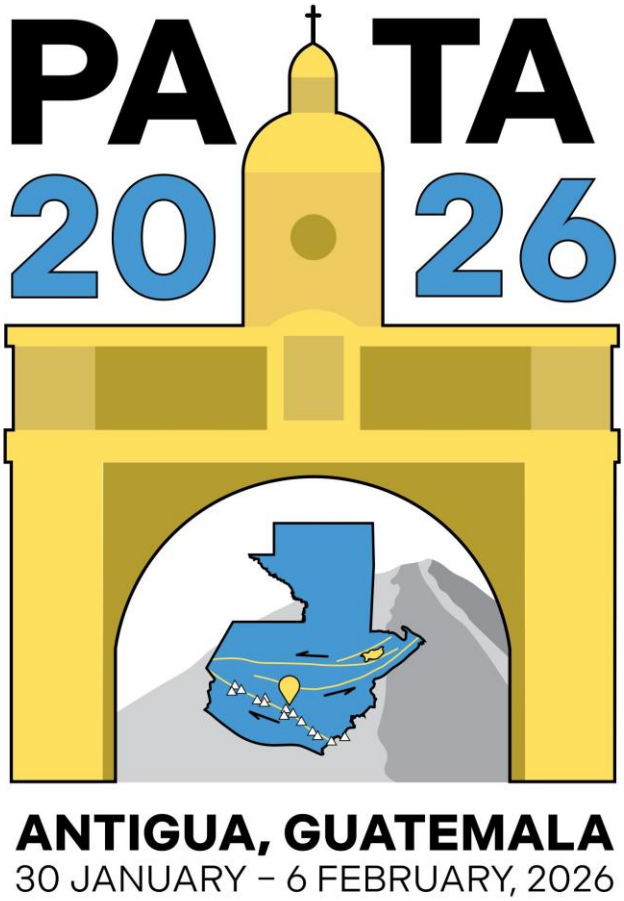
Post-meeting Field Trip guide



Extensional Deformation in western Guatemala

Field trip leader:

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This guide is lightweight and participants are encouraged to discuss their observations and ideas regarding the history of volcanism, deposition, and deformation and how it relates to active tectonics and seismic hazards and the tectonic evolution of the region.

