GUATEMALA SPRING BREAK TRIP

2025

UNIVERSITY OF PITTSBURGH AT JOHNSTOWN
GEOLOGY CLUB


GUATEMALA
MEXICO
BELIZE
HONDURAS
EL SALVADOR
North Pacific Ocean
Caribbean Sea
Gulf of Honduras
Day 1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7
Day 8
Guatemala
Antigua Guatemala
Chimaltenango
Solola
Lago de Atitlan
Coban
Salama
Rabinal
Tactic
Guastatoya
Escuintla
Mazatenango
Huehuetenango
Quetzaltenango
Flores
Tikal
Belmopan
San Salvador
Guatemala
Day 5
International Boundary
Road
River
National Capital
Department Capital
City or Town
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The following was compiled by Ryan Kerrigan, Associate Professor pf Geology at University of Pittsburgh a Johnstown, Johnstown, PA in the winter of 2024-2025 as supporting material for the Pitt-Johnstown Geology Club Spring Break Trip to Guatemala on February28th to March 9th, 2025.

Much of the details come from Wikipedia. If you use this field guide, please consider donating to Wikipedia.

TABLE OF CONTENTS

THINGS YOU SHOULD BRING

Please limit yourself to one checked bag and one carry-on (day-pack)

Most Important:
• Passport & credit card

Personal Items:
• Sunscreen
• Lip balm with sunscreen
• Sunglasses
• Bug spray (with lots of Deet)
• Tissues
• Toiletries
• Van/Plane Entertainment (books, cards, small board games, etc.)
• Travel Towel

Clothes:
• *It should be warm…*
• Rain jacket (but it is the dry season)
• Hiking boots or good cross trainers
• Lightweight hiking pants
• Swimming Suit
• Hats (both for sun protection and warmth)
• Flip-flops or sandals?

Equipment:
• Water Bottle
• Field Notebook
• Pencils/Pens
• Rock Hammer (must be packed in checked luggage)
• Hand lens

Money:
• You can get Guatemalan Quetzals from your bank - go to the bank and ask. They usually require a few days to get it for you. You might be able to get a better exchange rate this way…
• You can also exchange money at the airport or at Guatemalan banks
• Your credit/bank cards should work fine, but it is always a good idea to tell those companies you are going overseas so they don't shut you down to thinking it might be fraudulent.

Other:
• **WhatsApp** – I would like everyone to download WhatsApp. This is a phone/text service that is free and will allow us to stay in contact via Wifi. This way we will not need to add expensive international calling/data plans to our phone.

TRIP RULES

1. Don't do anything that would put yourself or others else in danger.
2. Buddy System – do not wander off by yourself, ALWAYS have another group member with you AT ALL TIMES!!!
3. Do not invite strangers back to our hotels
4. Please practice moderation – do not overdo it. Please.

You are representing the University of Pittsburgh at Johnstown. Do not embarrass the university. Do not do anything that would jeopardize future trips of the Geology Club!

After the trip:

After the trip, I would like you to upload your pictures to shared cloud folder. I use these pictures in lectures and advertising for future trips.

You will attend the Geology Banquet on Friday April 11th, where the attendees of the Geology Club Spring Break trip will present pictures from the trip.

Important Phone Numbers

Pitt-Johnstown Geology Prof Ryan Kerrigan: +1 612 229 6810
GeoTravel Guatemala Guide Matt Purvis: +502 3168 8625

FLIGHTS

Flights

Departing Flights

Flight #1: *Departure:* United Airlines, UA 5034, Fri 28 Feb 2025, 6:30 AM, John Murtha Johnstown-Cambria County Airport (JST)
Arrival: Fri 28 Feb 2025, 7:35 AM, Washington Dulles International (IAD)

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Return Flight

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GUATEMALAN BASICS

Emergency Number: 122
USA embassy: 011 502 2354 0000 or 1-301-985-8164

- *Currency:* Guatemalan Quetzal (GTQ)
- *Exchange Rate:* 1 USD = ~7.71 GTQ or… 100 GTQ = ~$13 USD
- *Time zone:* Central Standard Time (minus one hour from EST (our time))
- *Credit Cards:* While cards will be accepted in many locations, we will definitely encounter "cash only" establishments. Please bring cash with you. Your bank will exchange USD for Guatemalan Quetzal, if you order then ahead of time.
- *ATMs:* Available in most towns
- *Electrical outlets:* Same as us. Guatemala uses 120 volt, 60 cycle electricity and has two types of electrical outlets: type A and type B.
- *Tipping:* Tipping in Guatemala is not required, but it is appreciated and can be a significant part of a service worker's income. Restaurants – about 10% tip is usually appropriate, but you can tip more if the service was exceptional. Upscale restaurants may automatically include a tip on the bill.
- *Etiquette:* Learn a couple of Spanish phrases before going on the trip. You are in their country, at least make an attempt to conform to their culture, it is only courteous
- *Temperature:* March weather and climate: it's going to be warm. Daily highs average around 100°F and lows around 60°F. Up in the mountains it might be cooler.
- *Cloud Cover:* Generally low, this is the dry season.
- *Precipitation:* It is the dry season, they generally get 2 days of rain for the month of March
- *Daylight:* ~12 hours of daylight (06:00–18:00)

11 Fun Facts About Guatemala

Guatemala's national symbol, the quetzal, is a revered bird and appears on the Guatemala flag and the country's currency
Guatemala's traditional clothing can tell you a lot
Guatemala is the birthplace of chocolate
Guatemala is the heartland of the ancient Maya civilization
Old American school buses get a new life in Guatemala
Kites are used to honor the dead
Guatemalans speak Spanish … and many other languages
Guatemala has a rich coffee culture
In Guatemala, you can roast marshmallows on an active volcano and ATV through vast protected areas
One of Guatemala's unique saints, Maximón, is famous for drinking liquor and smoking cigars.
The Guatemalan Civil War was the longest in Latin American history

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WORLD'S #1 QUICK REFERENCE GUIDE

Quick Study® ACADEMIC

Spanish Phrases

For Everyday Conversation

BASICS/GREETINGS

BASICS

Please ____. *Por favor ____.*
Thank you very much. *Muchas gracias.*
Thanks for ____. *Gracias por ____.*
You're welcome. *De nada.*
Pardon me/excuse me.
Con permiso. (requesting permission)
Perdón. (requesting attention or forgiveness)
I'm sorry. *Lo siento.*
That's all right. *Está bien.*
Okay. *Está bien./Vale.* (inf.)
Sure! *¡Por supuesto!/¡Claro!*
All right. *De acuerdo./Bien.*
Don't worry. *No te preocupes.* (inf., sing.)
Don't mention it. *No hay de qué.*
Once again *Otra vez*
Once more *Otra vez más*
For example *Por ejemplo*
Where is ____? *¿Dónde está ____?*
I don't know. *No sé.*
Where are you from? *¿De dónde es usted?* (for., sing.)
I'm from ____. *Soy de ____.*
Where do you live? *¿Dónde vives?* (inf., sing.)
Do you speak English?
¿Habla usted inglés? (for., sing.)
I speak a little Spanish.
Hablo un poco español.
Speak slower, please.
Hable más despacio, por favor. (for., sing.)

I am learning Spanish for the first time.
Estoy aprendiendo español por la primera vez.
Please listen carefully.
Por favor escuche atentamente. (for., sing.)
I don't understand. Would you repeat that?
No entiendo. ¿Puede repetirlo? (for., sing.)
Would you please write that down?
Puede escribirlo, por favor? (for., sing.)
Text me. *Enviarme un mensaje de texto.*
Yes, of course. *Sí, claro.*
It's good. *Es bueno.*
It's better. *Es mejor.*
It's great! *¡Es fenomenal!*
It's bad. *Es malo.*
It's worse. *Es peor.*
It's terrible! *¡Es terrible!*
It's interesting. *Es interesante.*
It's odd. *Es curioso.*
It's strange. *Es extraño.*

GREETINGS/FAREWELLS

Hello! What's your name?
¡Hola! ¿Cómo se llama usted? (for., sing.)
My name is ____. And you?
Me llamo ____. ¿Y usted? (for., sing.)
Good morning. *Buenos días.*
Good afternoon. *Buenas tardes.*
Good evening/night. *Buenas noches.*
What's up? *¿Qué pasa?/¿Qué tal?*
Not much. *No mucho.*

How are you?
¿Cómo está usted? (for., sing.).
¿Cómo estás? (inf., sing.)
[I'm] Fine, thanks. And you?
[Estoy] Bien, gracias. ¿Y tú? (inf., sing.)
We are fine, thank you.
Estamos bien, gracias.
Very well, thank you. And you?
Muy bien, gracias. ¿Y usted? (for., sing.)
So-so. *Más o menos.* (inf.)
Welcome! *¡Bienvenido/os/a/as!*
(male sing./pl., female sing./pl.)
When did you arrive? *¿Cuándo llegaste?* (inf., sing.)
Long time no see. *¡Cuánto tiempo!*
I'm happy to see you again!
¡Qué gusto volver a verlo/verla! (for., sing. m./f.)
It's nice to see you! *¡Gusto de verlo/verla!*
(for., sing. m./f.)
I would like to introduce you to ____.
Quisiera presentarle/les a ____. (for., sing./pl.)
Hello. Pleased to meet you.
Hola. Encantado/a de conocerlo/la. (for., sing. m./f.)
Same here. *Igualmente.*
It has been a pleasure! *¡Ha sido un placer!*
Good-bye. We had a good time!
Adiós. ¡Lo pasamos muy bien!
See you soon. *Hasta ahora.*
See you later. *Hasta luego.*
See you tomorrow. *Hasta mañana.*

QUESTIONS

What is it? *¿Qué es?*
What are you going to do tonight?
¿Qué vas a hacer esta noche? (inf., sing.)
What can I bring you? *¿Qué le puedo traer?* (for., sing.)
What can I do for you?
¿Qué puedo hacer para usted/ustedes? (for., sing./pl.)
What did you say? *¿Qué dijiste?* (inf., sing.)
What happened? *¿Qué pasó?*
Who is it? *¿Quién es?*
Who's speaking? *¿Quién habla?*
Where are we? *¿Dónde estamos?*
Where do I put the suitcases?
¿Dónde pongo las maletas?
When did he/she do it? *¿Cuándo lo hizo?*

How is it? *¿Cómo es?*
How do you say ____? *¿Cómo se dice ____?*
How do they say it? *¿Cómo lo dicen?*
How much? *¿Cuánto?*
How many? *¿Cuánto/os/a/as?*
(male sing./pl., female sing./pl.)
How old are you?
¿Cuántos años tienes? (inf., sing.)
Is either Monica or Antonia going to the party?
¿Van Mónica o Antonia a la fiesta?
Does anyone want to go dancing with me?
¿Quiere alguien ir con migo a bailar?
Do you know anything about music?
¿Sabes algo de música? (inf., sing.)

Do you have brothers/sisters?
¿Tienes hermanos/as? (inf., pl.)
Do you want to go for a walk around the city with me?
¿Quieres ir a pasear por la ciudad conmigo? (inf., sing.)
Are you sure? *¿Estás seguro/a?* (inf., sing.)
Are you ready? *¿Estás listo/a?* (inf., sing.)
Do you know where we are?
¿Sabes dónde estamos? (inf., sing.)
Do you know Ms. Aurelia?
¿Conoce usted adoña Aurelia? (for., sing.)
Hello? *¿Aló?/¿Bueno?/¡Diga!/¡Dígame!*
(Use these words when answering the phone)
May I speak with ____? *¿Puedo hablar con ____?*
May I leave a message? *¿Puedo dejar un recado?*

EXCLAMATIONS

Congratulations! *¡Enhorabuena!/¡Felicitaciones!*
(Not used for birthdays/anniversaries)
Happy Birthday! *¡Feliz cumpleaños!/¡Felicidades!*
Silence, please! *¡Silencio, por favor!*
Be careful! *¡Ten cuidado!*
Help me! *¡Ayúdeme!* (for., sing.)
I'm so sorry! *¡Lo siento muchísimo!/¡Mil perdones!*
I've told you hundreds of times!
¡Te lo he dicho cientos de veces!
You don't say! *¡No me digas!*
At your service! *¡A sus órdenes!* (for., sing.)
It's not a big deal! *¡No es para tanto!*
Thanks for the offer! *¡Gracias por la oferta!*
I agree!/I don't agree!
¡Estoy de acuerdo!/¡No estoy de acuerdo!
Of course! *¡Claro que sí!/¡Por supuesto!*
No way! *¡De ninguna manera!*
You've got a deal! *¡Trato hecho!*
Good idea!/Good choice! *¡Buena idea!*
It's great! *¡Es fenomenal!*
It's incredible! *¡Es increíble!*
It's marvelous/wonderful! *¡Es maravilloso!*

It's perfect! *¡Es perfecto!*
It's ridiculous! *¡Es ridículo!*
It's urgent! *¡Es urgente!*
How strange that ____! *¡Qué extraño que ____!*
How great that ____! *¡Qué fenomenal que ____!*
How terrible that ____! *¡Qué terrible que ____!*
How interesting that ____! *¡Qué interesante que ____!*
How wonderful that ____! *¡Qué maravilla que ____!*
How weird that ____! *¡Qué raro que ____!*
What a shame that ____! *¡Qué vergüenza que ____!*
What a pity! *¡Qué lástima!*
What a mess! *¡Qué lío!*
What a hurry she's in! *¡Qué prisa ella tiene!*
What sparkly snow! *¡Qué centelleante nieve!*
What a car he brought! *¡Qué carro él compró!*
How shiny it is! *¡Qué brillante es!*
How pretty! *¡Qué bonita!*
How lovely! *¡Qué hermoso!*
How tall you are! *¡Qué alto eres!* (inf., sing.)
How far away you live! *¡Qué lejos vives!* (inf., s.)
How interesting! *¡Qué interesante!*
How well he/she works! *¡Qué bien trabaja!*

NEGATIVES

No, I don't know anything [about it].
No, no sé nada.
We never go to the theater.
Nunca vamos al teatro.
I have no desire to eat vegetables.
No tengo ningunas ganas de comer legumbres.
I never hear the alarm clock.
Nunca oigo el despertador.
No problem. *Ningún problema.*
I'm not going to the party tomorrow.
No voy a la fiesta mañana.
Nobody is going to the cinema, right?
Nadie va al cinema, ¿no?
No, there is no ____ here.
No, no hay ____ aquí.
No, Pablo is not going and neither is Antonio.
No, Pablo no va y Antonio tampoco.
Camila y Carla? Neither one is going.
¿Camila y Carla? Ninguna de los dos van.
No, no one wants to go.
No, no quiere ir nadie.
It's not this way./That's not so. *No es así.*
I don't like ____. *No me gustan ____.*

1

BRIEF ITINERARY

Day 1: Friday, February 28th, 2025 – Fly to Guatemala
Kind of a long day of flights…

5:30 AM: You should arrive at the Johnstown airport no later than 5:30AM.

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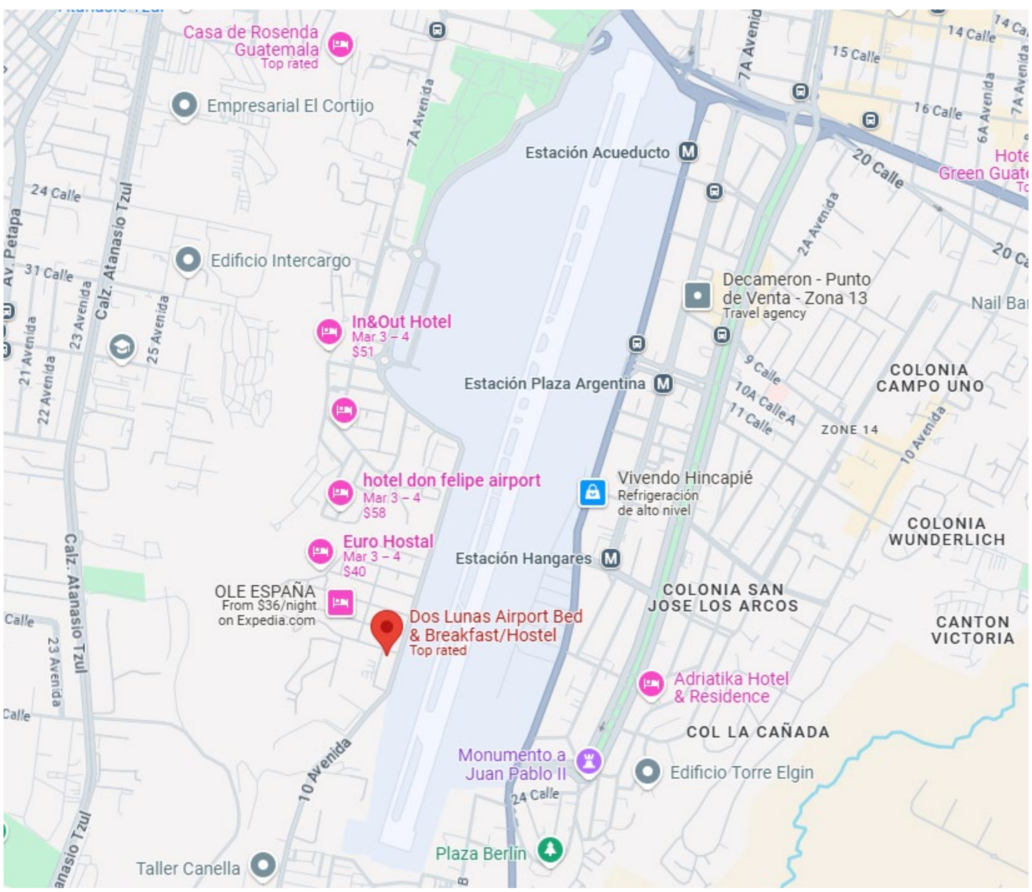
Arrival: Fri 28 Feb 2025, 11:14 PM, La Aurora International Airport, Guatemala City (GUA)

12:00 AM: If all goes well we should arrive at the hotel at midnight…

We will stay at the Hotel Dos Lunes, close to the airport.
Dos Lunas Airport Bed & Breakfast/Hostel
21 Calle 10-92, Cdad. de Guatemala 01013, Guatemala
+502 2261 4248



Day 2: Saturday, March 1st, 2025 – East of Guatemala City

7:30 AM: Wake up, breakfast provided by the hotel.

8:30 AM: Load into the bus.

10:00 AM: Road cut through the amphibolites and phyllites of the El Tambor formation overlain with the conglomerates and “red beds” of the Subinal formation.

12:00 PM: Lunch at Sarita Restaurant at El Rancho, right in the Motagua Fault!

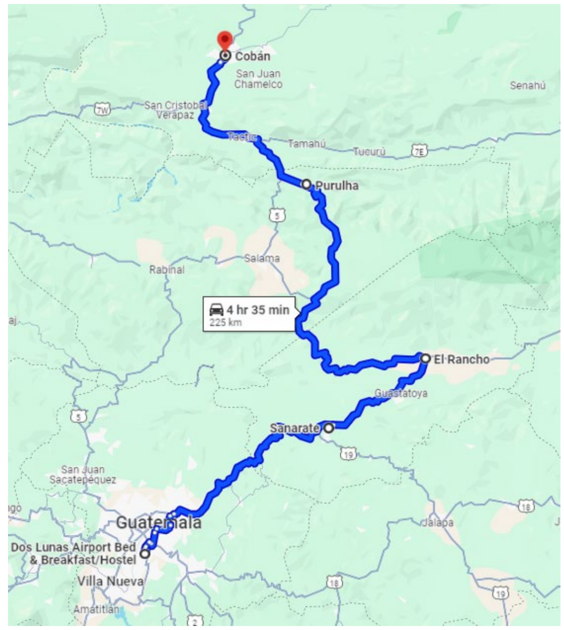
1:00 PM: Road cut northwest of El Rancho through highly serpentinized ultramafics with multiple phases of deformation.

2:00 PM: Quarry south of Purulha exposing more ultramafics, although not as highly serpentinized. Ophiolite exposed? Then briefly drive along Polochic Fault through Tactic

4:00 PM: Check into the guesthouse in Coban

Don Francisco
(https://www.facebook.com/hotelposadadonfrancisco/)
Km. 215.5 Ruta a San Pedro Carcha, Cobán, Guatemala
Email: posadadonfrancisco@gmail.com Phone: +502 4118 2988

5:00 PM: Group meal.



Day 3: Sunday, March 2nd, 2025 – Semuc Champey

7:00AM: Wake up, breakfast not included at hotel. What time does the restaurant open?

9:00AM: Load the bus

11:00AM: Arrive at Semuc Champey

12:00PM: Grocery store lunch,

4:00PM: Return to Coban and the Don Francisco Hotel

Day 4: Monday, March 3rd, 2025 – Rabinal

7:00AM: Wake up, breakfast not included at hotel, pack up, and load into the buses.

8:00AM: Leave the hostel and drive to Rabinal

Go to grocery store for lunch supplies for Day 4 and Day 5

9:00AM: Quarry with greenschist meta-sediments, probably part of the Maya Block pre suture.

