Fuego field trip: Ciudad Vieja, La Reunión and San Miguel Los Lotes

This field trip is focused on the impacts of hazardous flows around Fuego and Agua volcanoes. We will visit several sites that have been impacted by lahars and pyroclastic flows over the last five hundred years, some as recently as 2018. The trip is relatively short and should take about four to five hours to complete. This guide includes an itinerary, a background to the sites we will see in the itinerary, and information on the field trip stops.

Itinerary and map of stops

Activity	Time (minutes)
Drive to Ciudad Vieja	20
First stop: Ciudad Vieja	45
Drive to La Reunion	20
Second stop: La Reunion	45
Lunch	60
Drive to San Miguel Lotes	15
Third stop: San Miguel Los Lotes	45
Drive back to Antigua	45
Total:	**295 mins (~5 hours)**

Note: all timings are approximate.

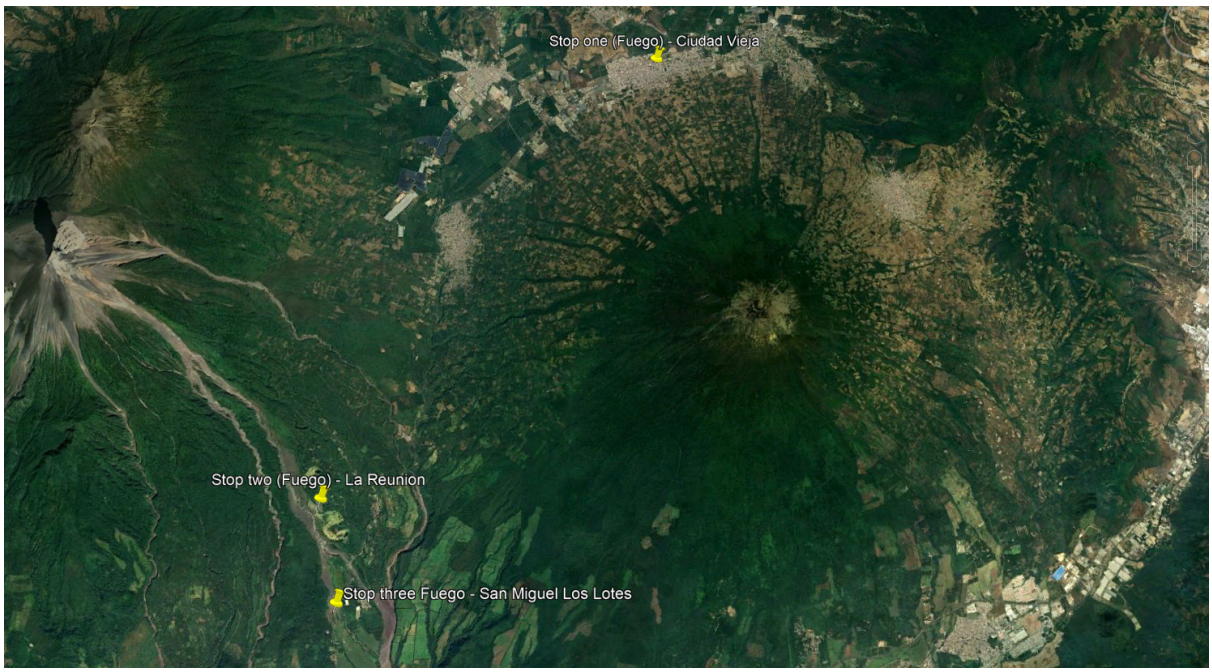

Figure 1: stops of Fuego field trip.

Background

Both Fuego and Agua volcanoes are associated with hazardous flows that have had significant impacts on nearby populations. On this trip, we will see impacts of lahars from Agua volcano and pyroclastic flows from Fuego volcano. Lahars are defined as "general term for rapid flowing mixtures of rock debris and water from a volcano" (Vallance, 2005). They are a hazard common to volcanoes worldwide and one of the deadliest, accounting for the majority of fatal incidents at distances greater than 15 km (Brown et al., 2017). Lahars can be triggered as either a primary (syn-eruptive) or secondary (post-eruptive) hazard. Primary lahars can be caused by ice cap melt during eruption of glaciated volcanoes, by the interaction of freshly erupted material with local waterways, or by eruption through a crater lake. Secondary lahars are particularly common in tropical environments, where previously deposited volcanic material can be remobilised by heavy rainfall. Small-volume lahars typically travel only a few kilometres from their source, but large-volume debris flows can travel many kilometres from a volcano. Both lahars and pyroclastic flows destroy everything in their path. Pyroclastic flows are fast-moving, extremely hot currents of gas, tephra, and volcanic clasts that descend from a volcano under the effect of gravity. Pyroclastic flows can be produced by eruptive column collapse, sustained pyroclastic fountaining, lateral blast, or dome collapse (Branney & Kokelaar, 2002). They are fatal to anyone they encounter, so associated risk to population can only be mitigated by evacuation or relocation.