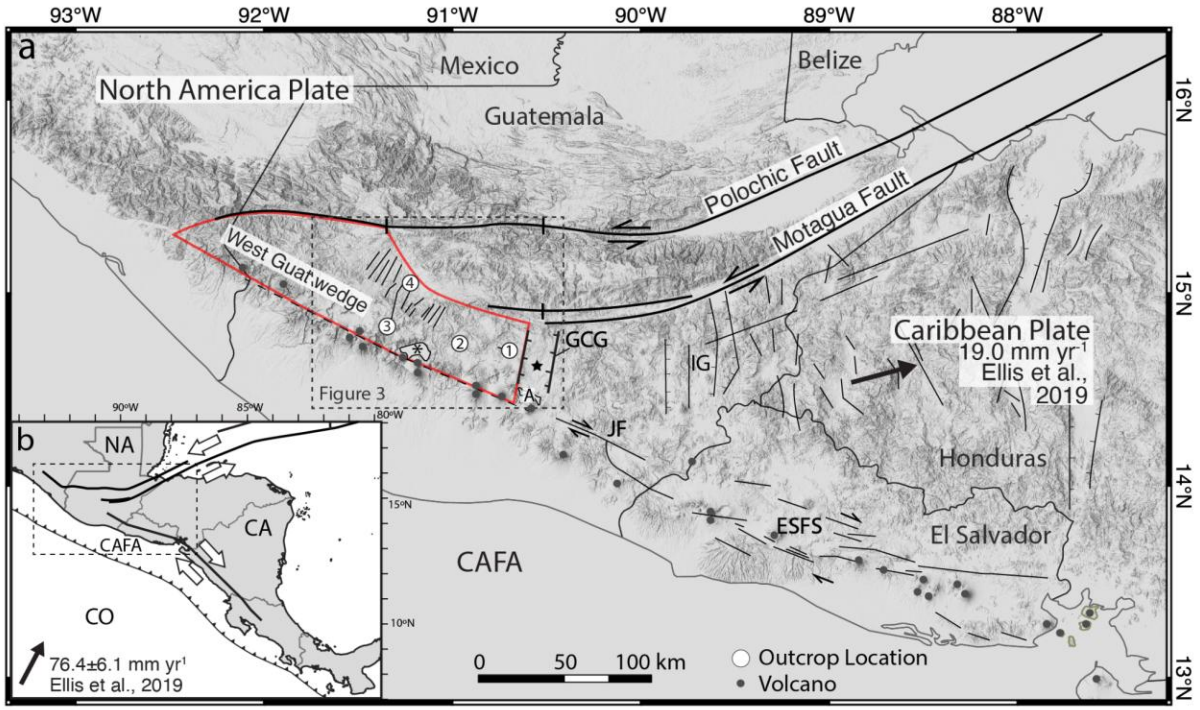


Figure 1. a) Annotated DEM map with major structures related to the North America, Forearc, and Caribbean system in northern Central America. Guatemala City graben (GCG), Guatemala City (star), the Ipala graben (IG), the Jalpatagua fault (JF), the El Salvador fault system (ESFS), and the Central American Forearc (CAFA). Western Guatemalan wedge is outlined in red. b) Inset map of major plate boundaries and relative motion in Central America. Major plates are CO, Cocos plate; NA, North America plate; CA, Caribbean plate; and the CAFA. Solid black lines indicate the Polochic-Motagua fault system and the forearc boundary. White arrows indicate relative motions across boundaries. Motions of the Caribbean and Cocos plates are from Ellis et al. (2019), in relation to a stable North American plate.

Overall Objectives

- Examine field evidence for extensional deformation west of the Guatemala City graben
- Evaluate the kinematics and orientation of normal faulting relative to regional stress fields
- Explore how stratigraphy records the timing and cessation of deformation
- Discuss implications for strain localization and seismic hazard in central Guatemala

Field Trip Itinerary

08:30 – Depart Antigua by bus
09:30 – Arrive at San Gabriel Mine
09:30–10:00 – Restrooms, distribution of personal protective equipment (PPE), orientation
10:30–13:30 – **Stop 1: Xenacoj Highway outcrop**(structural and stratigraphic observations; discussion-focused)
13:30–14:30 – Lunch and restrooms at San Gabriel Mine
14:30 – Depart San Gabriel Mine
16:00 – Return to Antigua

Xenacoj Highway outcrop – Extensional Deformation West of the Guatemala City Graben

Location: Santo Domingo Xenacoj, Guatemala (Location 1 in Figure 1)
Approx. coordinates: 14.695°N, −90.696°W
Time at stop: ~3 hours
The highway construction in Santo Domingo Xenacoj exposes a structurally complex, kilometer-scale outcrop that records Neogene extensional deformation west of the Guatemala City graben (GCG). The site provides an opportunity to examine fault geometry, kinematics, and stratigraphic relationships that help constrain the western limit and timing of extension associated with the evolving interactions between the North American plate, Caribbean plate, and Central American Forearc.

General tasks of stop

Geologic overview as a group
Orientation and Initial Observations

- Overall geometry of the outcrop
- Identification of major faults and lithologic units