4:00PM: Reach the guesthouse

5:30PM: Check-in at the guesthouse

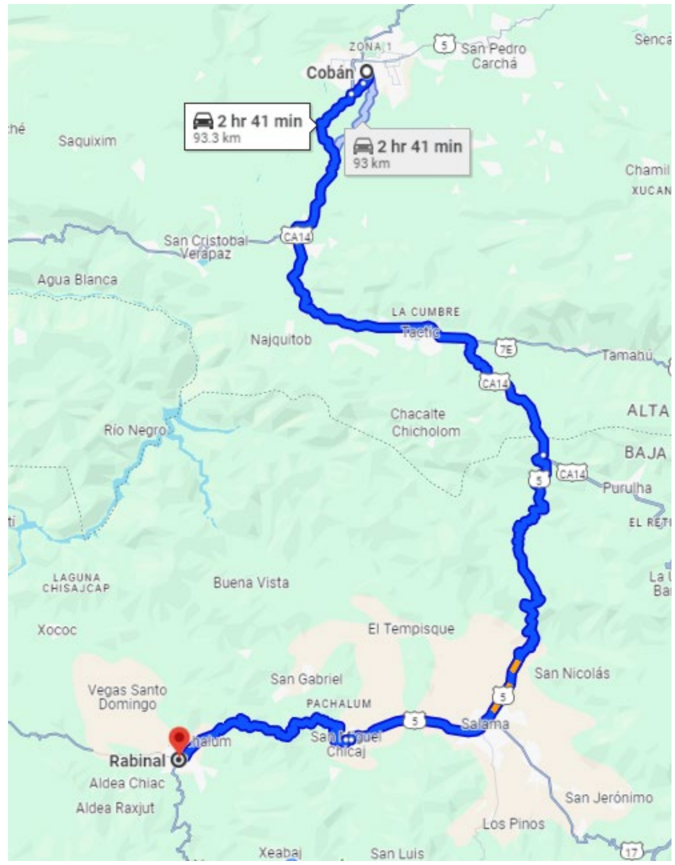
Hotel y Restaurante Maria De Los Angeles (https://www.facebook.com/hotelmariadelosangeless/)

3ra Calle 6-80 zona 2, Rabinal, Guatemala

Email: hotelmariangel@hotmail.com

Phone: +502 7938 8919

6:00PM: Group dinner at the guesthouse



Day 5: Tuesday, March 4th, 2025 – Antigua

7:00AM: Wake up, breakfast not included at hotel. Hotel does have a restaurant.

8:30AM: Depart from the hostel

10:30AM: North of El Chol - Gneisses, amphiboles, garnets, feldpars, micas. Possible eclogite? Multiple phases of folding.

12:30AM: South of Granados, we recross the Motagua and see the Subinal on top of the El Tambor again.

4:30PM: Arrive at hotel in Antigua:

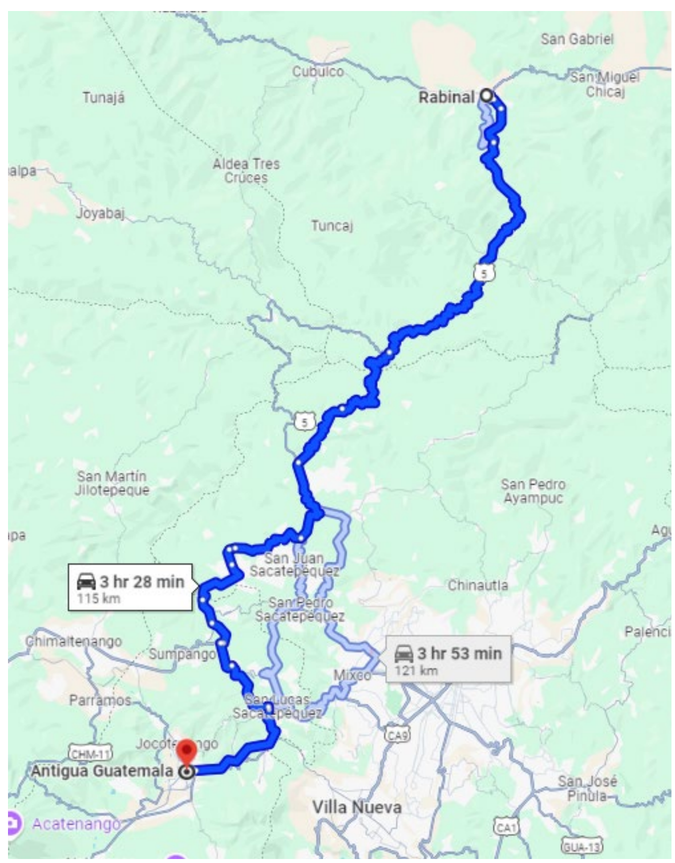
Selah Hotel y Coffee, Antigua (https://hotel-selah.guatemalaantiguahotels.com/en/)

6ta calle poniente Casa No.58-1A, Antigua Guatemala, Guatemala

Email: selahotelantigua@gmail.com

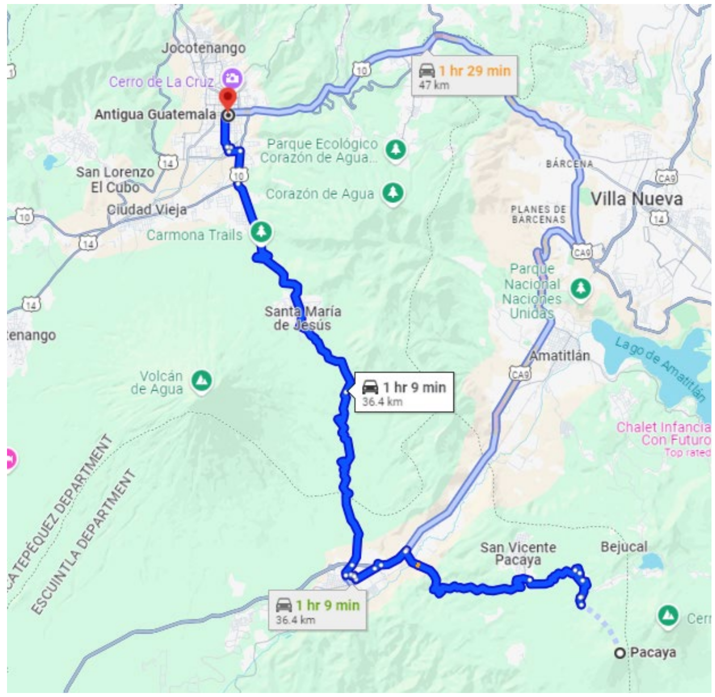
Phone: +502 7832 5063

6:00PM: Fend for yourself for dinner



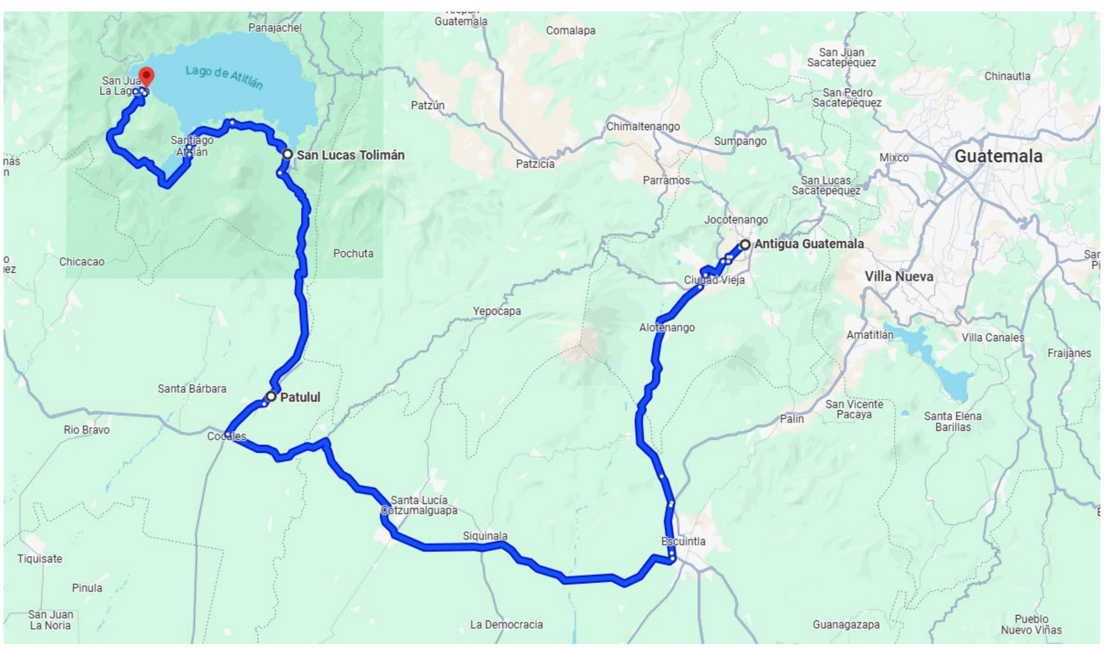
Day 6: Wednesday, March 5th, 2025 – Volcan Pacaya and Antigua

6:00AM: Wake-up, breakfast included at the guesthouse
7:00AM: Depart for Pacaya
8:30AM: Hike Volcan Pacaya
2:00PM: Return to Antigua – free day in the city



Day 7: Thursday, March 6th, 2025 – Volcanoes around Lake Atitlan

7:00AM: Wake-up, breakfast included at hotel, pack our things, and load the vans.
8:00AM: Drive to San Pedro La Laguna, Laka Atitlan. Take the Southern Route down the RN14 with views of Fuego volcano. Discuss 2018 eruption. Possible stop at quarry North of San Miguel Los Lotes to see PDC deposits that destroyed the town.
12:00PM: Lunch at SantaLu Mall.
4:00PM: Arrive in Mikaso in San Pedro
Hotel Mikaso
(https://www.hotelmikaso.com/en)
MPVJ+JQ San Pedro La Laguna, Guatemala
Email: info@mikasohotel.com Phone: +50277218232
Rest of the Day: Enjoy San Pedro and Lake Atitlan, you are on your own.



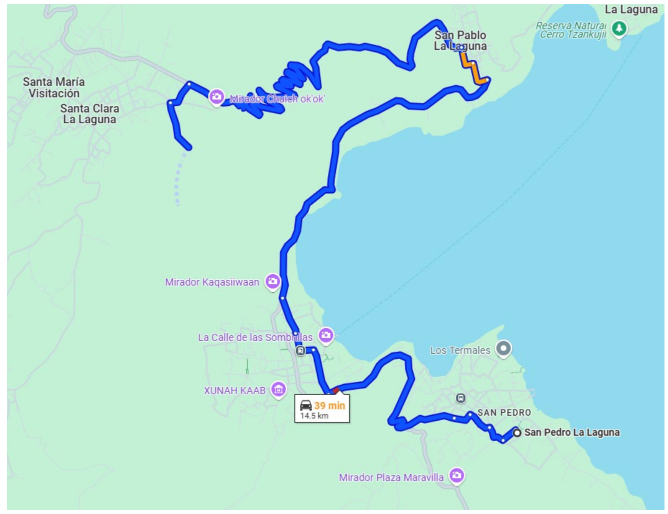
Day 8: Friday, March 7th, 2025 – Lake Atitlan and the Mayan Face

7:00AM: Wake-up, breakfast not included at the guesthouse – breakfast options close by Idea Connection

9:00AM: Depart for Mayan Face hike

1:30PM: Lunch San Juan

3:00PM: Women weaving collective in San Juan



Day 9: Saturday, March 8th, 2025 – Geology and Archeology Stops on our way back to the airport

7:30AM: Wake-up, breakfast not included at hotel

8:30AM: Depart the hotel

9:00AM: Massive intrusive (Atitlan 2 Caldera leftovers?), fault breccia on top, massive pumice deposits. Co-Atitlan 3 Caldera formation?

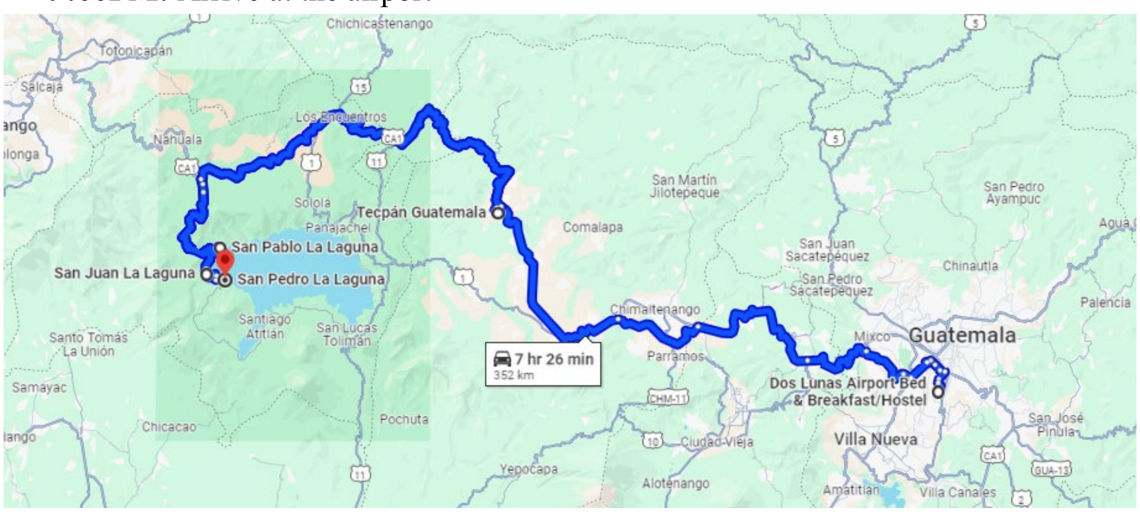
10:30AM: Massive Atitlan 3 Ignimbrite deposits. Near Maria Tecun

1:00PM: Grocery store lunch Maybe at Iximche ruins

4:00PM: Leave Iximche Ruins

7:00PM: Dinner close to the airport

9:00PM: Arrive at the airport



Day 10: Sunday, March 9th, 2025 – In transit and return home

Flight #1: Departure: United Airlines, UA 1562, Sun 28 Mar 2025, 12:05 AM, La Aurora International Airport, Guatemala City (GUA)

Arrival: Sun 9 Mar 2025, 6:15 AM, Washington Dulles International (IAD)

Flight #2: Departure: United Airlines, UA 5046, Sun 9 Mar 2025, 12:35 PM, Washington Dulles International (IAD)

Arrival: Sun 9 Mar 2025, 1:32 PM, John Murtha Johnstown-Cambria County Airport (JST)

INTRODUCTION

Most of this section was taken from the 2005 Field Guide to Guatemalan Geology produced by Stanford University Department of Geological and Environmental Sciences for their Stanford Alpine Project
I just cherry picked some of the relevant sections.

Regional Tectonic Setting and Metamorphic History

Julie C. Fosdick

Guatemalan geology is characterized by the presence of active volcanoes, rugged terrain in the central cordillera, transform faulting, northern lowlands and extensive karst topography. Many of these features are the result of an active history of subduction, associated arc volcanism, plate collisions, ultra-high-pressure metamorphism, and deep-ocean basin or shallow-shelf deposition within the general plate tectonic evolution of the Caribbean region. The geologic terranes that compose Guatemala are best appreciated by evaluating the complex spatial and temporal evolution of plate boundaries between the Pacific, Caribbean, and Cocos plates. Though the geologic history of the Caribbean plate, and more specifically, Guatemala, remain poorly defined, the available studies illustrate a dynamic and complicated area of ongoing interest and debate.

Guatemala is centrally located within an area of active plate convergence and transform plate motion. The Middle American Trench is located along its southwest coast, formed by the Cocos plate subducting beneath the North American-Caribbean plates. The transverse plate boundary between the Caribbean and North American plates transects Guatemala's central region. Modern-day plate configurations can explain many of the geologic and geomorphic features of Guatemala, though regional variations in its geology are largely attributed to the older stages of the tectonic and volcanic evolution.

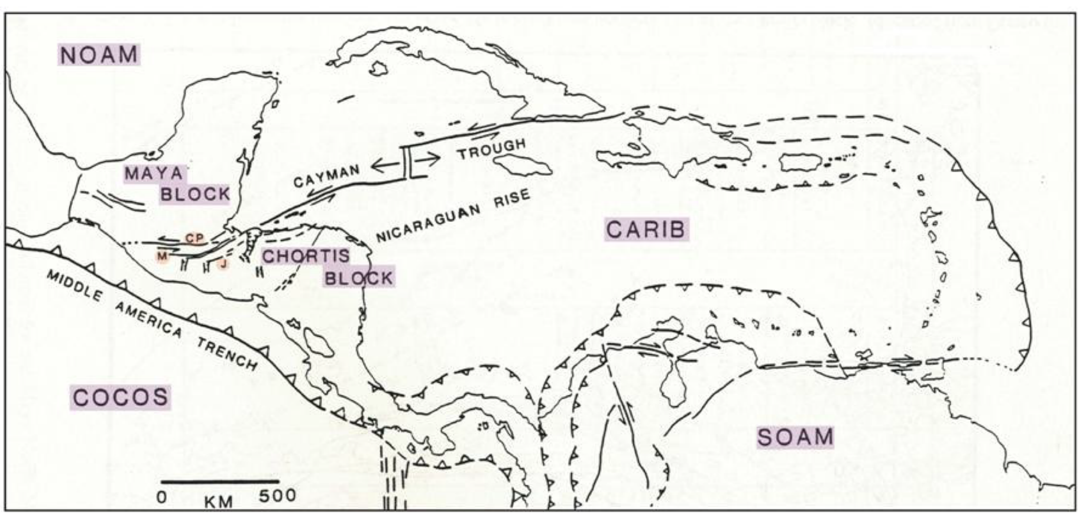
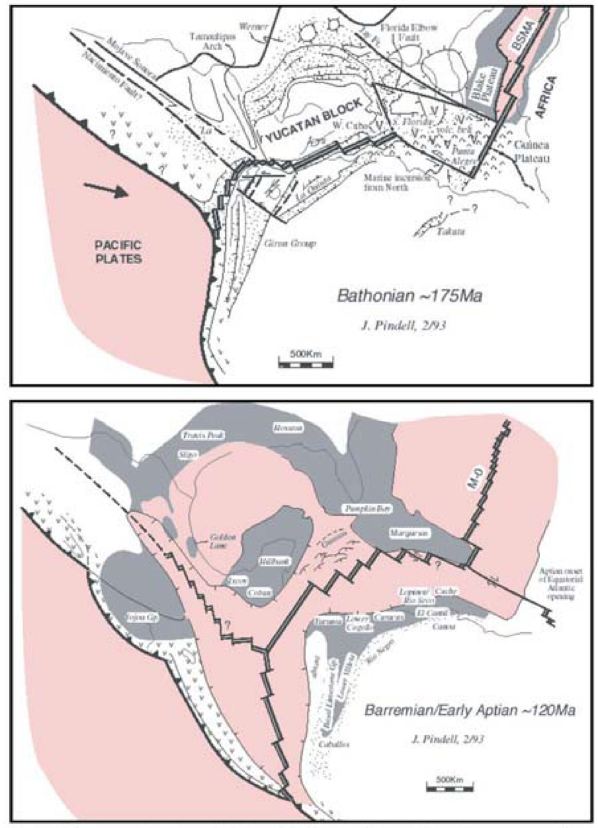


Plate tectonic setting of Central America showing the relative motions of the NOAM, Cocos, CARIB, and SOAM plates. Guatemala is subdivided into the Maya Block, of NOAM, and the Chortis Block, of CARIB association. These geologically distinct tectonic blocks are separated by the Motagua Suture Zone. CP = Chixoy-Polochic fault zone; M = Motagua fault zone; J = Jocotan fault zone

Many plate tectonic models for the Caribbean region have been hypothesized in the last 30 years (Dietz and Holden, 1970; White and Burke, 1980; Duncan and Hargraves, 1984; Pindell and Barrett, 1990), and yet a single, regionally integrated story has yet to gain popularity among Caribbean geoscientists. Additional geochronology, geologic mapping, and regional stratigraphic correlations are needed to resolve a regional tectonic evolution. The Pindell (1994) model provides a general summary of the major tectonic events that pertain to Guatemalan geology, including a) the Middle Jurassic break-up of the North American and South American plates, b) evolution of the proto-Caribbean seaway and oceanic crust, c) multiple island-arcs (proto- Greater Antilles and Costa-Rica/Panama island arcs), d) deep-water sedimentation along the northern Yucatan Peninsula, e) convergence between the Caribbean and proto-American plates, f) subduction zone and continental arc along western north and central America, g) Neogene transform plate boundary between Caribbean and North American plates.

Regardless of which model one subscribes to for regional tectonics, the major plate-tectonic components that are critical to any model are subduction-related magmatic arcs, orogenic collision zones, and remnant fragments of the oceanic lithosphere (Meschede and Frisch, 1998). Arc magmatism during the Late Jurassic period formed the volcanic arc that constitutes part of the Chortís block of southern Guatemala. Younger subduction magmatism within the Caribbean plate includes the Middle Cretaceous to Paleogene volcanic arcs such as Cuba, Puerto Rico, and the Virgin Islands. During the Late Cretaceous, continental collision occurred between a volcanic arc and the Mexico/Yucatán continental crust of the Maya block of northern Guatemala. This collision



. Plate reconstructions at 175 Ma and 120 Ma showing inception of an ocean spreading ridge in the proto-Caribbean region, island-arc magmatism, and ocean basin deposition (Pindell, 1994).