Fuego is an active stratovolcano (~3,800 m asl) with a well-defined summit crater that marks the southernmost expression of the north–south trending Fuego-Acatenango volcanic complex (**Figure 2**). It is located within the second of eight segments of the Central American volcanic front (Carr et al. 2002). Fuego has produced primarily high-Al basalt (~51% SiO_2) since 1974. Melt inclusions (MI) in erupted olivine indicate that Fuego's magmas, like many other arc basalts and basaltic andesites, contain dissolved H_2O concentrations ranging from 2.1 wt% to 6.1 wt% (Sisson and Layne 1993; Roggensack 2001). The high volatile content of Fuego's magmas probably influences eruptive behavior during periods when an open vent condition dominates, in concert with potentially rapid changes in magma ascent rate (Roggensack 2001; Newcombe et al., 2020).

Fuego has had at least 60 historical[1] subPlinian eruptions and several longer periods (months to years) of low-level strombolian activity, making it one of the most active volcanoes in Central America. Fuego's most recent eruptive regime began with a VEI 2 eruption on 21 May 1999 (Lyons et al., 2010; Waite et al., 2013), and activity between that date and the present day has been dominated by persistent Strombolian activity and open-vent conditions. This activity is interspersed with frequent explosive "paroxysmal" eruptions that produce ash-rich explosions and lava flows and occasional pyroclastic flows (e.g., 5 May 2017). Fuego entered

[1] (i.e., since written records began with the arrival of Spanish *conquistadores* in 1524)

a phase of greater activity in 2015, characterized by greater (near-monthly) frequency of paroxysms (Naismith et al., 2019). The largest of these paroxysms, both by erupted volume and by impact on populations surrounding the volcano, occurred on 3 June 2018 (Pardini et al., 2019). Fuego's current activity is characterized by frequent explosions, effusion of short (hundreds of meters) lava flows, lahars, and paroxysm that occur every several months. Fuego is monitored by Guatemala's national scientific monitoring agency (INSIVUMEH); responses to its eruptive crises are coordinated by Guatemala's national risk reduction agency (CONRED) and volunteer groups (COLREDes) in communities around the volcano. These groups are coordinated by CONRED's subsidiary office (DPV) in Antigua Guatemala.

The eruption of 3 June 2018 began in the early hours of the morning with powerful incandescent fountaining and a tall eruptive column. The first pyroclastic flows descended drainage ravines on the west flanks of Fuego and were observed by INSIVUMEH observers from INSIVUMEH's Fuego Volcano Observatory (OVFGO). The eruption in its initial progress appeared to be a "typical" paroxysm (Pardini et al., 2019). However, beginning at 12:00, the intensity of the paroxysm increased, and the direction of tephra dispersal and pyroclastic flow descent shifted towards Fuego's SE flanks. Between 14:00 and 16:00, a series of pyroclastic flows descended the Las Lajas ravine and destroyed the community of San Miguel Los Lotes and the Las Lajas bridge, causing the deaths of several hundred people (CONRED, 2018). This eruption remains the greatest in terms of human impact within Fuego's extended history.