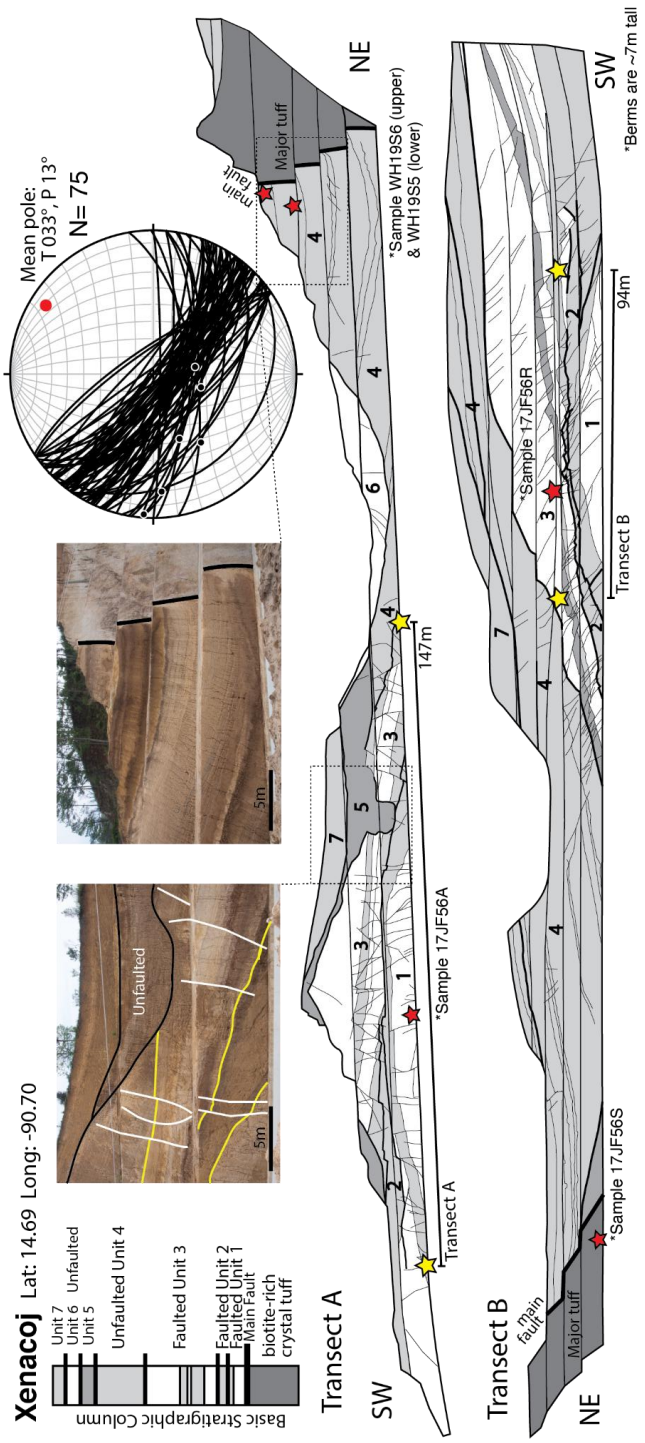
Fault Kinematics and Extension

- Minor fault populations and slip indicators
- Extension directions and variability

Stratigraphy, Timing, and Synthesis

- Stratigraphic relationships and unconformities
- Regional context and implications

Geologic Overview



The outcrop consists of volcanic and volcaniclastic deposits of Miocene to Pleistocene age exposed along the roadway. Older units are pervasively faulted and locally folded, whereas younger deposits blanket the outcrop and are undeformed (Figure 2). The section records alternating episodes of volcanic deposition, surface stabilization, erosion, and tectonic deformation.

A prominent normal fault forms the main structural feature at this location (Figure 2), separating a massive volcanic unit in the footwall from a complex hanging-wall succession of faulted tephras and reworked deposits.

Figure 2. Annotated outcrop sketch and major structures. Transect A is the northern side of the highway and Transect B is the southern side.

Prominent structures

Main Normal Fault

- Strike: ~124°
- Dip: Steep to moderately SW
- Sense of slip: Normal, down to the SW
- Minimum displacement: ≥40 m

Observable features include a well-developed fault zone, hanging-wall drag, and thickness variations in adjacent strata. The geometry suggests significant extensional displacement prior to deposition of the youngest units.

