONRED

Such events may be detectable with AVHRR

Rüdiger Escobar, CONRED
Guatemalan volcanoes include 3 continuously active centers, Santa María (Santiaguito), Fuego and Pacaya. But that is NOT all!

These volcanoes are important foci for study of volatile emissions, but we must face issues of how to obtain data on inactive vents…
Pacaya, Guatemala

- Continuously active since 1965
- Porphyritic Hi Al Basalt, variable MgO
- Highly variable degassing
- Large gravity anomalies
- Collapse features
- Hazards need attention

Summary of 1965-2006 activity underway to encourage visiting scientists to study this dynamic volcano.

MAGMA COMPOSITIONS

Last decade Pacaya basaltic fountaining, flows: 1965-2001

Magma body near surface, open vent

Pacaya magma compositions

Kinematic GPS/gravity
**El Salvador** has many accessible volcanoes, but a paucity of real volcanic activity in the last century or more. A sleeper for volcanic hazards, there is a dense population, living in remarkably hazardous locations. How can we devise a strategy for measuring volatile flux?