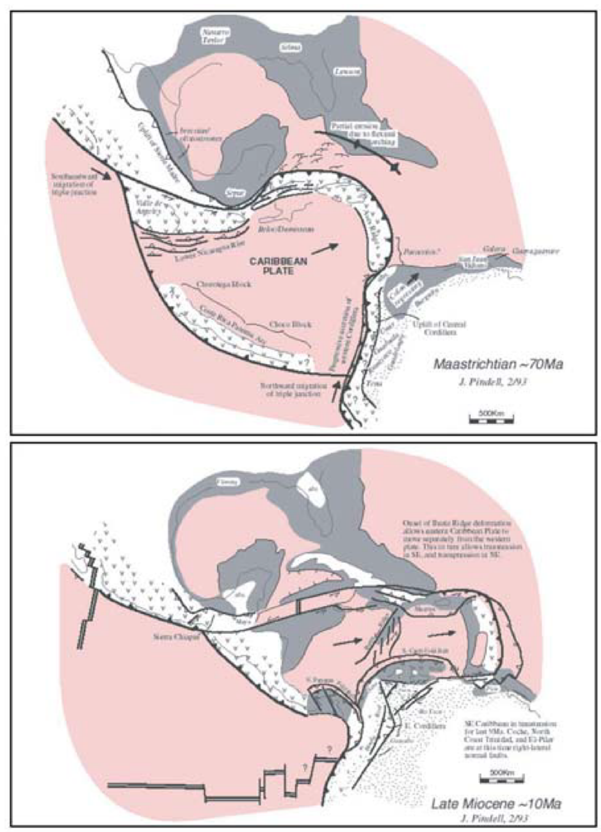
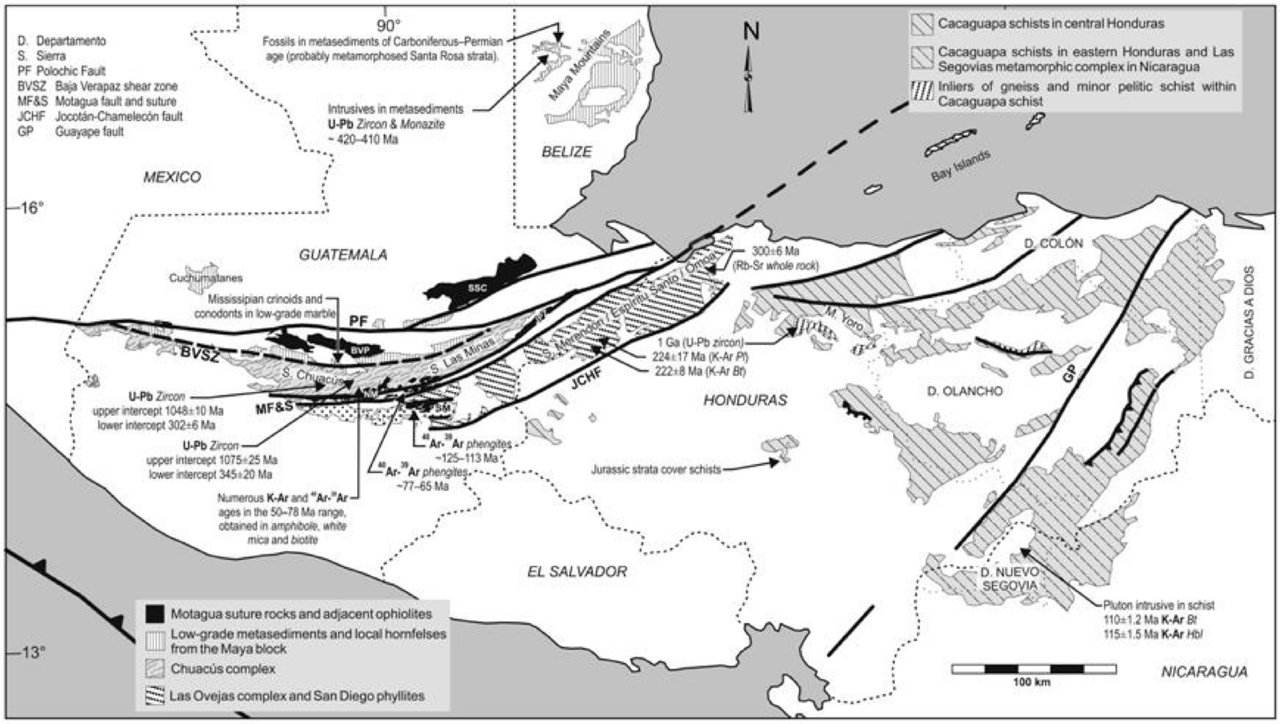


Plate reconstructions at 70 Ma and 10 Ma showing development of transform along northern margin of the Caribbean plate and evolution of subduction zones (Pindell, 1994).

resulted in the deformed ophiolites and high-pressure assemblages in the central belt of Guatemala (Martens et al., *in press)*. In northern Guatemala, the formation of new oceanic crust by the process of Late Cretaceous/Early Cenozoic sea-floor spreading formed the low-lying sedimentary basin of the modern-day Yucatán Peninsula. The geology of this region consists of alternating siliclastic, carbonate, and evaporite deposits, indicating a dynamic sedimentary environment alternating from deep-water to shallow shelf setting through time.



Metamorphic map of Central America showing the various terranes along the Motagua Valley, Guatemala, including the Chuacus complex and low-grade metasediments that will be visited during the fieldtrip (courtesy of Martens et al. *in press*).

Tectonic Blocks

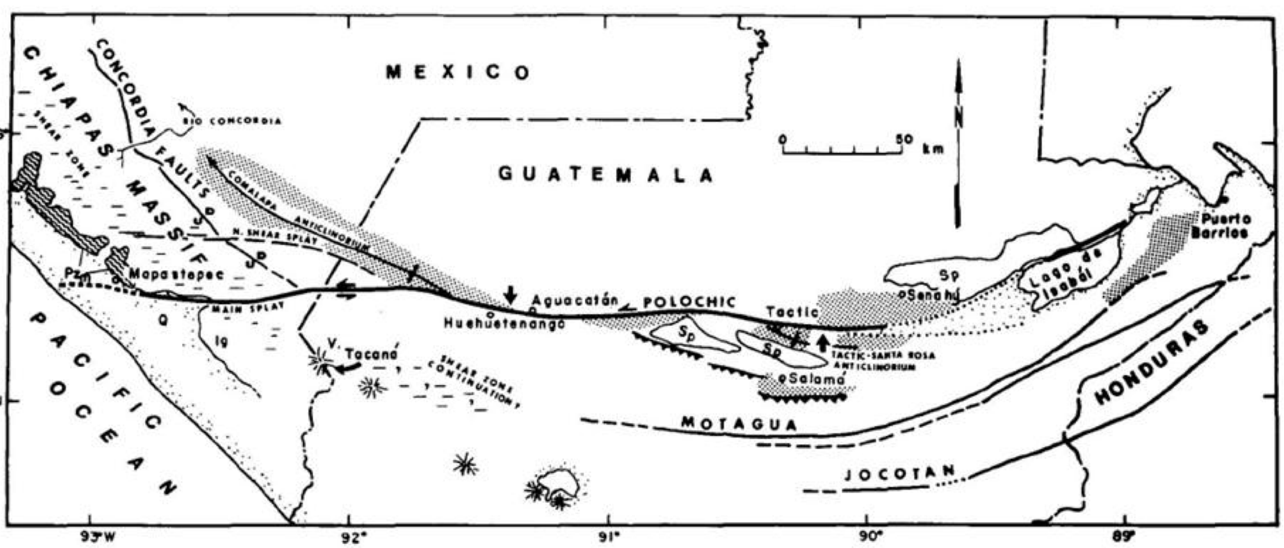
Guatemala is subdivided into two major tectonic blocks, the Maya block and Chortís block, juxtaposed along the present-day Motagua Valley fault zone.

The Maya Block

Northern Guatemala is a part of the Maya Block, the southernmost part of the NOAM plate. The oldest rocks within the Maya Block are igneous and metamorphic cratonic basement rocks, unconformably overlain by Upper Paleozoic metasedimentary rocks. Radiometric dating of these rocks has identified intense deformation and metamorphism during the Devonian period (Finch and Dengo, 1990). Mesozoic sedimentary rocks overly the Paleozoic section and consists of a thick sequence of alternating redbeds, marine limestone, and evaporates, indicating a long-lived and alternating terrestrial and marine deposition along the Yucatán Peninsula (Donnelly et al., 1990). The thick carbonate deposits are responsible for the karst topography in northern Guatemala. Regional deformation of the Paleozoic and Mesozoic rocks occurred during a collisional orogeny, resulting in the uplift of the southern Maya block and the formation of the fold and thrust belt that today composes the central Guatemala cordillera. Tertiary rocks are largely marine clastic and volcanic, indicating a period of active volcanism, tectonic activity, and high erosion rates.

The Chortís Block

Guatemala, south of the Motagua Valley, is part of the Chortís block and is considered the northernmost part of the Caribbean plate. The tectonic history of the Chortís block is quite controversial and has been generally recognized as having originated elsewhere and having been tectonically moved to its present position (Donnelly et al., 1990). Studies of the Mesozoic stratigraphy and basement rocks of the Chortís block suggest strong correlations with southwestern Mexico. This relationship is considered by many authors to indicate an eastern translation of the block to its present position south of the Maya block. This suturing event occurred by the end of the Mesozoic, contemporaneous with widespread and sporadic tectonic and magmatic activity. Brittle deformation and regional uplift characterizes the Late Cretaceous Chortís block, possibly related to regional uplift to the north in the Laramide Cordillera of Mexico. The Cenozoic history is dominated by plate interactions of the Caribbean plate with the North American and Cocos plate, the present-day subduction zone and transform margin, respectively (Donnelly et al., 1990). In the first case, oblique convergence with the Cocos plate has produced Quaternary development of an Andean-type volcanic front along the Pacific margin of Guatemala. In the second instance, left-lateral transform motion between the North American and Caribbean plates has resulted in strike-slip displacement along the Motagua-Polochíc fault zone.



Map of western Guatemala and southern Chiapas showing the trace of the Motagua Fault zone and its relationship to the exposed Paleozoic sedimantary core (shaded) fold belt of northern Guatemala. Arros indicate match-up points for reconstruction along the Polochic fault (From Burkart, 1978).

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Arc Volcanism

Gwyneth Hughes

The volcanoes of Guatemala are part of the Central American arc that extends 1100 km from the Mexico-Guatemala border to central Costa Rica. Subduction of the Cocos plate beneath the Caribbean plate has created the 15 km wide volcanic arc. Present and prehistoric volcanism in this region has significantly impacted both the regional landscape and the people of Guatemala.

Three types of volcanism dominate the regional geology of southwest Guatemala: the volcanic front defined by tall stratovolcanoes, silicic calderas that lie behind or north of the arc, and basaltic cones in southern Guatemala associated with extensional faulting (Carr and Stoiber, 1990). The large stratovolcanoes, such as Pacaya, Fuego, Acatenango and Santa Maria, are still very active and as of May 24, 2005, all of these but Acatenango were erupting to some degree. Various types of volcanic activity can occur at each volcano including ash falls, lava flows and pyroclastic flows. While the stratovolcanoes are the most obvious feature of volcanism, it is important to note that the pyroclastic deposits of large, silicic, caldera-forming eruptions make up much of the landscape. Lake Atitlán lies inside a 15 by 25 km Atitlán caldera, the third in a series of calderas occurring in the same area since 14 Ma. The output and plutons associated with these successive calderas are visible in Lake Atitlán's vicinity. The Los Chocoyos eruption of Atitlán III in 84 ka emitted 270 km^3 of magma, creating the thick, pink, Los Chocoyos formation, an ignimbrite that crops out throughout the volcanic highlands (Newhall, 1986).

Arc volcanism in Guatemala extends back to the Jurassic. Before the formation of the current Central American arc, the Chortís arc was active from the Jurassic to the Eocene as evidenced by plutons associated with a subduction setting. During the Eocene, the current subduction setting developed and the Central American arc overprinted the pre-existing Chortís arc in Guatemala (Pindell and Barrett, 1990).

As long as people have inhabited the area, the volcanic arc has both posed a natural hazard and provided resources to the population. The Maya, for example, mined obsidian from the volcanic highlands for tool-making (Rice et al., 1985). Additionally, the ash that

Map of the major Guatemalan volcanoes. (USGS) the Maya used to temper their ceramics was likely blown into the lowlands rather than mined and transported, indicating that the arc was quite active during the Classic Period (600-900 C.E..) (Ford and Rose, 1995). Volcanism has posed a major hazard in modern times -- the arc has produced over 16km^3 of volcanic output since 1680. Perhaps the most famous eruption was the 1902 Volcán Santa Maria plinian-type eruption that killed 1,500 people. While the active volcanoes pose a threat, they also provide a major source of income in the form of tourism and potentially, in the future, geothermal energy production.

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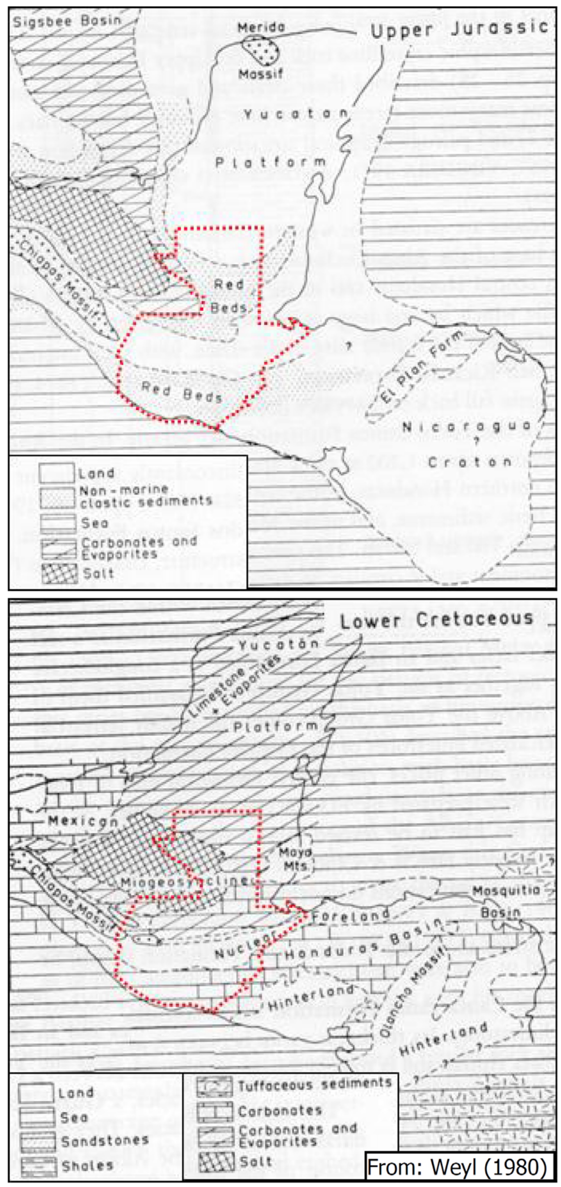
Sedimentary Geology

Kevan Moffett

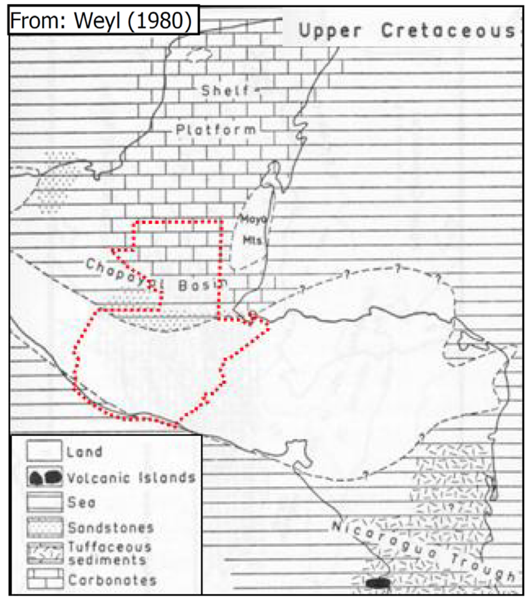
There are three regions with different sedimentary stratigraphy in Guatemala. The following section focuses on the bulk of the nation's sedimentary rocks, all north of the North American-Caribbean plate boundary on the Maya Block. A smaller region with different geologic history is located southeast of the plate boundary (on the Chortís Block); the reader should pursue references on Honduran stratigraphy for more information about this area. The third region is the Pacific Coastal Plain, which is compose almost entirely of poorly dissected sediments of volcanic origin up to 30 km wide and an estimated 4000 km deep. The remainder of the country is either part of the central metamorphic belt or the volcanic arc, both already discussed above.



From: Weyl (1980)

The sedimentary history of Guatemala is closely connected to the tectonic time-line of this highly active region. The oldest unit known to crop out at the surface is in the Santa Rosa Group, found in the Sierra de los Cuchumatanes – the northwestern Guatemala highlands – as well as in some locations just to the north of the Polochíc fault and in the Maya Mountains of Belize. Characterized by basal shale with overlying greywacke and then sandstone, this group is thought to have its origin in submarine fans deposited in the Pennsylvanian or Permian periods; this is supported by the presence of Permian carbonates in some of the same locations. There are magnificent sites in the Cuchumatanes exposing 7500 meters of sedimentary section – the thickest continuous outcrop in all of Central America, and one is also one of the oldest (middle Paleozoic). The overall stratigraphy of the Maya block of northern Guatemala dips northwards with an estimated gain of over 3000 m depth from central to northern Guatemala. This trend continues into southern Mexico, where it is much more difficult to find outcrops of very old sedimentary rocks.

During the Jurassic period the North American and South American plates separated, and the volcanic arc comprising much of southern Guatemala (the Chortís block) formed. During this tectonically active period, thick "red beds" were deposited as alluvial fans in grabens and basins in the region. Collectively called the Todos Santos Formation, these sedimentary rocks are characterized by red continental conglomerates, sandstones, and shales. In the northern lowlands of Petén and the central Alta Verapaz regions of Guatemala, the upper portion of the Todos Santos Formation includes interbedded carbonates and evaporites, merging in places with overlying Cretaceous carbonates.



Marine transgression commenced in the early Cretaceous period, during which time massive shelf carbonates were formed along a passive margin in the proto-Yucatan region. This widespread sequence exists through Guatemala and southern Mexico and is known as the Ixcoy or Cobán Formation of shelf limestones. These massive carbonates are responsible for the karst terrain of much of northern and central Guatemala. These thick deposits are characterized by about a kilometer of dark gray, fossil-free dolomite and limestone containing lithoclastic breccias, overlain by a central section of fine-grained clastics and topped by another kilometer of fine-grained gray/brown layers including microfossils. The late Cretaceous (90 Ma) saw the collision of the Maya and Chortís blocks most notably causing massive metamorphism in central Guatemala and deposition of the Jalapa Mélange along the suture zone (and what is now the modern transform plate boundary). This was followed by deposition of the resulting foredeep (75 Ma) of the Verapaz Group, which has three different regional expressions: the Chemal red shale, calcarenites, and conglomerate limestones in central Guatemala; the Sepur red sandstones, shales, and fossil-rich limestones of the shallow marine deposits slightly to the north; and the Lacandón carbonate Yucatán shelf deposits of Petén in northern Guatemala.

Tectonic quiescence and continental erosion in the Paleocene allowed for further foredeep subsidence and deposition of the Petén Group over the Verapaz Group in the lower Eocene. The Petén Group includes the Cambio, Reforma and Toledo Formations' clays and shales and the overlying Toledo and Santa Amelia Formations' carbonates and evaporites (in the northern Yucatán region). Subsequent uplift led to deposition of further "red beds". Two further limestone formations follow, the Carillo Puerto Formation on the Yucatán and a shallow reef system associated with Lago Izabal and Río Dulce near the Gulf of Honduras. This period also documents deposition of the Subinal Formation in southeastern Guatemala.

Finally, Pliocene-Quaternary clastic deposition accounts for greater than 2000 meters of sediments in some of the grabens in central Guatemala (such as that in which Guatemala City resides) and Quaternary alluvium partly fills the great basin of northwestern Petén as well as dominating the coastlines.

Refer to the geologic map at the beginning of the Introduction for an overview of the sedimentary units and their locations.

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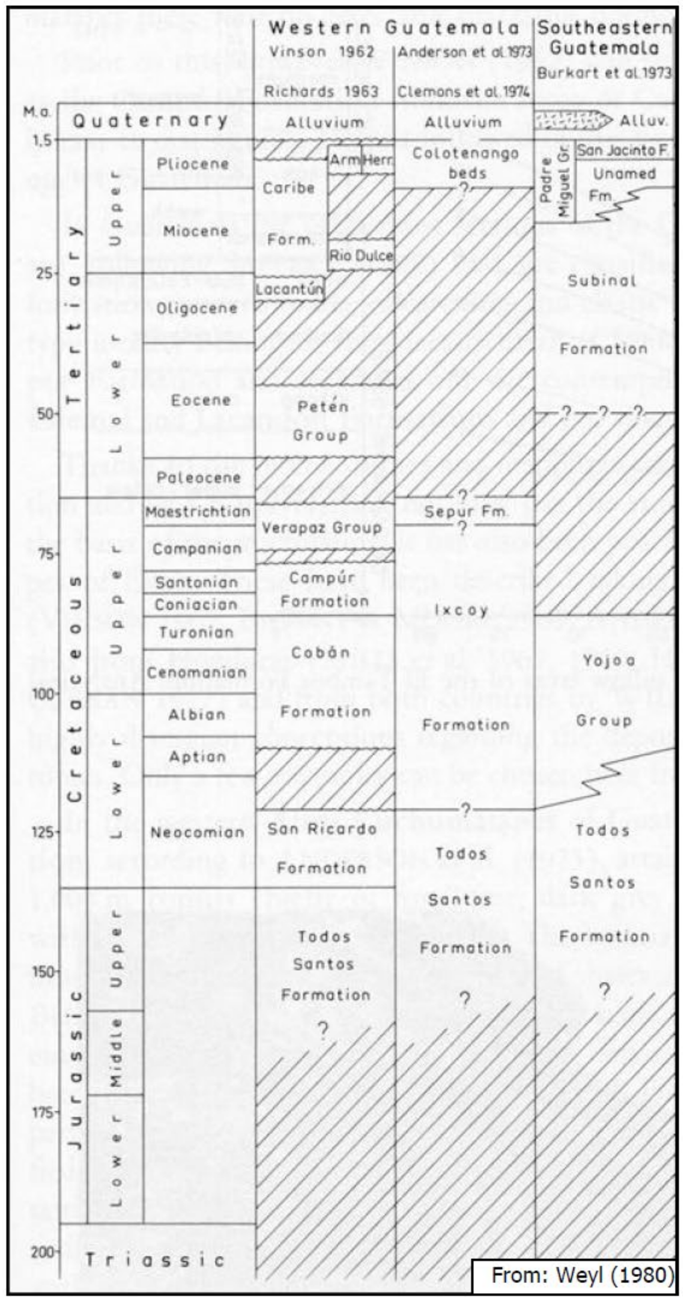

From: Weyl (1980)

Archeology and Mayan civilization

Sid Carter

Overview of Ancient Maya Civilization

Maya culture emerged around 2000 B.C.E., reached an apogee of complexity from 600 C.E. to 800 C.E., and experienced a complex decline about 900 C.E.. Based on this general pattern of cultural progression, archaeologists have divided Maya chronology into the Preclassic (2000 B.C.E. – 300 C.E.), Classic (300 – 900 C.E.), and Postclassic (900 – 1542 C.E.) periods. At its greatest extent, Maya civilization was spread across all of modern Guatemala and El Salvador and parts of southern Mexico and northern Honduras. In addition, the Classic period Maya had economic and, perhaps, ideological ties to central Mexican cultures, particularly to the urban center of Teotihuacan. By the Classic period, major sites in the lowland Maya region flourished as city-states that vied for economic and political prominence through shifting alliances and military power. This trip focuses on two of these sites: 1) Tikal, a large site in the central Petén area that was an important center from about 800 B.C.E. to 1000 C.E.; and 2) Quirigua, a relatively small site in the lower Motagua River Valley that prospered from 450 – 850 C.E..