Secondary Faults

- Predominantly NW–SE striking normal faults
- Offsets range from centimeters to meters
- Faults are abundant in older units but terminate below an unconformity capped by undeformed tephras

Extension Directions and Kinematics

Minor fault slip data indicate extension that is more **NE-directed** than that observed at other nearby localities west of the GCG (Figure 3). Faulting is dominated by dip-slip motion, with little evidence for significant strike-slip components at this site. From minor faults measured along two transects, we estimate **11.5% of 033/034-directed elongation** occurred within the hanging wall block (Transect A, Figure 2)).

This variability in extension direction provides an opportunity to explore the spatial and temporal complexity of strain accommodation near the western margin of the graben system.

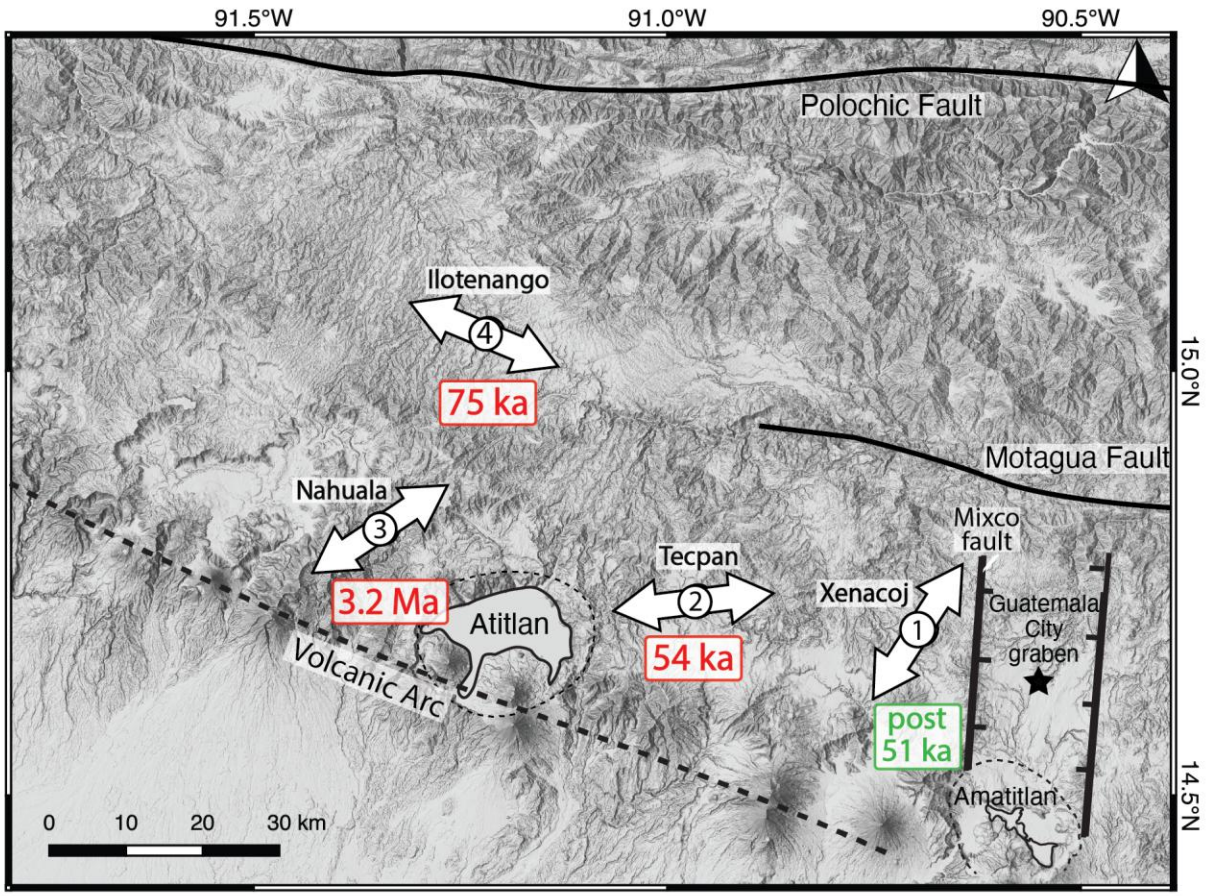


Figure 3. Map of studied outcrops in western Guatemala. Arrows indicate orientation of maximum elongation estimated from fault data. Ages below each location number indicates the age of the older, unfaulted units, indicating an estimation for when deformation ceased in the immediate area. Ages roughly young eastward, towards the Guatemala City Graben.