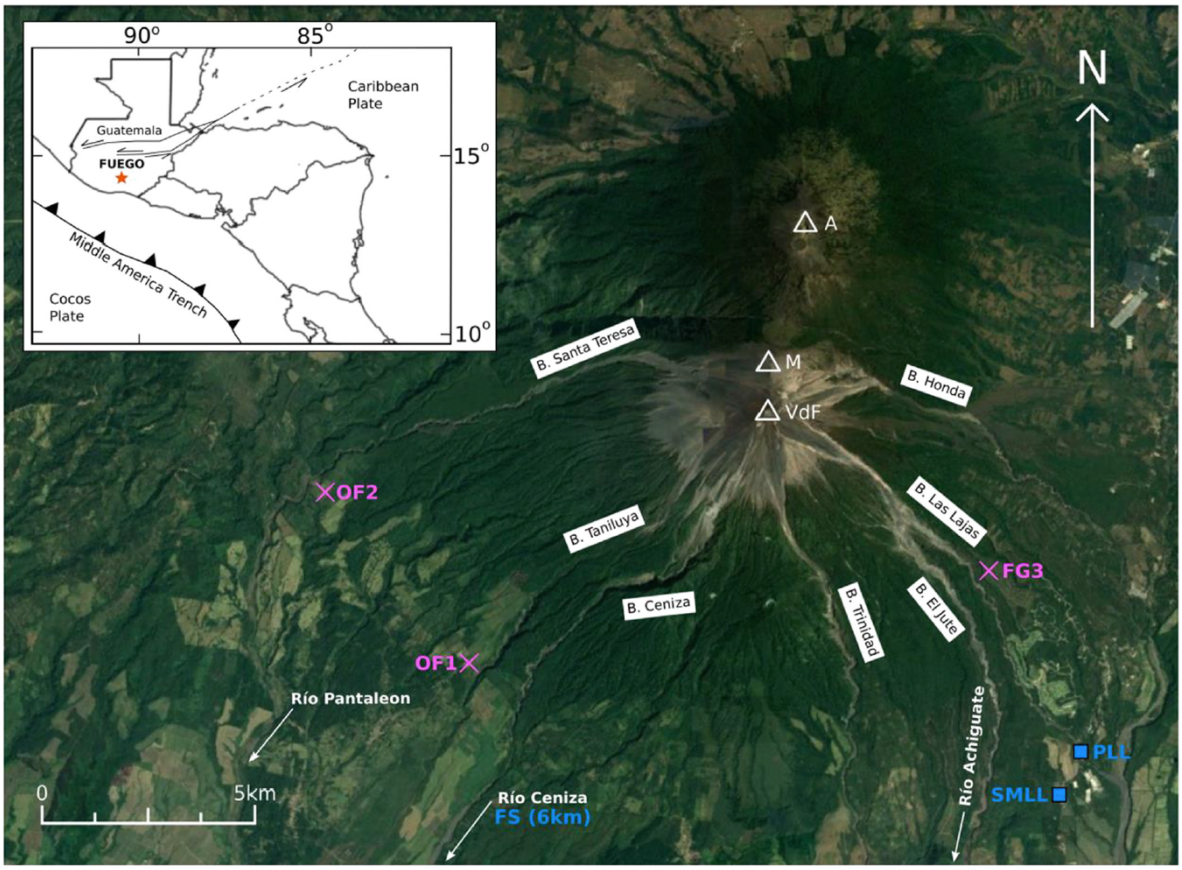

Figure 2: Map of Fuego volcano including its seven barrancas (drainage ravines) and major rivers, with (inset) location of Fuego within Guatemala. Fuego's barrancas confine movement of pyroclastic flows and lahars. Principal eruptive centres of the Fuego-Acatenango complex are (north to south) Volcán Acatenango (indicated as A), La Meseta (M) and Volcán de Fuego (VdF). INSIVUMEH's main Fuego observatory, OVFGO1, is located in the village of Panimaché Uno and is indicated by a pink cross and "OF1" (OVFGO2/"OF2" is no longer active). Blue labels indicate the community of San Miguel Los Lotes (SMLL) and the Las Lajas bridge (PLL). Map data: Google Earth V 7.1.8.3036 (2018). (Source: Naismith et al., 2019)

First stop: Ciudad Vieja and the house of Doña Beatriz

Ciudad Vieja was the first colonial capital of Guatemala, established by the Spanish in 1527. It was destroyed by a volcanic mudslide from Agua volcano in 1541. In September 1541, the Volcán de Agua ("Water Volcano") received several days of heavy rainfall (possibly a tropical storm). This rain caused a massive lahar (a mudflow of volcanic debris and water) to descend on Ciudad Vieja, burying it under several metres of mud and debris. The event destroyed most of the city, which was then abandoned, and the capital was moved a few miles away to Antigua Guatemala (then known as Santiago de los Caballeros de Guatemala). Antigua Guatemala was also destroyed by natural forces: an earthquake in 1773 caused widespread destruction and the decision to move the capital to its current location, Guatemala City (which has also been devastated by earthquakes, most notably on 4 February 1976).