The cultural achievements of Maya civilization include: 1) an elaborate cosmology, which established relationships between humans, supernatural beings, and maize agriculture as well as the mediation of these relationships through rituals, such as the Mesoamerican ballgame, bloodletting, and human sacrifice; 2) a base-20 mathematical system; 3) a complex calendrical system, which recognized the solar year and incorporated two cyclical calendars and a linear calendar; and 4) a hieroglyphic writing system, which documented mythology and the history of rulers. During this trip's visits to Tikal and Quirigua, the visibility of these features of Maya culture was limited to their reflections in ceremonial architecture and sculpture. However, this trip's focus on the geological variability of Guatemala invites consideration of two geological materials exceptionally important in Maya culture: jade and obsidian. As discussed below, geological perspectives on the sources of jade and obsidian have made crucial contributions to the archaeological understanding of Maya economy and society.

Jade in the Maya Region

Jade was prized by the Maya as an intrinsically valuable material and a vibrant medium for representational art, as evidenced in burials and ceremonial contexts throughout the Preclassic and Classic Maya world. The symbolic associations of the green hues of jade with life and agriculture were important throughout Mesoamerica.[1] Maya artisans fashioned jade into burial masks, statuettes, ceremonial containers, ear spools, and necklaces. Although the density and hardness of jade undoubtedly made processing the material difficult, the associated durability of jade added to the value of the finished goods and facilitated the extended life of many jade artifacts as heirlooms. The only tool-material available to the Ancient Maya hard enough to work Jade was Jade itself. In addition, the Maya appear to have revered blue-green jade artifacts of the Olmec (1500 – 300 B.C.E.), as suggested by Olmec artifacts engraved with Maya glyphs. While possession of jade artifacts appears to have been restricted to the Maya political/religious elite, jade functioned in ritual and economic activities that were visible throughout Maya society.


COLORS OF JADE

In contrast to the broad geographical distribution of jade artifacts throughout Mesoamerica, the sources of jade appear to be restricted only to the high pressure/low temperature metamorphic rocks in the Motagua River Valley of Guatemala. Jadeite (rock composed principally of jadeite) occurs as small bodies in association with serpentinites along the Motagua fault zone, which defines the boundary between the Maya block of the North American plate and the Chortís block of the Caribbean plate.[2] Since jadeites are products of chemical alteration due to fluid interaction (i.e., metasomatism) in mineralogically-heterogeneous protoliths, they exhibit considerable chemically variability within a single geological source area.[3] As a result, attempts to constrain Mesoamerican sources of jade through multielemental chemical analysis have led to confusion regarding chemical variation and the number of jade sources represented by such variation.[4] In contrast, ongoing mineralogical analysis of jade samples and artifacts suggests that most of the visually and chemically distinct types of jade found in Mesoamerica still originated in the Motagua River Valley.

Obsidian in the Maya Region

Unlike jade, obsidian appears to have been accessible to all segments of Maya society. Although the extent of elite control on the distribution of obsidian in the Maya remains a topic of debate, obsidian implements and debitage (waste material from production) have been found in domestic contexts associated with the full range of Maya socioeconomic status.[5] Obsidian was used primarily for chipped stone cutting tools (such as prismatic blades and triangular points). Yet, the recovery of obsidian artifacts from ceremonial caches and burials suggests that some obsidian tools had ceremonial significance beyond their utilitarian functions; for example, the Maya seem to have favored obsidian blades for bloodletting rituals.[6]

Three volcanic areas of highland Guatemala were the primary sources of obsidian in the Maya world. While lowland Maya sites rarely obtained obsidian from only one source during any period, the San Martin Jilotepeque source area was dominant during the Preclassic period, the El Chayal source area was dominant during the Classic period, and the Ixtepeque source area was dominant during the Postclassic period.[7] In addition to these


ENGRAVED OBSIDIAN

sources, at least seven central Mexican sources of obsidian are represented in low abundance at lowland Maya sites ranging in age from the Late Preclassic to the Early Postclassic.[8] As with the highland Guatemalan sources, the identification of most of these central Mexican sources has been based on analysis of their trace elemental compositions. However, obsidian from one central Mexican source (Pachuca) has been recognized at sites throughout the Maya area due to its distinctive golden-green color. Although there is no evidence for green obsidian being valued as a prestige commodity by Maya elite at Tikal,[9] the contextual associations of green obsidian tools in the Copán Valley suggest that these goods were valued as elite commodities at Copán, perhaps due to the symbolic significance of their color and/or their association with the central Mexico.[10]

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GEOLOGIC OVERVIEWS

Paleogeographic Reconstruction of the Central America

The following is a series of geologic paleogeographic reconstructions showing the configuration of Central America from 165 Ma to present. I thought these were nice.

Mann, P., 2007, Overview of the tectonic history of northern Central America, in Mann, P., *ed.*, Geologic and tectonic development of the Caribbean plate boundary in northern Central America: Geological Society of America Special Paper 428, p. 1–19, doi: 10.1130/2007.2428(01).

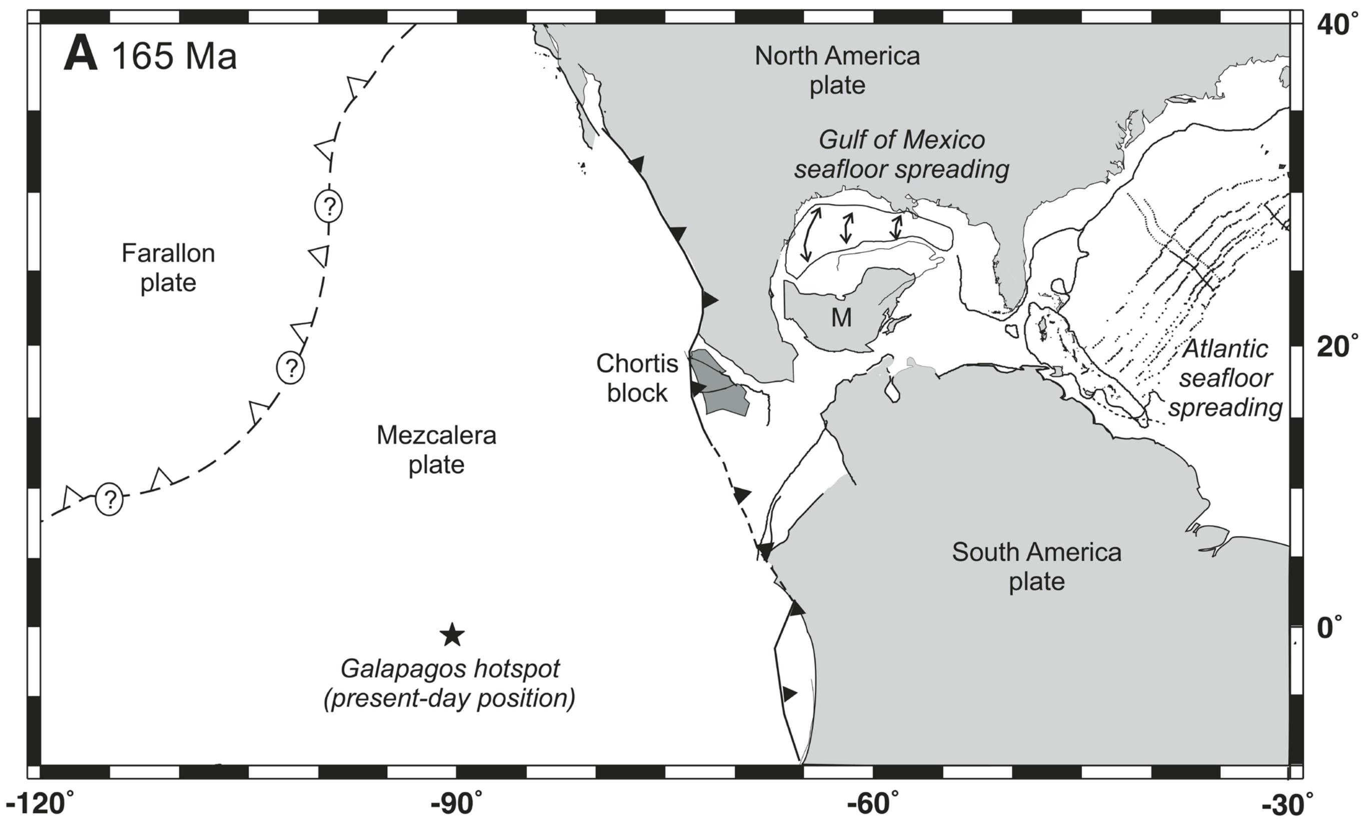
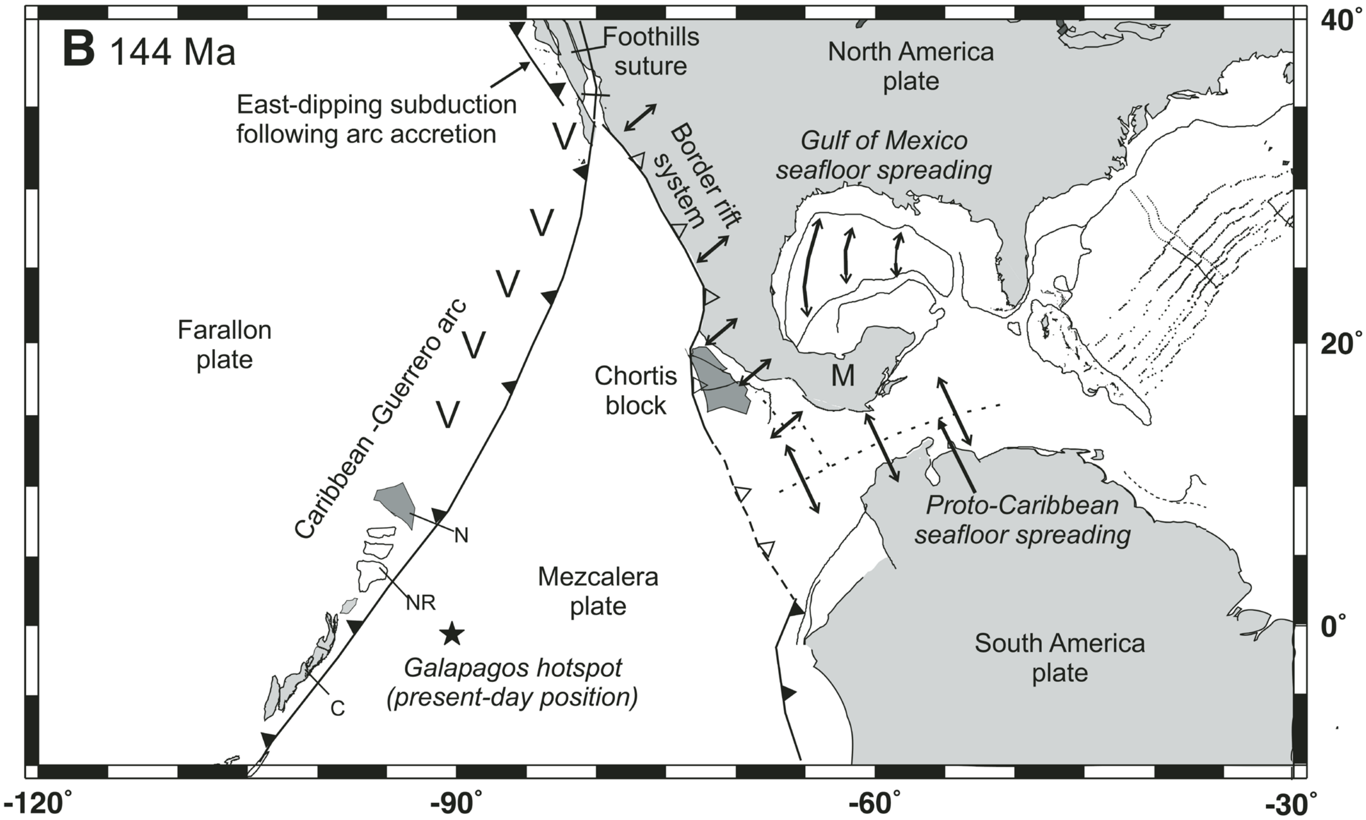
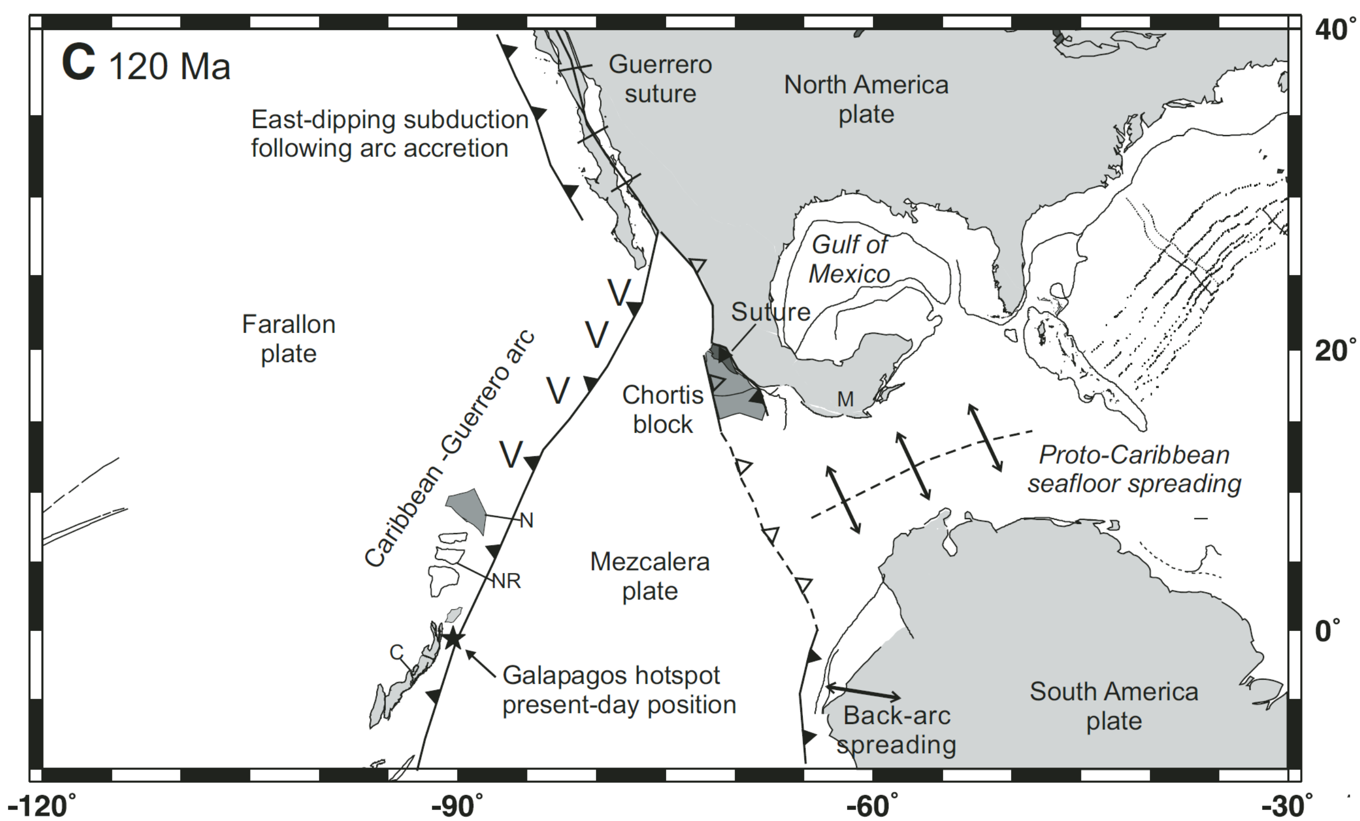


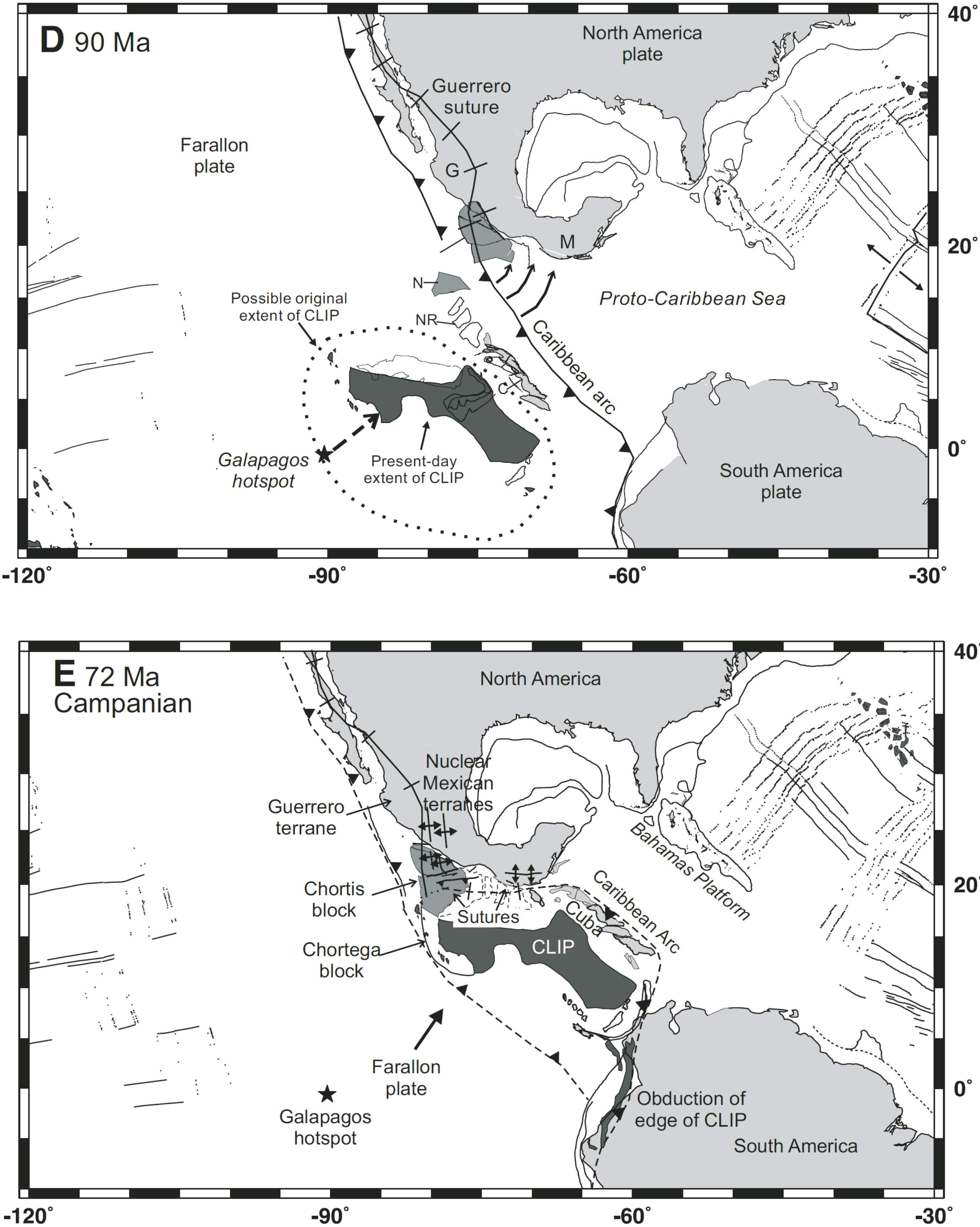
Figure 4. (*on this and following pages*) Reconstructions of the development of the Western Cordillera and Caribbean from Jurassic to present. (A) ca. 165 Ma; (B) ca. 144 Ma; (C) ca. 120 Ma; (D) ca. 90 Ma; (E) ca. 72 Ma; (F) ca. 49 Ma; (G) ca. 22 Ma; (H) present-day. See text for discussion. C—Cuba; CLIP—Caribbean large igneous province; CT—Cayman trough; G—Guerrero terrane; LA—Lesser Antilles; M—Maya block; N—Nicaragua; NR—Nicaraguan Rise; and Y—Yucatan basin. The countries of Costa Rica and Panama correspond to approximate area of the Chorotega block; the countries of Honduras, Nicaragua, and Guatemala correspond to the Chortis block.