Stratigraphy to constrain deformation timing

Although this stop is not focused on detailed stratigraphic correlation, stratigraphic relationships provide critical constraints on deformation timing.
Key observations include:

- M**assive, biotite-rich crystal vitric tuff** in the footwall of the main fault. $^{40}Ar/^{39}Ar$ dating indicates age of 9.115 ± 0.008 Ma (Late Miocene)
- Overlying faulted tephras, volcaniclastic deposits, and paleosols
    - 1.495 ± 0.057 Ma (Pleistocene) for the **lowest, faulted** tan vitric tuff in the hanging wall (17JF56 A, $^{40}Ar/^{39}Ar$ dating)
    - 1.145 ± 0.061 Ma (Pleistocene) for the **highest, faulted** gray pumice lapilli tuff in the hanging wall (17JF56 MR, $^{40}Ar/^{39}Ar$ dating)
- An erosional unconformity overlain by **unfaulted** tephras ≤75–51 ka
    - Collected samples did not have enough radiogenic Ar for dating purposes.

    - One unit is geochemically similar to E Tephra from the Amatitlan caldera, estimated age of 51 ka.

The stratigraphy records a **punctuated history** of volcanic deposition and extensional deformation that ceased prior to late Pleistocene time. Younger deposits indicate surface stabilization and the absence of continued fault activity at this location.
By combining the structural and stratigraphic data, fault timing most likely occurred in a window of ~1.1 Ma, recording 11.5% elongation (Transect A), which indicates a minimum elongation rate of 0.007 mm/yr for the outcrop.

Points of Possible Discussion, Questions remaining

A. Origin of the Biotite-Rich Deposit

What is the most likely source of the massive biotite-rich crystal vitric tuff exposed in the footwall? Very few studies have identified this unit. The extent and thickness have not been mapped. The closest and most likely volcanic source is the Amatitlan caldera to the southeast.
Consider:

- Proximal caldera-forming eruption vs. local volcanic source
- Reworked pyroclastic flow vs. primary fall or ignimbrite
- Why the deposit is unusually thick and biotite-rich

B. Variability in Extension Direction

Why is the extension direction here more NE-directed than at other outcrops west of the Guatemala City graben?
Possible considerations:

- Local stress rotation near the western termination/fault of the graben
- Arc-perpendicular extension between the Central American Volcanic Arc and Motagua Fault
- Structural inheritance or mechanical anisotropy
- Temporal evolution of the stress field

C. Paleostratigraphic Synthesis

What collective paleostratigraphic story is recorded at Xenacoj outcrop?
Discuss:

- Episodic vs. continuous deformation
- The role of unconformities and paleosols
- How stratigraphy constrains when extension ceased

D. Regional Implications

If this were the only outcrop available, would you argue for active extension west of the Guatemala City graben today? Why or why not?

Conclusion

Xenacoj Location 1 records significant Neogene extension that was active prior to late Pleistocene time and subsequently became inactive as strain localized into the Guatemala City graben. The site highlights the importance of integrating structural observations with stratigraphic context to understand the spatial and temporal evolution of deformation along the Caribbean plate boundary.

Further reading: Garnier, B., Tikoff, B., Flores, O., Jicha, B., DeMets, C., Cosenza-Muralles, B., et al. (2022). Deformation in western Guatemala associated with the NAFCA (North America-Central American Forearc-Caribbean) triple junction: Neotectonic strain localization into the Guatemala City graben. Tectonics, 41, e2021TC006739. https://doi.org/10.1029/2021TC006739