Second stop: La Reunion

La Reunion was a high-end golf resort built in the later 2000s adjacent to the Eastern edge of the Las Lajas barranca. The resort consisted of a large and grand club house, a restaurant, and a wide range of accommodation, some of which was located very close to the barranca. Remarkably, no-one was killed here during the 2018 eruption, in stark contrast to the hundreds of deaths in San Miguel Los Lotes. There are number of factors to consider here, which will be discussed in situ, but it is very often the case that those with least resources are most badly affected. Here, stronger engagement with scientists, ease of evacuation (which has multiple facets including life versus livelihood), several previous evacuations (both simulated and real) and a serendipitous view of the eruption not visible from San Miguel Los Lotes modulated outcomes.

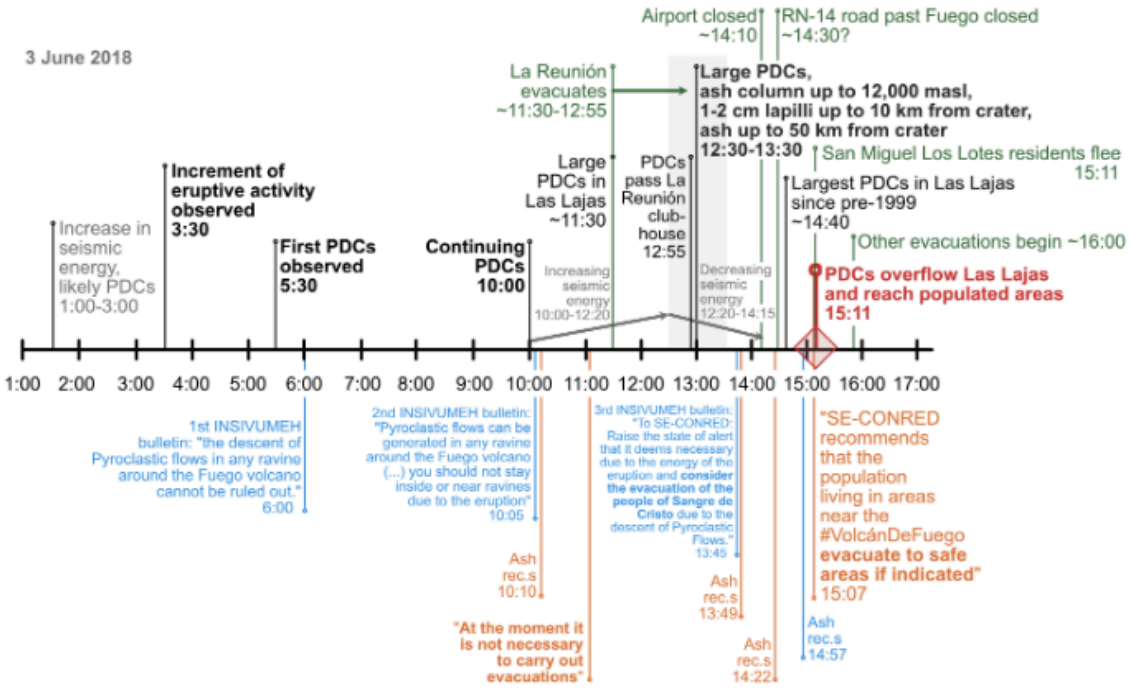

Figure 3: Timeline of significant volcanic activity known to INSIVUMEH in near-real time (black, bold) and not known (gray); guidance or warnings from INSIVUMEH (blue) and SE-CONRED (orange) in official information statements; risk-reducing actions (green); and the destructive PDCs (red, bold). Source: Bartel (2023).

Third stop: San Miguel Los Lotes

Fuego's eruptive cycle changed on 3 June 2018 when an explosion occurred at 12:00 (UTC) at the summit causing an ash plume rising to 15 km asl (reported by the Washington Volcanic Ash Advisory Center, VAAC) and a series of destructive PDCs travelling up to 12 km from summit down Barranca Las Lajas. Based on plume height retrieval and an eruption column model, Pardini et al. (2019) estimated the Dense Rock Equivalent (DRE) volume at 0.04 ± 0.1 km3. Paroxysmal climax was reached only 5–6 h after the onset and lasted for 2.5 h between 17:30 and 20:00 UTC. The local authorities evacuated about 12,000 people, but the rapid-onset eruption still caused hundreds of fatalities (Naismith et al., 2019), mostly in the town of San Miguel Los Lotes. As a result, this volcanic event became the third deadliest eruption in the 21st century (at the time of writing). In addition, PDCs destroyed critical infrastructure, which affected evacuation lifelines including a bridge located on the road RN-14.

Figure 4: Footprint of San Miguel Los Lotes

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