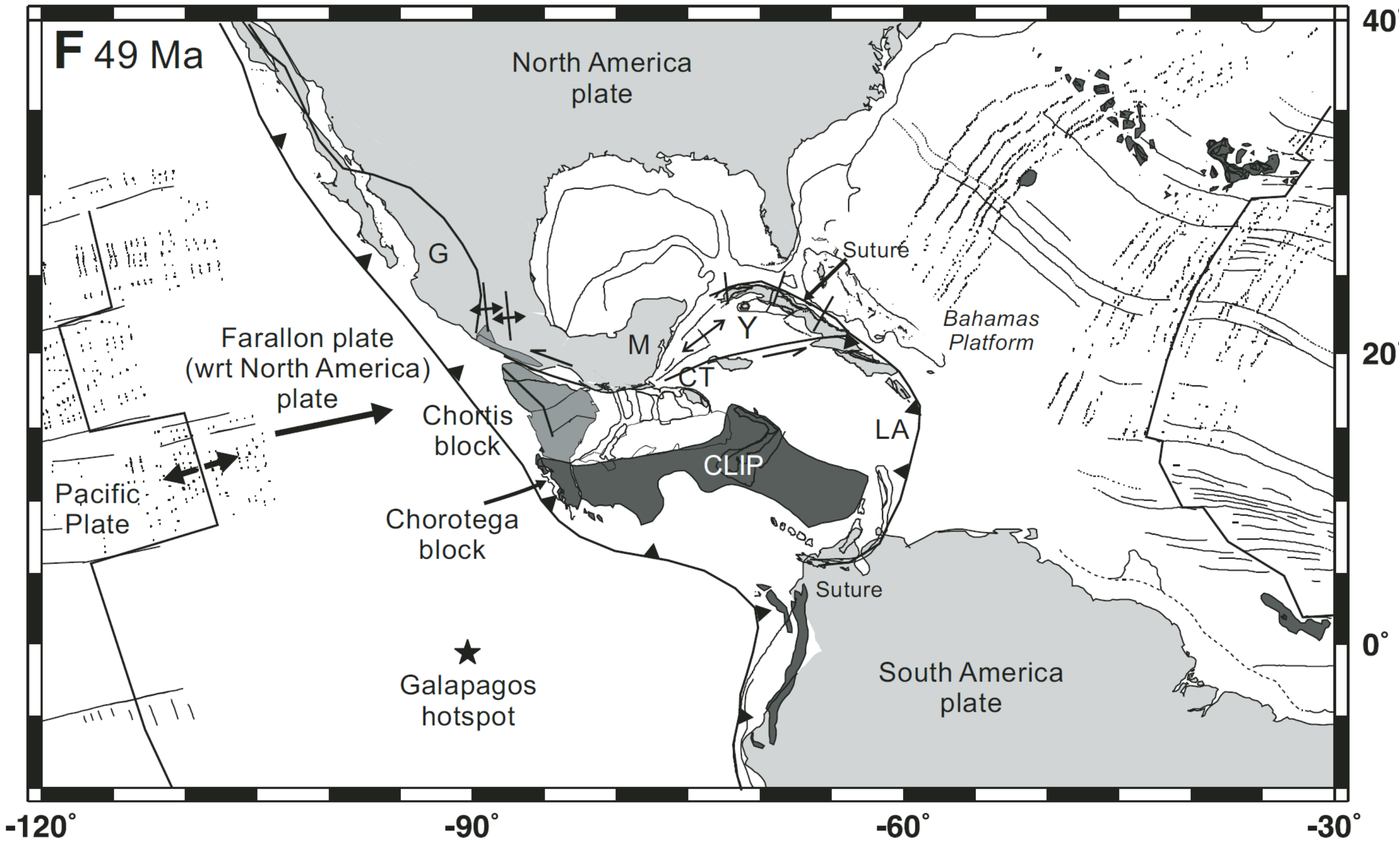


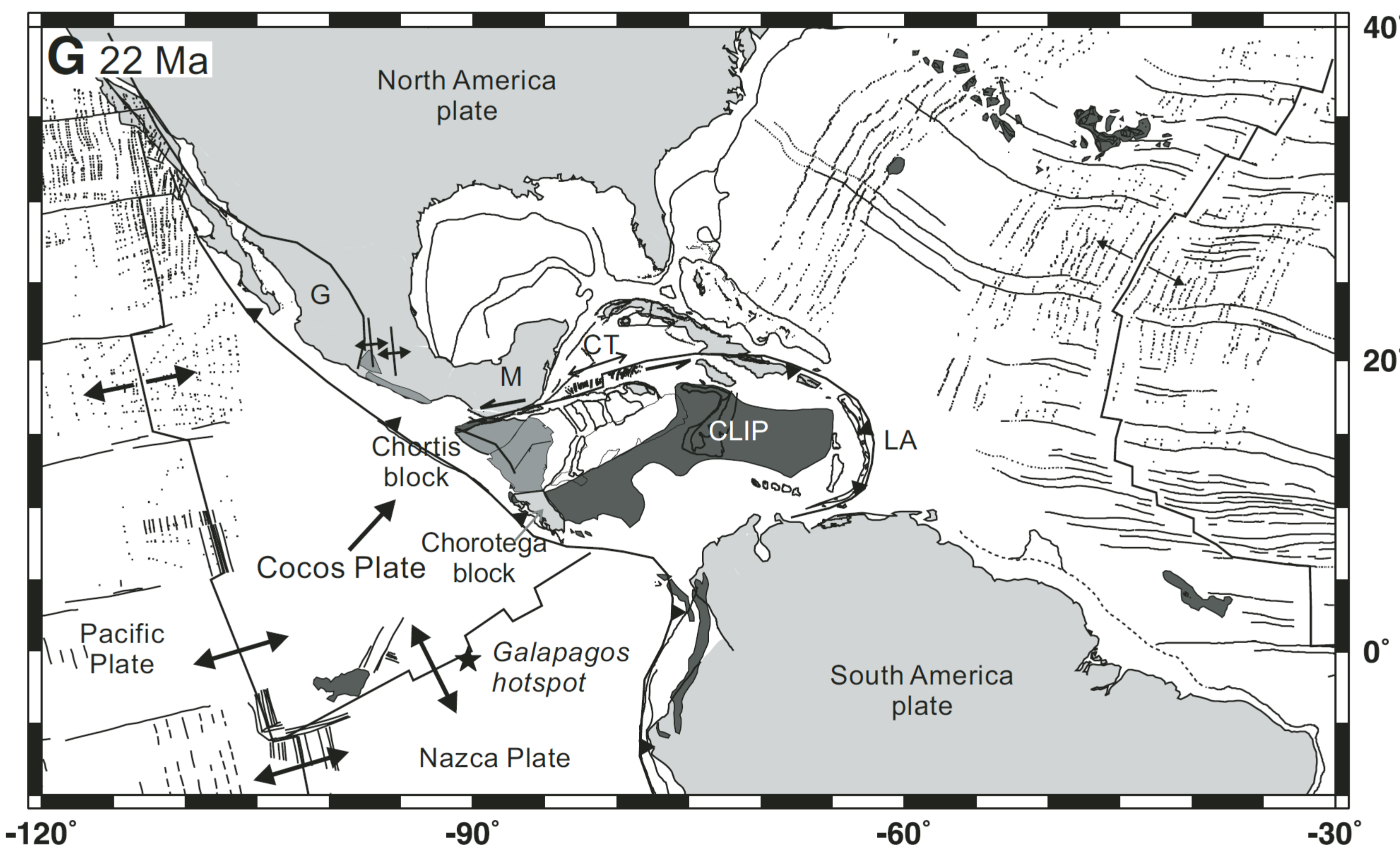
B 144 Ma
Foothills suture
North America plate
East-dipping subduction following arc accretion
Border rift system
Gulf of Mexico seafloor spreading
Farallon plate
Caribbean -Guerrero arc
Chortis block
M
N
NR
C
Proto-Caribbean seafloor spreading
Mezcalera plate
Galapagos hotspot (present-day position)
South America plate
40˚
20˚
0˚
-120˚
-90˚
-60˚
-30˚

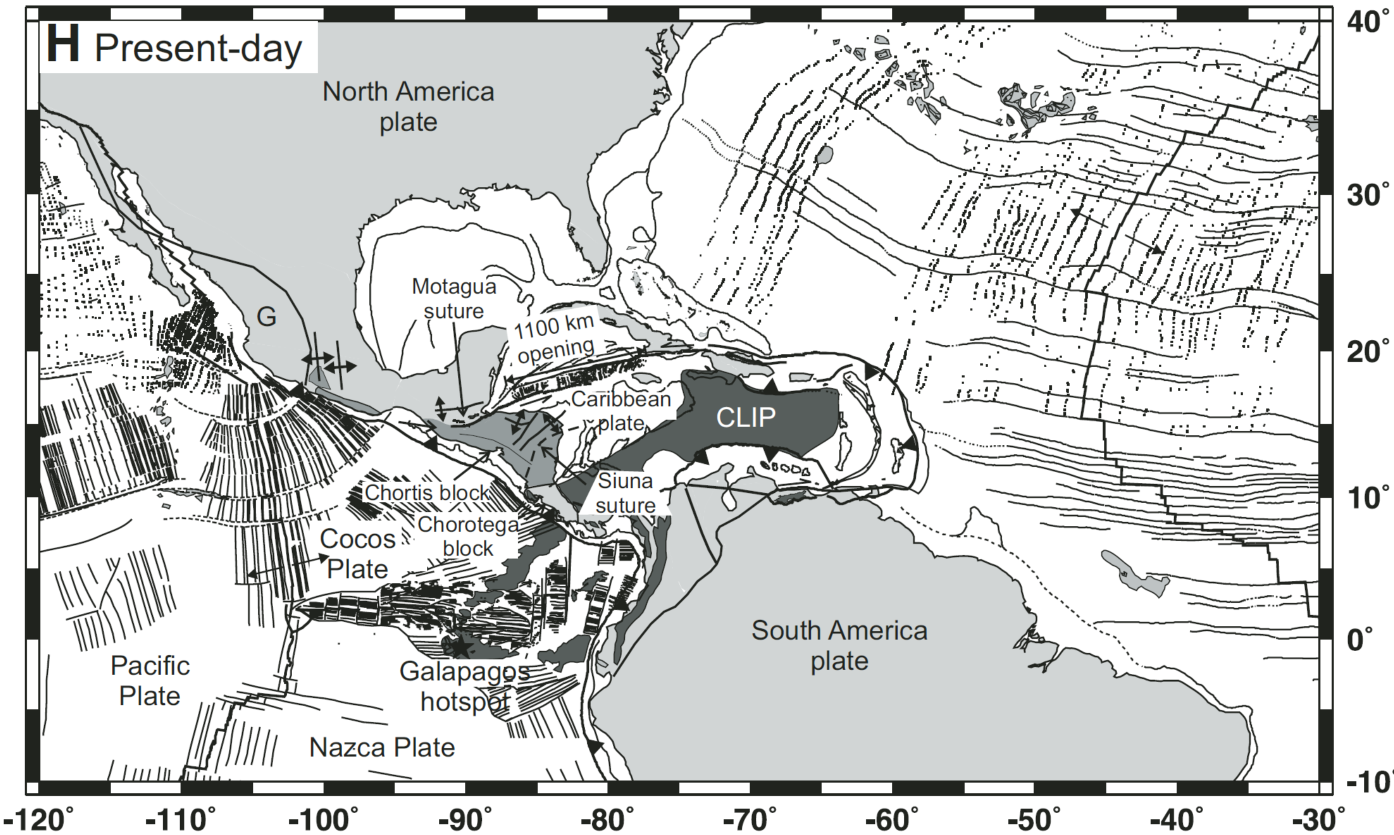


C 120 Ma
Guerrero suture
North America plate
East-dipping subduction following arc accretion
Gulf of Mexico
Suture
Farallon plate
Caribbean -Guerrero arc
Chortis block
M
Proto-Caribbean seafloor spreading
N
NR
C
Mezcalera plate
Galapagos hotspot present-day position
Back-arc spreading
South America plate
40˚
20˚
0˚
-120˚
-90˚
-60˚
-30˚


D 90 Ma
North America plate
Guerrero suture
Farallon plate
G
M
N
NR
C
Proto-Caribbean Sea
Possible original extent of CLIP
Caribbean arc
Galapagos hotspot
Present-day extent of CLIP
South America plate
40˚
20˚
0˚
-120˚
-90˚
-60˚
-30˚
E 72 Ma Campanian
North America
Nuclear Mexican terranes
Guerrero terrane
Bahamas Platform
Chortis block
Sutures
Caribbean Arc
Cuba
CLIP
Chortega block
Farallon plate
Galapagos hotspot
Obduction of edge of CLIP
South America
40˚
20˚
0˚
-120˚
-90˚
-60˚
-30˚


F 49 Ma
North America plate
G
M
Y
CT
Suture
Bahamas Platform
Farallon plate (wrt North America) plate
Chortis block
LA
CLIP
Pacific Plate
Chorotega block
Suture
Galapagos hotspot
South America plate
40˚
20˚
0˚
-120˚
-90˚
-60˚
-30˚


G 22 Ma
North America plate
G
M
CT
Chortis block
CLIP
LA
Cocos Plate
Chorotega block
Pacific Plate
Galapagos hotspot
Nazca Plate
South America plate
40˚
20˚
0˚
-120˚
-90˚
-60˚
-30˚


H Present-day
North America plate
G
Motagua suture
1100 km opening
Caribbean plate
CLIP
Chortis block
Siuna suture
Chorotega block
Cocos Plate
Pacific Plate
Galapagos hotspot
Nazca Plate
South America plate
40°
30°
20°
10°
0°
-10°
-120°
-110°
-100°
-90°
-80°
-70°
-60°
-50°
-40°
-30°

DETAILED ITINERARY

Day 1: Friday, February 28th, 2025 – Fly to Guatemala
Kind of a long day of flights…

5:30 AM: You should arrive at the Johnstown airport no later than 5:30AM.

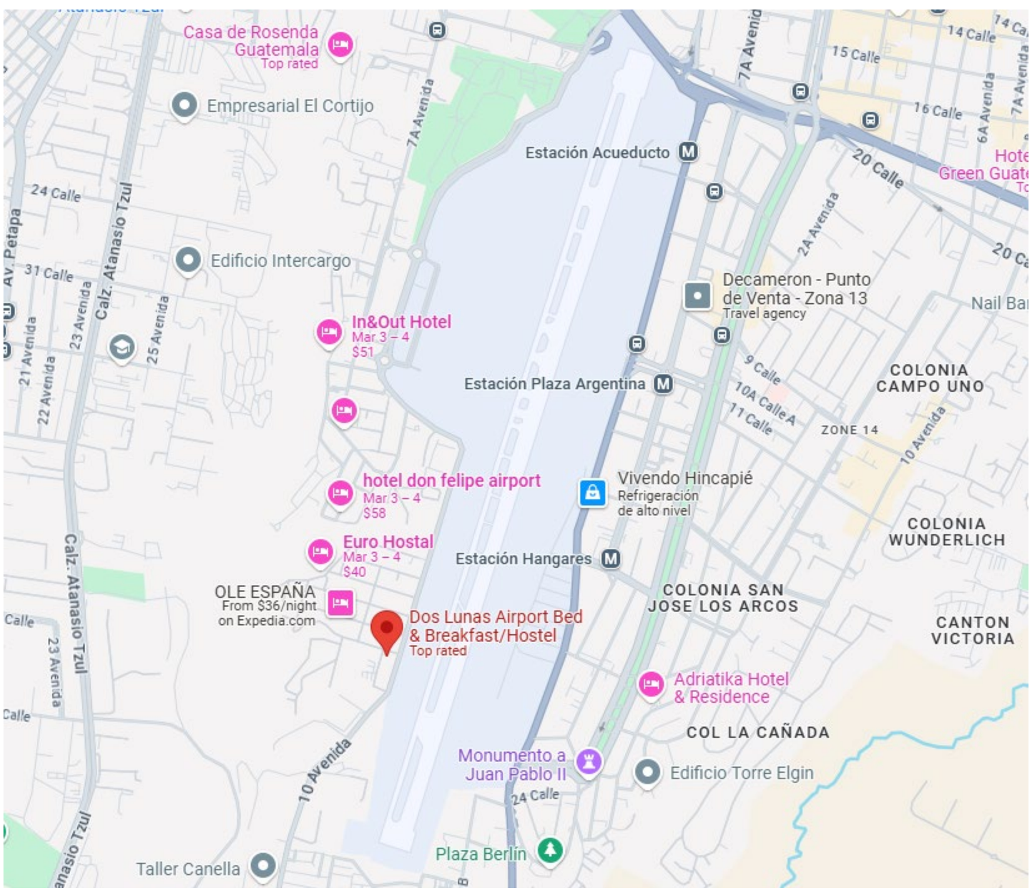
Flight #1: *Departure:* United Airlines, UA 5034, Fri 28 Feb 2025, 6:30 AM, John Murtha Johnstown-Cambria County Airport (JST)
Arrival: Fri 28 Feb 2025, 7:35 AM, Washington Dulles International (IAD)

Flight #2: *Departure:* United Airlines, UA 1524, Fri 28 Feb 2025, 8:25 AM, Washington Dulles International (IAD)
Arrival: Fri 28 Feb 2025, 11:00 AM, George Bush Intercontinental Airport, Houston (IAH)

Flight #3: *Departure:* United Airlines, UA 1902, Fri 28 Feb 2025, 8:20 PM, George Bush Intercontinental Airport, Houston (IAH)
Arrival: Fri 28 Feb 2025, 11:14 PM, La Aurora International Airport, Guatemala City (GUA)

12:00 AM: If all goes well we should arrive at the hotel at midnight…

We will stay at the Hotel Dos Lunes, close to the airport.
Dos Lunas Airport Bed & Breakfast/Hostel
21 Calle 10-92, Cdad. de Guatemala 01013, Guatemala
+502 2261 4248



Day 2: Saturday, March 1st, 2025 – East of Guatemala City

7:30 AM: Wake up, breakfast provided by the hotel.

8:30 AM: Load into the bus.

10:00 AM: Road cut through the amphibolites and phyllites of the El Tambor formation overlain with the conglomerates and "red beds" of the Subinal formation.

12:00 PM: Lunch at Sarita Restaurant at El Rancho, right in the Motagua Fault!

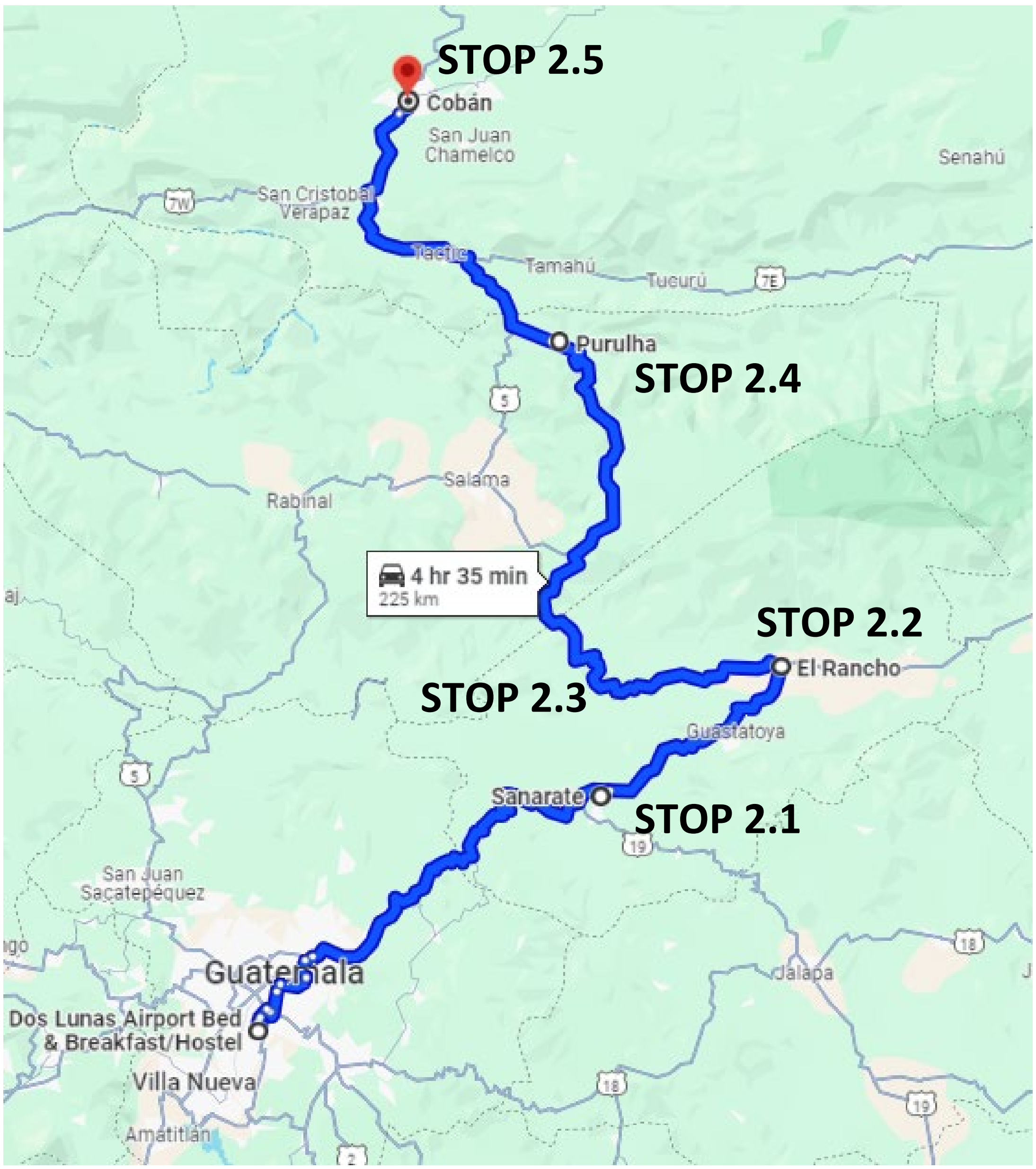
1:00 PM: Road cut northwest of El Rancho through highly serpentinized ultramafics with multiple phases of deformation.

2:00 PM: Quarry south of Purulha exposing more ultramafics, although not as highly serpentinized. Ophiolite exposed? Then briefly drive along Polochic Fault through Tactic

4:00 PM: Check into the guesthouse in Coban

Don Francisco (https://www.facebook.com/hotelposadadonfrancisco/)
Km. 215.5 Ruta a San Pedro Carcha, Cobán, Guatemala
Email: posadadonfrancisco@gmail.com Phone: +502 4118 2988

5:00 PM: Group meal.



Introduction to Day 2 Stops

This introduction is from the following guide book:

Martens, U., Solari, L., Siison, V. Harlow, G., Torres de Leon, R. Ligorria, J. P., Tsujimori, T., Ortega, F., Brueckner, H., Giunta, G., Lallemant, H.A., 2007, High Pressure Belts of Central Guatemala: The Motagua Suture and the Chuacus Complex. Field Trip Guide of the IGCP 546 – "Subduction Zones of the Caribbean," 32 pgs.

Our first day will have his visit some of the same spots from this guidebook.

Introduction

The International Geoscience Program called for proposals in 2007 defining "The Deep Earth" among five areas of special interest. Prof. Antonio García-Casco from Universidad de Granada and PhD candidate Uwe Martens from Stanford University submitted the proposal "Subudction Zones of the Caribbean", a project aiming to continue efforts from previous IGCP projects to unravel the complex geologic evolution of the Caribbean area, but focusing particularly on deep earth processes and materials, from both ancient suture zones and active convergent margins. The proposal was awarded support as IGCP project 546 for the years 2007-2011. Colleagues from a number of countries and institutions worldwide enthusiastically gave support to the project.

Our project endorses the program "Earth Sciences for Society - an International Year of Planet Earth". Earth's systems greatly impinge on our daily lives. Interpreting the history of the Earth, and using that knowledge as a basis for forecasting likely future events is a matter of global concern. Therefore, one of IGCP 546 main goals is to establishing links between ancient and current subduction zones of the Caribbean, inasmuch as this is critical for a well founded understanding of the tectonic evolution of the associated convergent plate-margins, which will hopefully enable a better understanding of the geodynamics of such a populated and geologically hazardous region.

The project will have a duration of 5 years (2007-2011). Our cooperative plan is to organize a series of workshops and field trips throughout the Caribbean that will enable a systematic comparison of high-pressure belts, help unravel the history of subduction in the region, and contribute scientific knowledge to better predict and mitigate hazards created by subduction in the Caribbean. Our major fieldwork targets will be:

* Guatemala. Motagua suture (Motagua valley and adjacent mountain ranges), sierra de las Minas, sierra de Chuacús.

* Dominican Republic. Río San Juan-Puerto Plata area and, Samaná Peninsula.

* Cuba. Central Cuba (Villa Clara and Escambray) and eastern Cuba (Sierra de Cristal, Sierra del Convento, Sierra del Purial).

* Venezuela. Villa de Cura and Cordillera de la Costa belts, and Margarita Island.

* Nicaragua. Siuna area and Nueva Segovia district.

One of the greatest examples of an ancient subduction zones in the Caribbean is the Motagua suture of Central Guatemala. This was selected as the first locality for IGCP project 546, and is the topic of the following field guide. We will conduct a series of scientific and educational activities in Guatemala between the 28th of November and the 9th of December of 2007. The activities include an international field trip to the Motagua suture zone of Guatemala open to researchers, students and interested people throughout the world, an international conference on Caribbean subduction zones, and a shortcourse on tectonics and geologic hazards for undergraduate students at Guatemala's National San Carlos University.

In arranging this educational and scientific activities, we have worked along with Dr. Alfredo Galvez from Guatemala's Ministry of Mining and Energy, who co-organized the event. He facilitated the organization through logisitic support, and arranging partial funding through the Guatemalan Government and mining companies. We also would like to thank our colleagues of the Geology Department of San Carlos University in CUNOR (particularly Luis Chiquín and Axel Gutiérrez), and colleagues of the Geological Society of Guatemala (especially Byron Mota) for helping to organize and promote these educational and scientific events.

Geologic Overview of High-Pressure Belts Along the Northwestern Border of the North America-Caribbean Plate Boundary

Sutures that were subduction zones and collisional belts occur throughout the perimeter of the Caribbean plate in Ecuador, Colombia, Venezuela, Trinidad-Tobago, Dominican Republic, Nicaragua, Cuba, Jamaica and Guatemala (Fig.1). These Caribbean sutures include crustal materials metamorphosed at mantle depths (~35 km- ~100 km). Investigating high-pressure rocks from Caribbean sutures is not only critical to reconstruct the complex geologic history of this region, but essential to our understanding of the subduction factory, which ultimately controls major sources of seismicity and volcanism.

Several well-known Caribbean sutures are located along the North America-Caribbean plate boundary, which is a left-lateral transform system that extends from western Guatemala to the Antillean arc (Fig. 1). This complex transform zone includes a small spreading ridge oriented perpendicular to the plate boundary, which has produced ~950-1000km of oceanic crust perpendicular to the ridge axis from the Bay Islands of Honduras to Jamaica at the Cayman trough (Fig.1; Rosencrantz and Sclater, 1986). When initial extension during rifting is added, a total opening of ~1100 km along the trough constrains the minimum displacement between the Caribbean and North American plates.

The western portion of the transform runs along continental Guatemala, where displacement is mainly accommodated through the Motagua Fault Zone (MFZ), which includes three left-lateral, arcuate, subparallel strike-slip fault systems: Polochic–Chixoy, Motagua (Cabañas–San Agustín), and Jocotán–Chamelecón (Fig.2). The MFZ juxtaposes the continental Maya and Chortis blocks (Dengo, 1969; Fig.3 and Fig. 4), possibly along the Cabañas fault (e.g., Donelly et al., 1990), which is the active fault that runs on the southern side of the Motagua valley that produced the tragic 1976 Guatemala earthquake. Recently Ortega-Obregón et al. (in press) suggested that, instead, the limit between the above blocks is the Baja Verapaz Shear Zone, located north of Guatemala City. The Maya and Chortís blocks have contrasting lithologic character, suggesting simple juxtaposition of differing terranes, and/or considerable displacement along the Motagua Fault, as suggested by the opening of the Cayman trough (Francis, 2005).

Geologic units in the Maya Block include the high-grade Chuacús Complex (McBirney, 1963; van den Boom, 1972; Ortega-Gutiérrez et al., 2004), Carboniferous-Permian sediments of the Santa Rosa Group, and deformed granitic rocks such as the Rabinal Granite. This granite has Ordovician white mica K-Ar ages, and intrudes low-grade metasediments of the lower Paleozoic or Precambrian San Gabriel sequence (Ortega-Obregón et al., in press). The Chuacús Complex includes relics of eclogitic rocks (Ortega-Gutiérrez et al., 2004), and is bounded on the north by the Baja Verapaz shear zone, recently recognized as a reverse fault with a small left-lateral component, and on the south by the San Agustín fault. These features may suggest that the Chuacús complex is a terrane, and that the southern boundary of the Maya block is the Baja Verapaz shear zone (Ortega-Gutiérrez et al., 2007). This interpretation is controversial. The Chortís block south of the fault contains the greenschist-facies San Diego phyllite, the amphibolite-facies Las Ovejas complex with felsic and mafic intrusives, and large relatively undeformed granitoids of uncertain age. There are several granitic intrusions in the Chortís block ranging from Grenvillian though Triassic, Cretaceous, and Early Tertiary age (Donnelly et al., 1990; Manton, 1996; Martens et al., 2007). It also contains the El Tambor "ophiolite complex," recently dated on the basis of radiolaria to be of Late Jurassic age (Chiari et al., 2006). Both blocks are mantled with modern arc volcanics to the south and west, further complicating interpretation of their geologic history.

Tectonic slices of serpentinite mélange containing high-pressure rocks occur both north (Maya block of Dengo, 1969) and south (Chortís block) of the Cabañas fault. North of the Motagua mélange the high-grade Chuacús complex contains mafic boudins with relics of eclogite-facies assemblages. This juxtaposition of three high-pressure belts of oceanic and continental origin is one of the most intriguing features of the Caribbean region (Harlow et al., 2004; Ortega–Gutiérrez et al., 2004). Metamorphic conditions and geochronology of the eclogitic belts indicates a disparate geologic evolution. South of the fault high-pressure rocks include lawsonite eclogite, blueschist, and jadeitite in serpentinite matrix, recording P-T conditions that require among the coldest and

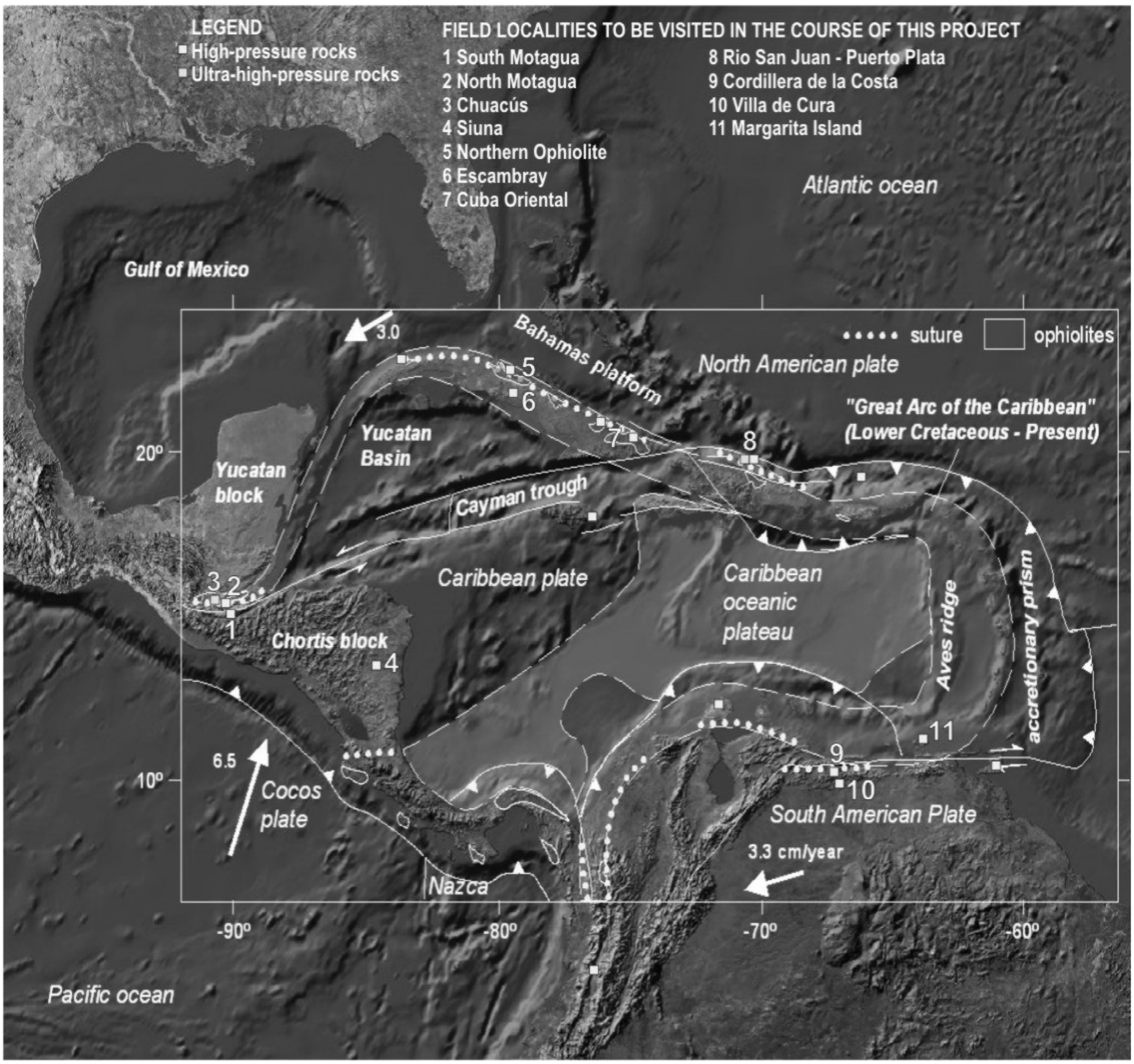


Figure 1. Tectonic map of the Caribbean, showing suture zones, ophiolites , current convergent and transform margins, and localities of high-pressure rocks. Numbers refer to localities to be visited in the course of IGCP 546 "Subduction Zones of the Caribbean".

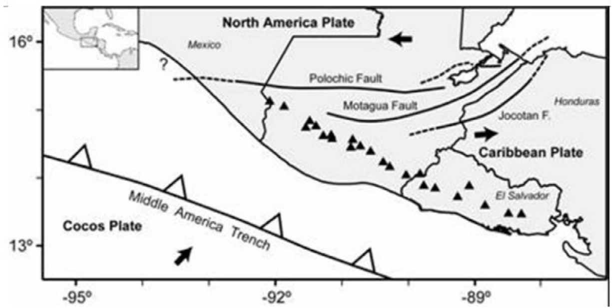


Figure 2. Main faults that accomodate relative displacement between the Caribbean and North American plates in Central Guatemala.

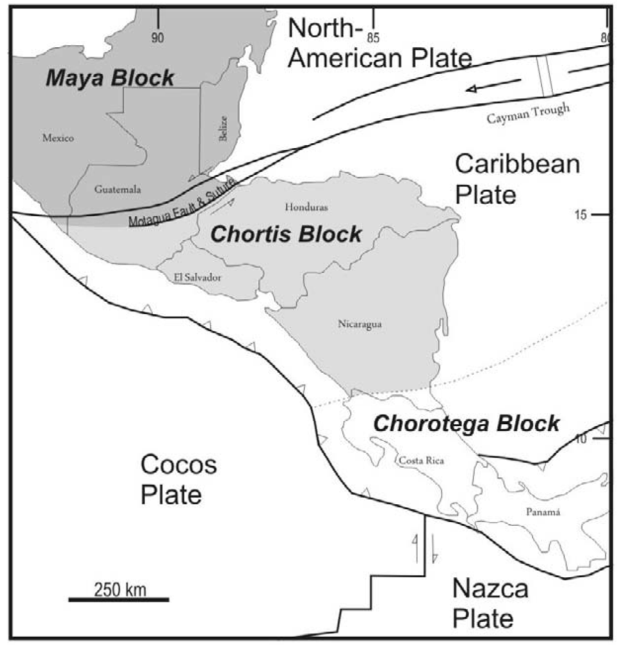


Figure 3. Tectonic blocks in Central America. The limit between the Maya and Chortís blocks is disputed, but most authors regard the Motagua fault as the boundary.

wettest deep subduction trajectories on Earth, to ~2.5 GPa and only 470 ºC, near forbidden zone conditions (Tsujimori et al. 2006a,b). In contrast, north of the Motagua fault, serpentinite mélange hosts garnet amphibolite, omphacite-taramite metabasite, jadeitite, albitite, and, more recently reported, altered clinozoisite-amphibole-eclogite in the western reaches of the serpentinite mélange (Tsujimori et al., 2004; Brueckner et al., 2005). These rocks span a wide range of conditions, from greenschist-blueschist at lower P (200-400 °C at ≤1 GPa) to moderate LT eclogite facies of 500-600 °C at ~ 2 GPa. Gneisses of the continental Chuacús complex contain mafic layers and boudins with relics of eclogite-facies mineral parageneses. Peak metamorphic conditions for Chuacús eclogites have been estimated at ~700°C and ~24 kbar, near UHP conditions (Martens et al., 2005).

Compounding the differences, Harlow et al. (2004) reported disparate $^{40}Ar/^{39}Ar$ ages on the mica and amphibole from serpentinite-hosted HP-LT rocks: north of the Cabañas fault, rocks yield ages between 65 and 77 Ma, whereas rocks south of the fault yield ages of 116-125 Ma. Ages from the northern jadeitites and albitites record their formation time, and ages in the southern eclogites record the time of late fluid infiltration. Therefore the two age clusters probably reflect the time of blueschist metamorphism in each area. This result is in sharp contrast with Nd/Sm geochronologic analyses that yield an average age of eclogitization of ~130 Ma for all serpentinite-hosted eclogites (Brueckner et al., 2005). The age of Chuacús continental eclogites has not been established precisely, but geologic relations imply a post-Triassic age (Martens et al., 2007). The oldest K/Ar and 40Ar/39Ar ages of the Chuacús are ~70 Ma, which reflect cooling after late-stage epidote-amphibolite metamorphism (e.g., Sutter 1979; Ortega Gutiérrez et al., 2004).

How ~1100 km of relative displacement between the North America and Caribbean plates has been partitioned in the MFZ, how the Chortís and Maya blocks migrated over time, how high-pressure belts in central Guatemala became juxtaposed, and whether they formed in one or several subduction zones remain key unresolved problems of Caribbean geology (e.g., Brueckner et al., 2005). The occurrence of jadeitite, lawsonite eclogite, clinozoisite eclogite, continental eclogite, and a tectonic-timing conundrum represent only some of the aspects of Guatemala's fascinating geology.

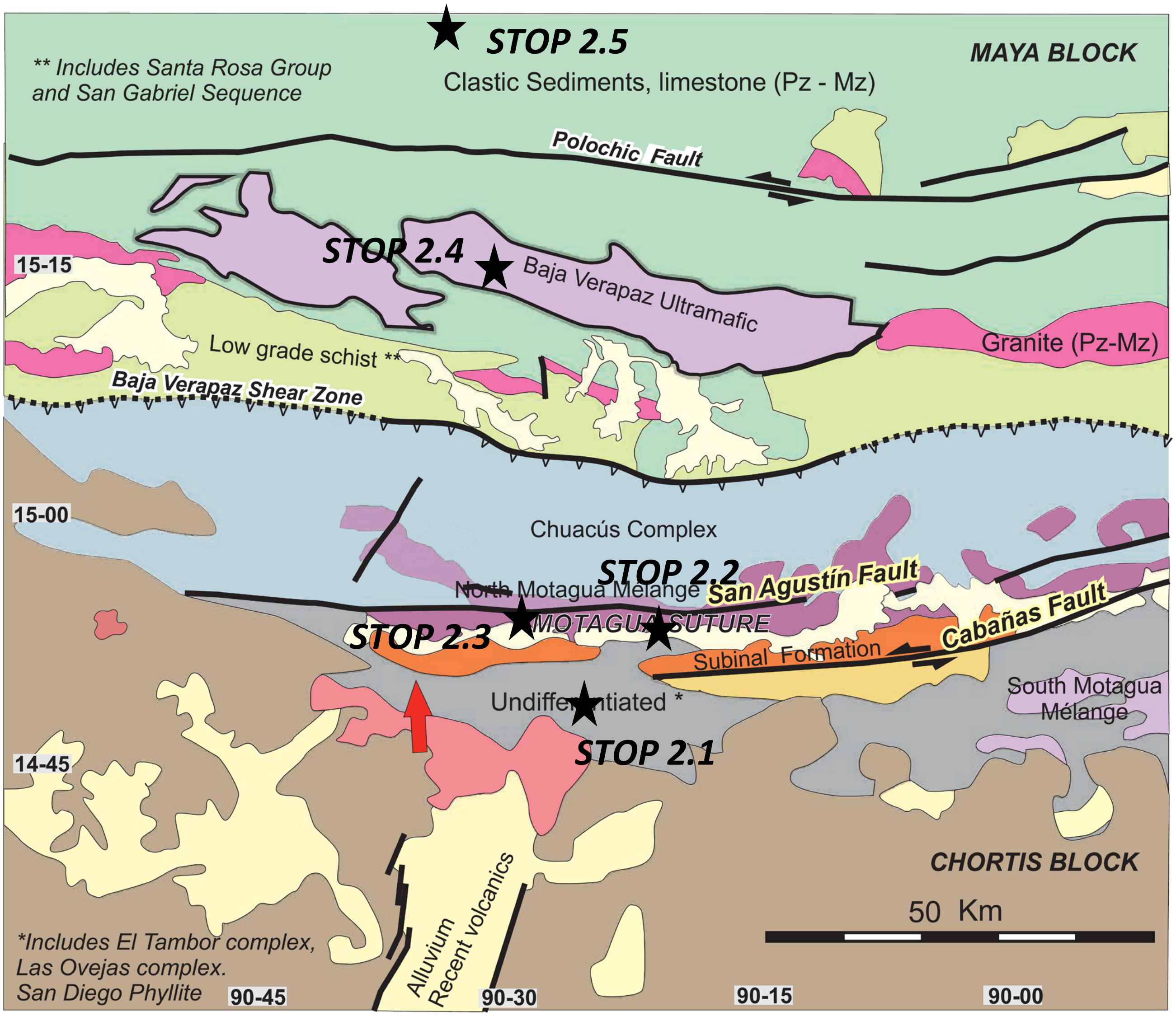


Figure 4. Geologic Map of Central Guatemala. Notice the South Motagua Mélange, the North Motagua Mélange, and the Chuacús Complex, the three juxtaposed units that contain high-pressure rocks

STOP 2.1 – El Tambor and Subinal formations

This stop write-up is from the same guidebook:

Martens, U., Solari, L., Siison, V. Harlow, G., Torres de Leon, R. Ligorria, J. P., Tsujimori, T., Ortega, F., Brueckner, H., Giunta, G., Lallemant, H.A., 2007, High Pressure Belts of Central Guatemala: The Motagua Suture and the Chuacus Complex. Field Trip Guide of the IGCP 546 – "Subduction Zones of the Caribbean," 32 pgs.

This is Stop #1 in the Martens et al., 2007 guidebook

Subinal Formation

The Subinal Formation (Fig. 6) is a succession of continental red beds, including conglomerate, sandstone and minor siltstone and shale. It outcrops in the Motagua valley region, north of the Cabañas fault and south of the San Agustín fault, extending from south of Granados in Baja Verapaz, to Los Amates in Izabal. The best outcrops of the Subinal Formation occur along highway CA9, between km 76 and 80, between Guastatoya and El Rancho. There lens-shaped beds of sandstone and conlgomerat represent former channel of an alluvial system. Red beds in southeastern Guatemala, in the Chiquimula, Jocotán, Esquipulas areas, were ascribed to the Subinal Formation (IGN, 1970). However, Gutiérrez (2008) regarded red beds in southeastern Guatemala as part of the Valle de Angeles group. The thickness of the Subinal Formation has been estimated at ~750 m south of Granados, ~1000m along highway CA9 in El Progreso (Gutiérrez, 2008), and 754m in Subinal and Monte Verde in El Progreso (Hirschmann, 1963).

Conglomerates contain abundant serpentinite cobbles derived from the Motagua suture (Hirschmann, 1963). South of Granados conglomerates include cobbles of serpentinite, quartz-white-mica schist, micaceous gneiss, amphibolites, and eclogite. Sandstones are immature and contain abundant white mica and tremolite. Other detrital minerals include biotite, chlorite, tremolite, chromite, rutile, and zircon. Along CA9 (including location 2 of this fieldtrip) conglomerates contain cobbles of Cretaceous limestones, sandstones, shale, volcanic rocks, granite, quartz, chert, marble, chlorite schist. Minor quartzofeldspathic gneiss and serpentinite has been found, and fossilized wood is common. Sandstones are rich in detrital white mica, which may have been derived from the Chuacús complex.

This detrital material suggest provenance from

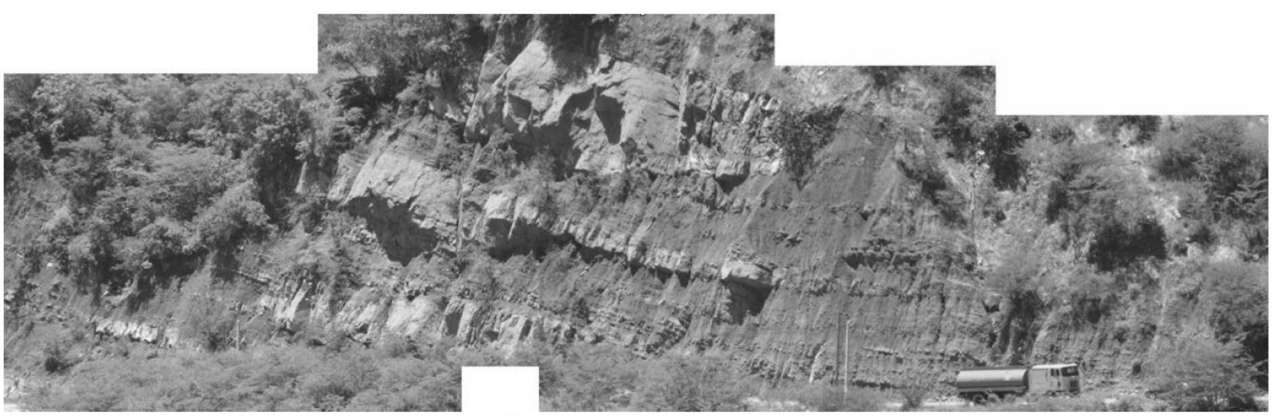


Figure 6. Outcrop of Subinal Formation along highway CA9.

rocks exposed to the north in the Sierra de Chuacús, including the Chuacús complex, and the North Motagua Mélange. Limestone cobbles within Subinal conglomerates in the El Progreso area contains fossils that are analogous to those found in Maastrichtian beds of Palo Amontonado. The presence of serpentinite, amphibolite, and eclogite constrains the time of exhumation to the surface of high-pressure rocks in Central Guatemala.

The age of the Subinal Formation is not known precisely. Volcaniclastic rocks of the Guastatoya Formation and the Grupo Padre Miguel cover Subinal red beds. In the San Agustín Acasaguastlán quadrangle, west of Estancia de la Virgen, an isolated unit of calcareous conglomerate and red limestone were assigned by Bosc (1971) to the Subinal Formation. These rocks contain upper Campanian to Maastrichtian foraminifera. Gutiérrez (2008) observed that the Late Cretaceous fossils are analogous to those found in Palo Amontonado beds, and concluded that calcareous rocks near Estancia de la Virgen are part of this latter formation, and are not useful to constrain the age of the Subinal Formation. Preliminary palinologic work shows that Subinal beds in the eastern portion of the Motagua valley were deposited in the Oligocene or Miocene (pers. comm. Enrique Martinez, UNAM).

The Subinal Formation has been regarded as a molasse (Hirschmann), possibly formed after the collision that generated the Motagua suture (Giunta et al., 2002). On the other hand, the geographic distribution of the Subinal Formation, its association with the Motagua fault, and the preliminary Oligocene-Miocene age of fossil polen suggest that the Subinal Formation was formed in pull-apart basins formed by strike-slip tectonics.

Stop 1 (30 minutes) Subinal Formation Highway CA-9. Presenters: Uwe Martens, Axel Gutiérrez. (Stops are depicted in Fig. 5)

The section is composed of up-fining bedsets ranging from conglomerate to fine sandstone. The section is tilted ~30° to the southeast, and it has been cut by normal faults.
Sedimentary structures are not common, but some sandstones show lamination. Volcanic and sedimentary clasts are the most common in the conglomerates. Serpentinite, granite and pumice are minor. Fossilized wood and trace fossils have been described in the area.

The Motagua Fault Zone

In terms of active structural geology, two main W-E striking fault strands have been identified in the Motagua valley: the San Agustín fault, which runs along the northern border of the valley, and the Cabañas fault, which runs along the southern part of the valley. The Cabañas fault separates geologic units of contrasting character (e.g., IGN, 1970; IGN, 1979), and its current activity was demonstrated by the devastating Guatemala 1976 earthquake (Espinosa, 1976), which claimed more than 23,000 lives, with damage reaching almost USD 2 billion (i.e. 18% GNP of Guatemala). The recorded surface rupture was 230 km and left-lateral, horizontal displacement across the fault averaged ~1.1m (Bucknam et al., 1978).

The Cabañas fault is actively disrupting the Motagua suture and altering the original positions of the Maya and Chortis blocks (Plafker, 1976; Schwartz, 1979; Rosencrantz et al., 1986; Keppie and Morán-Zenteno, 2005; Lyon-Caen et al., 2006). Superposition of high-pressure belts in Guatemala may have been the result of terrane dispersal by the Motagua fault system (e.g., Harlow et al., 2004). A key to understanding eclogitic belt superposition is to evaluate the accumulated strike-slip displacement between the North America and Caribbean tectonic plates, and how this displacement was partitioned.

The understanding of the dynamics of the transform system between the Chortís and Maya blocks is a subject of scientific discussion. Detachment, translation and rotation of these lithospheric blocks may have been active since the late Jurasic (Mann et al., 2006). The total displacement due to strike-slip tectonics between the North American and Caribbean plates is constrained by ocean crust spreading at the Cayman trough. The trough has had episodic periods of activity with a peak during the Oligocene (~30 MA), and a posterior decrease in spreading rate around Miocene time (~26-20 MA). To calculate the total opening at the Cayman trough, initial extension during rifting needs to be accounted for. Rosencrantz & Scatler (1986) assigned an ad hoc stretching factor of two, and calculated a total opening along the trough of ~1100km. Surveys of ocean floor topography have allowed identifying strike-slip faults both north and south of the spreading center (Rosencrantz & Mann, 1991). This implies the existence of a small microplate between the Caribbean and North America plates, and more importantly, that adding ocean opening and extension in the Cayman trough only gives a minimum value for the relative displacement between the Caribbean and North American plates along the northern strike-slip boundary.

Adding generated oceanic crust and initial extension during rifting implies that the relative displacement between the Caribbean and North American plates is at least 1100km. How this relative displacement has been accomodated in Central Guatemala, and if this displacement accounts for the juxtaposition of the Chortis and Maya blocks is a matter of debate (e.g. Keppie and Moran-Centeno, 2005).

STOP 2.2 – Lunch in El Rancho and the Motagua Fault

Here we will be in the Motagua Fault – a large-scale strike-slip system along the transform boundary of the Caribbean plate and the North American plate.

This seemed like a nice overview paper on the Polochic-Motagua Fault System

Franco, A., Molina, E., Lyon-Caen, H., Vergne, J., Monfret, T., Nercessian, A., Cortez, S., Flores, O., Monterosso, D., and Requenna, J., 2009, Seismicity and Crustal Structure of the Polochic-Motagua Fault System Area (Guatemala). Seismological Research Letters, vol. 80, no. 6, pp. 977-984.

INTRODUCTION

We report results from a six-month seismological experiment in the area of the eastern Polochic-Motagua fault system (Guatemala) designed to both characterize the present seismicity and bring some constraints on the lithospheric structure. The seismic activity occurs in the upper 15 km of the crust, on the Polochic and the Motagua faults as well as in a NS-trending graben south of the Motagua fault and within the active folds north of the Polochic fault. From receiver function analysis the Moho discontinuity is found at about 35 km depth north of the Polochic fault and south of the Motagua fault, while the region in between is characterized by a 4-to-6-km thinner crust or by a 6–7% decrease of the Vp/Vs ratio.

The more than 2,000-km-long, mostly submarine, left-lateral strike-slip boundary between the North American and the Caribbean plates continues on land with the Polochic-Motagua fault system mainly located in Guatemala (Figure 1). This fault system accommodates 20 mm/yr of left lateral strike-slip movement (*e.g.*, Lyon-Caen *et al.* 2006) and includes three major convex subparallel EW-trending faults which are, from north to south, the Polochic, the Motagua, and the Jocotan. Both the Polochic and Motagua faults show evidence of recent activity in their historical seismicity (Table 1; and see also Carr and Stoiber 1977; White and Harlow 1993; Ambraseys and Adams 2001) and their morphology (*e.g.*, Burkart and Self 1985, Schwartz *et al.* 1979). South of the Motagua fault, a series of NS-trending grabens extends from the Honduras depression on the Caribbean Coast of Honduras to the Guatemala graben in the center of Guatemala. The last large earthquake (Mw ~7.5) in Guatemala occurred in February 1976, ruptured 230 km of the Motagua fault with an average slip observed at the surface of 1.4 m (Plafker 1976), and locally activated the northwestern part of the Guatemala-city graben (Figure 1). The trace of the Jocotan fault in Guatemala is cut by Pliocene or Pleistocene grabens, and evidences of activity on the Jocotan fault are conxsidered by Muehlberger and Ritchie (1975) anterior to this period.

According to many authors the Polochic-Motagua fault system corresponds to a main lithologic and geologic boundary between the Maya block north of the Polochic fault composed of carboniferan or Permian carbonates and a large Cenozoic volcanic plateau lying above the continental Chortis block south of the Motagua fault (*e.g.*, Dengo 1969; Donnelly *et al.* 1990). Although still subject to discussions, the northern limit of the Maya-Chortis block is considered to be the Motagua

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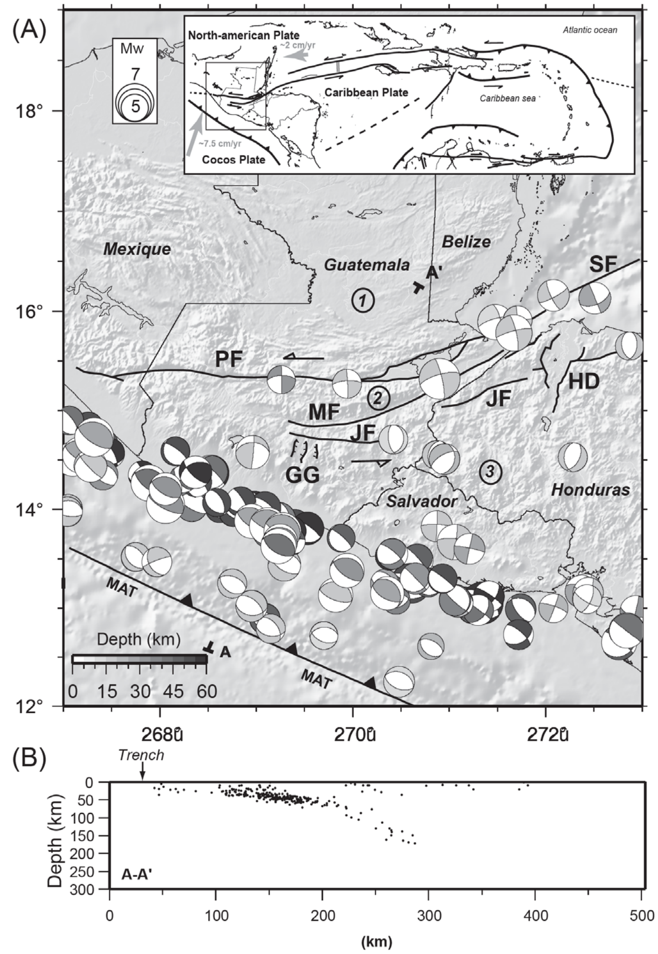
3. Institut de Physique du Globe de Strasbourg, CNRS, Strasbourg, France
4. Geosciences Azur, University of Nice, Sophia Antipolis, CNRS, Institut de Recherche pour le Developpement, Nice, France
5. Institut de Physique du Globe de Paris, CNRS, France
6. Universidad de Coban, Coban, Guatemala
7. Centro de Estudios Superiores de Energí a y Minas-Universidad de San Carlos de Guatemala, Guatemala Ciudad, Guatemala
8. Coordinadora Nacional para la Reducción de Desastres, Guatemala Ciudad, Guatemala

TABLE 1
Historical major earthquakes associated with the Polochic-Motagua fault system and reported by (a) Kovach 2004, (b) White 1985, (c) White and Harlow 1993, (d) Ambraseys and Adams 2001, (e) Carr and Stoiber 1977, (f) Plafker 1976, and (g) Global CMT catalog (http://www.globalnet.org).

Date	Estimated Magnitude	Associated with
Between 950–1000	??	Jocotan fault [a]
22 July 1816	Ms 7.6	Polochic fault [b]
3 December 1934	Ms 6.3	Jocotan fault or [c,d] graben zone
1945	Ms 6.0	Motagua fault [d,e]
4 February 1976	Ms 7.5	Motagua fault and Guatemala-city graben (*e.g.*, f)
11 October 1985	Ms 4.6	Polochic fault [d]
19 December 1995	Ms 5.3	Polochic fault [g]
25 June 2001	Ms 5.2	Polochic fault [g]

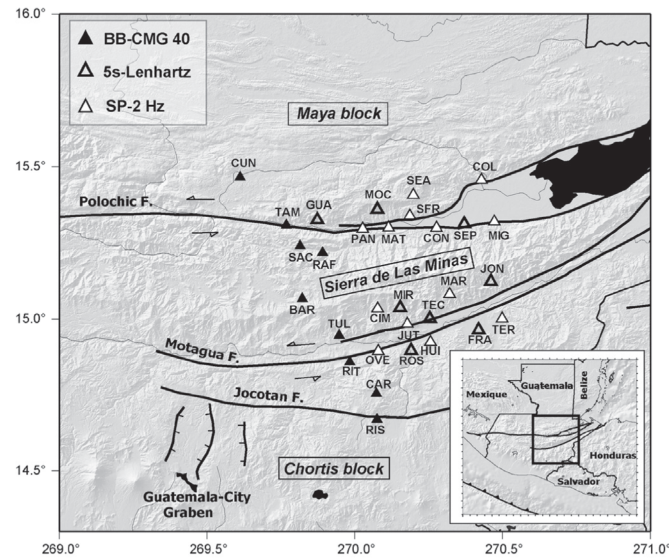
doi: 10.1785/gssrl.80.6.977



▲ **Figure 1.** A) Geodynamic setting and focal mechanisms from the CMT catalog since 1976. Only thrust events with *Mw* >6 have been plotted. In the inset, solid gray arrows indicate relative velocities with respect to the fixed Caribbean plate reference frame (DeMets *et al.* 2007; Lyon-Caen *et al.* 2006) and NNR-Nuvel 1 (DeMets *et al.* 1990). (PF) Polochic fault; (MF) Motagua fault; (JF) Jocotan fault; (SF) Swan fault; (GG) Guatemala-City graben; (HD) Honduras depression; 1—Maya Block; 2—Sierra de las Minas block; 3—Chortis block (see text and Figure 2 for more explanations). B) Cross-section perpendicular to the trench showing the seismicity from the centennial-relocated catalog of Engdahl and Villaseñor (2002).

fault (*e.g.*, Martens *et al.* 2007), which is the oldest and main plate boundary. The Polochic fault is younger and made its way within constraints about the North American platform. However, to the east, between the Polochic and Motagua fault zones, the Sierra de Las Minas block (Figure 1 and Figure 2) is composed of ancient metamorphic rocks, and its origin remains basically unknown (*e.g.* Fourcade *et al.* 1994).

Despite the high seismic risk of this highly populated area, the present seismicity of the Polochic-Motagua fault system area still remains poorly known. Indeed, the permanent national Guatemalan network run by INSIVUMEH is mainly located in the volcanic arc in order to monitor the activity associated with active volcanoes. Most of the recorded shallow seismicity relates to activity of the volcanoes and of the subduction zone. This network is thus not designed to study the Polochic and Motagua faults.



▲ **Figure 2.** Seismological network deployed in eastern Guatemala from January to July 2005. Each type of station is represented by a different symbol. (BB) broadband seismometers; (SP) short-period seismometers. All stations were used to locate the earthquake. Only stations with broadband or 5-s period seismometers were used in the receiver function study.

Recent GPS measurements show that most of the deformation through the Polochic-Motagua fault system is explained by strain accumulation on the Motagua fault that appears to be locked down to about 20 km (Lyon-Caen *et al.* 2006). Despite its recent historic seismic activity (*e.g.*, the 1816 *Mw* ~ 7.5 earthquake, Table 1) and a morphology clearly demonstrating recent activity (*e.g.*, Schwartz *et al.* 1979; Burkart *et al.* 1987), the Polochic fault appears to accommodate only a very small part of the total deformation. In addition, GPS observations indicate a cumulative extension rate of ~ 8mm/yr across the north-south grabens south of the Motagua fault. Interpretation of the GPS observations described above (Lyon-Caen *et al.* 2006; Franco 2008) raises some important questions, and its consistency with the background seismic activity needs to be evaluated: What could explain that apparently no strain is accumulated at present on the Polochic fault despite evidence for large earthquakes on this fault? Can the background seismic activity or the crustal structure give some hints on the different strain accumulation regime of the Polochic and Motagua? Do these two faults merge at depth? Are there important structural differences between the various geological units that need to be accounted for in the GPS interpretation (*e.g.*, rheological contrasts)?

Based on a temporary seismological network deployed in 2005 along this fault system, we present here some new constraints about the microseismic activity of the area as well as the structure at depth of the main structural units using the receiver function technique, and we discuss some implications of these results.

TABLE 2 *P*-wave velocity model used for the Hypo71 events location (from Molina and Tenorio 2000)	
Layer Depth	**P-wave velocity**
0 to 9 km	5.2 km.s-1
9 to 17 km	6.55 km.s-1
17 to 37 km*	6.75 km.s-1
Below 37 km	7.95 km.s-1
* Moho	

SEISMICITY OF THE EASTERN POLOCHIC-MOTAGUA FAULT SYSTEM

Data Acquisition

The temporary network deployed from January to June 2005 across the Polochic and the Motagua faults was composed of 30 stations from the French national pool of instruments (Lithoscope), recording continuously at 125 Hz and installed with an average spacing of ~10km and covering a ~100 × 100 km^2 area (Figure 2). Nine out of the 30 stations were equipped with three-component broadband seismometers (CMG40-60s), eight were equipped with three-component 5-s Lennartz seismometers, and 13 were equipped with three-component short-period (L22–2Hz period) seismometers.

Absolute Locations

A total of 502 local events were recorded during the six-month experiment, but only 276 earthquakes observed by at least four stations have been located using the Hypo71 software (Lee and Valdes 1985). We used a simple layered homogeneous *P*-wave velocity model (Table 2) proposed by Molina and Tenorio (2000) and constructed from a compilation of different regional velocity models (Fisher 1961; Shor and Fisher 1961; Ligorria and Molina 1997; Tenorio 1997; Kim *et al*. 1982). We estimated the *Vp/Vs* ratio using a generalization of the Wadati diagram (Chatelain 1978). The obtained value ranges between 1.71 and 1.77, and we assumed a classical mean value of 1.73.

In addition to the formal errors given by Hypo71 software, we estimated more realistic hypocentral errors by performing a series of stability tests. We looked at how hypocentral locations varied as a function of the initial trial depth and the assumed velocity model. Because some of the analyzed earthquakes lie outside the network or are constrained with only a few stations, we investigated the stability of the locations as well as their dependence on the choice of the initial parameters. We first compared the locations obtained by Hypo71 using different initial depths (4, 10, 16, and 25 km). Then, to test the influence of the velocity model on the event locations, we built four other models by increasing or decreasing by 5% and 10% the *P*-wave velocity in each layer and then compared the locations obtained by Hypo71 using these new models. We assume that the most stable locations reveal the better constrained events. We separate the analyzed earthquakes into four classes according to their location stability (Table 3). Class *a* contains 44 earthquakes and corresponds to a Hypo71 global root mean square (RMS) residual between the observed and calculated *P*- and *S*-arrival time smaller than 0.25 s and horizontal and vertical positions stable within 2 km. Class *b* contains 29 earthquakes with an RMS smaller than 0.25 s, horizontal positions stable within 2 km, and depths stable between 2 and 5 km. Class *c* contains 75 events with an RMS smaller than 0.5 s and hypocentral positions stable within 5 km. Class *d* contains 54 earthquakes poorly located at depth but satisfying a global RMS smaller than 0.5 s and horizontal position determination accuracy within 5 km. The remaining 74 events, which do not fit any of these four categories, were discarded. All selected epicenters are shown in Figure 3 and the depth of the 148 events of class *a, b*, and *c* are projected on various cross-sections (Figure 4).

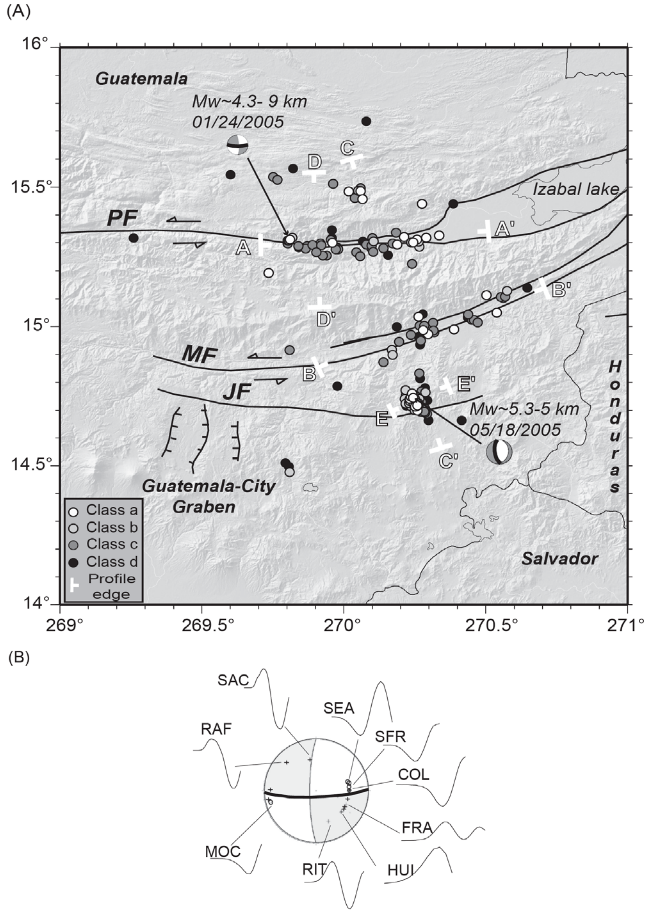
Seismicity Distribution and Seismogenic Thickness

The microseismic activity during the six-month study period is concentrated on the Polochic fault, the Motagua fault, and in two clusters located north of the Polochic fault and south of the Motagua fault where we recorded the greatest number of the events (Figure 3A and Figure 4). Despite the relatively small number of events recorded, the seismicity rate on the Polochic and the Motagua faults is comparable. The depth of the best-constrained Class *a* events that we located ranges between 2 and 14 km. Moreover, despite a less accurate location at depth, very few Class *c* events are located deeper than 15 km (Figure 4). We conclude that the thickness of the seismogenic zone should range between 10 and 15 km beneath the Polochic and Motagua faults as well as in the grabens area.

The focal mechanism associated with the *Mw* ~4.3 January 24 event located on the Polochic fault has one nodal plane corresponding to the Polochic fault plane that is very well con-

TABLE 3
Charaxcteristics of the different class event locations according to the stability tests (see text).

	Class *a*	Class *b*	Class *c*	Class *d*
RMS (s)	≤ 0.25 s	≤0.25 s	0.25 s≤RMS≤0.5 s	0.25 s≤RMS≤0.5 s
ERH (km)	≤ 2 km	≤ 2 km	2 km≤ERH ≤ 5 km	2 km≤ERH ≤ 5 km
|ΔH| (km)	≤ 2 km	≤ 2 km	2 km≤|ΔH|≤ 5 km	2 km≤|ΔH|≤ 5 km
ERZ (km)	≤ 2 km	—	2 km≤ERZ ≤ 5 km	—
|ΔZ| (km)	≤ 2 km	≤ 5 km	2km≤|ΔZ| ≤ 5km	> 5km
Event Number	44	29	75	54



▲ **Figure 3.** A) Map of the 202 Class *a, b, c*, and *d* events. Edges of vertical cross-sections shown in Figure 4 are indicated in white. (PF) Polochic fault; (MF) Motagua fault; (JF) Jocotan fault. B) Fault plane solution of the 24 January 2005 event with observed polarities and value of strike, dip, and slip indicated.

strained (Figure 3B). The other plane is not well constrained but is compatible with a quasi-pure vertical left-lateral strike-slip fault mechanism on an east-west plane, in agreement with the seismotectonic environment (strike: 88±1°, dip: 80±15°, slip: -10±5°). The depth distribution of the earthquakes on profiles perpendicular to the Polochic fault (C-C′ and D-D′ on Figure 4) do not show evidence for a non-vertical fault plane for the Polochic fault or the Motagua fault. Both the inverted fault mechanism and the vertical seismicity distribution are consistent with two subvertical faults above 15 km. However, based on our observations, we cannot constrain the fault geometry below 15 km.

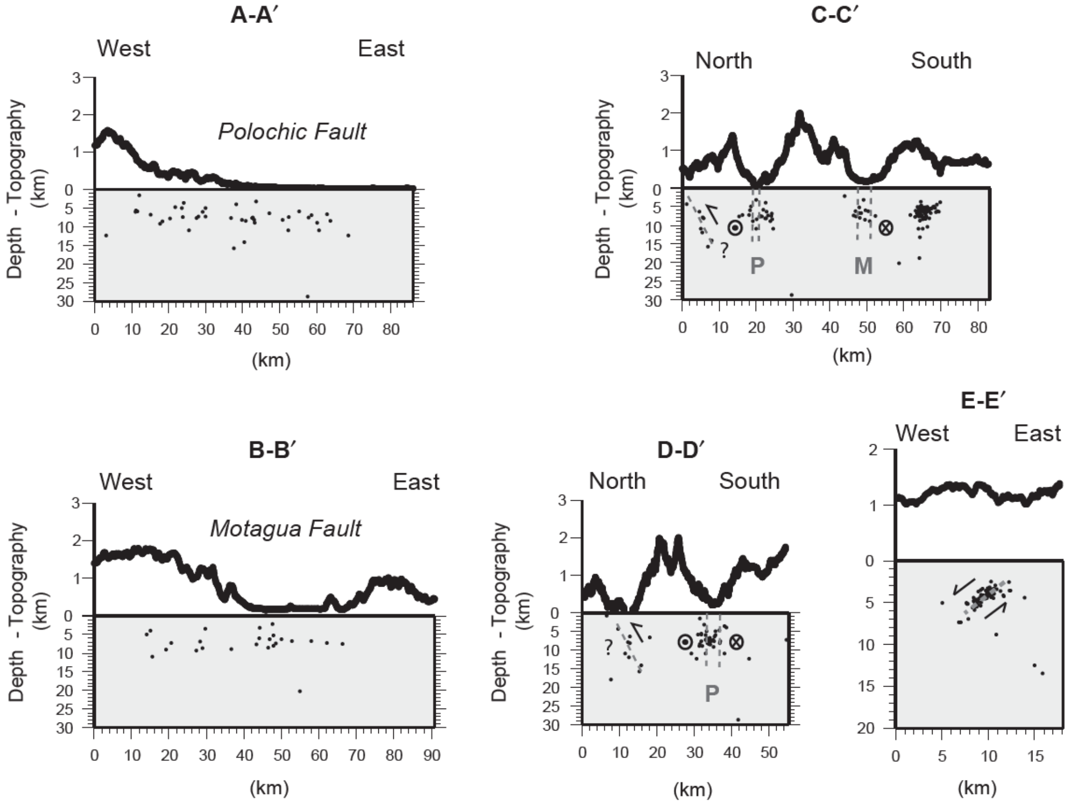
Most of the earthquakes located south of the Motagua fault occurred between 18 May 2005 and 21 May 2005, mainly following the *Mw* ~ 5.3 normal faulting earthquake that occurred on 18 May 2005. The cross-section EE′ (Figure 4) shows that the events align along a 59 ± 10° westward-dipping plane that corresponds to one of the nodal planes of the Global CMT fault plane solution of the *Mw* ~ 5.3 mainshock (Figure 3). Although it is not possible from the details of the analysis of the digital topography to assign a clear surface fault trace to this seismic sequence, it is clearly related to the extensional activity within the grabens and not to the Jocotan strike-slip fault.

Although no fault plane solution could be well constrained for the group of earthquakes located north of the Polochic fault, we suggest that they are related to the activity of a reverse fault on a south-dipping plane (Figure 4) associated with the north-south folds that can be observed on the Maya block.

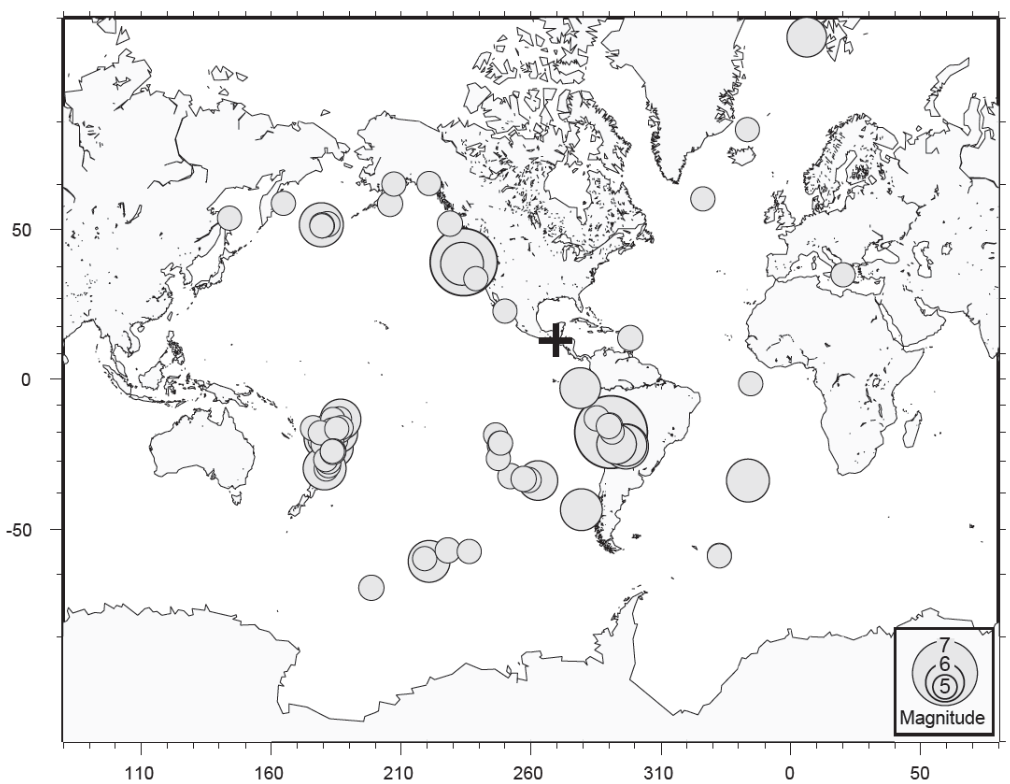
CRUSTAL STRUCTURE

We selected 86 teleseismic events with magnitude larger than 5.5 and with epicentral distances ranging from 20 to 100° (Figure 5). The records at the stations equipped with broadband or intermediate-band seismometers have been processed using the receiver function technique (*e.g.* Burdick and Langston 1977) to isolate *P* to *S* converted phases produced at impedance (product of density and seismic velocity) discontinuities below each station.

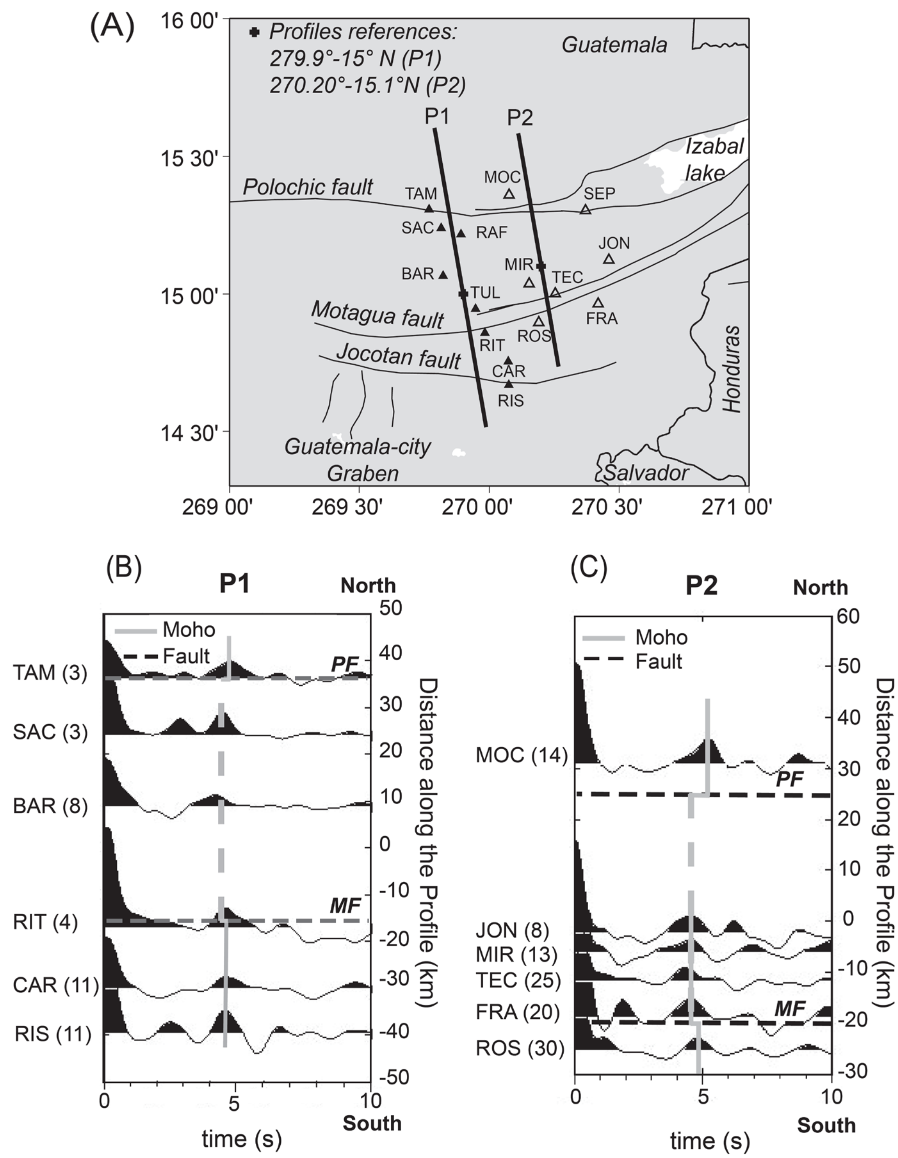
For each earthquake we removed the instrument response, rotated the horizontal components according to the theoretical back-azimuth, and filtered the data between 0.01 and 1 Hz. Then the radial and transverse components were deconvolved from the vertical one using the iterative approach in the time domain developed by Ligorria and Ammon (1999). We estimated a signal-to-noise ratio in amplitude for each receiver function by comparing the maximum amplitude of the peak (*P* arrival) and the mean background signal amplitude between 20 to 5 seconds before the *P* arrival. Receiver functions with a signal-to-noise ratio lower than three were discarded. The selected receiver functions were stacked at each station and projected along two profiles perpendicular to the fault system: receiver functions calculated from the broadband seismometers were projected along profile P1, and the ones calculated from the 5-s Lennartz seismometers were projected along profile P2 (Figure 6). The obtained receiver functions are fairly simple with a main *P* to *S* conversion observed ~4.5 seconds after the direct *P*-wave arrival (Figure 6). We interpret this phase to be the conversion at the Moho interface, which corresponds to a Moho depth between 35 and 38 km when using velocities from the IASP91 (Kennett and Engdahl 1991) global velocity model. This result is consistent with the *P*-wave velocity model from Molina and Tenorio (2000) used for the local event location (Table 2). On profile P2 we observe a slight reduction of the arrival time of the *P/S* phase of the order of 0.7 s between the Maya block and the Sierra de Las Minas unit south of the Polochic fault. A reduction of about 0.5 s is also observed between the Chortis block south of the Motagua fault and the Sierra de Las Minas unit (Figure 6). Although less clear, a similar feature can also be observed on profile P1 (Figure 6). This variation in the arrival time of the *P* to *S* conversion at the Moho indicates either a lateral variation of the crustal thickness or a lateral variation of the crustal velocities, or a combination of both. Unfortunately we did not observed clear multiple converted phases (*PpPs*, *PpSs*, *PsPs*) that would have helped us to determine the *Vp*/*Vs* ratio beneath each station based on the method developed by Zhu and Kanamori (2000), and our data are presently not suf-



▲ **Figure 4.** Seismicity cross-sections (see Figure 3 for location). Only quality a, b, and c events are plotted. For each cross-section, a topographic profile is shown on top.



▲ **Figure 5.** Repartition of the 86 events selected for the receiver function study. The cross indicates the network center.



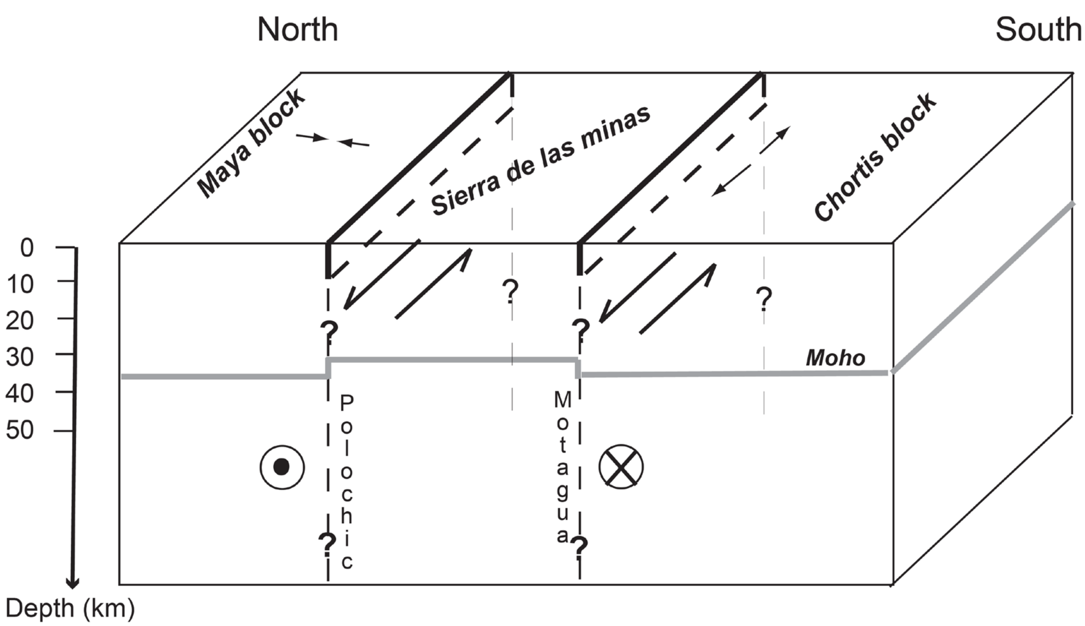
▲ **Figure 6.** A) Location of profiles P1 and P2. B) Stack of receiver functions at each broadband station projected along profile P1. The number close to the station name indicates the number of events selected to calculate the stack. Locations of the Polochic (PF) and the Motagua (MF) faults are reported (black dashed lines). The light gray line indicates the main *P* to *S* conversion at the Moho. C) Same as B but for profile P2 using the stations equipped with 5-s period seismometer.

ficient to perform a local tomographic study and resolve this trade-off. But if we assume a mean ray parameter of ~7 s per degree and a mean crustal *P*-wave velocity of 6.3 km.s^{-1}, the relative increase in the *P-S* conversion at the Moho observed on profile P2 is equally explained by a lateral crustal thickening of 4 to 6 km and a crustal *Vp*/*Vs* ratio increase of 6–7% (from 1.73 to about 1.85).

In fact, because the average elevation of the Sierra de las Minas is larger by about 500 m than the average elevation to the north and south, we would expect a crustal thickness increase rather than a decrease, all other parameters being equal. This lateral variation of crustal thickness or *Vp*/*Vs* ratio is likely related to the different geological origin of the Maya block Permian and Carboniferan carbonate series (north of the Polochic fault), the metamorphic rocks of the Sierra de Las Minas unit (between the two faults), and the Chortis block Cenozoic volcanic plateau (south of the Motagua fault, Figure 2). However, the profile P2 is relatively close to the active Izabal lake pull apart (~ 50 km, Figure 6), and in the absence of any reliable data from the Sierra de las Minas, we cannot rule out that our observations indicate crustal thinning in between the Polochic and the Motagua faults related to the setting up of the Polochic fault and the associated pull-apart basin.

DISCUSSION AND CONCLUSION

Our six-month seismological experiment focuses on the present seismicity of eastern Guatemala, which is poorly known from



▲ **Figure 7.** Lithospheric block diagram summarizing the observations discussed. Black arrows indicate deformation pattern, gray line indicates inferred Moho depth, dashed lines indicate the base of the seismogenic layer.

the national seismological network (mostly concentrated on the western part of the country). The block diagram on Figure 7 summarizes our interpretations of the overall stress regime and structure at depth in this area. Our data reveal a seismogenic thickness ranging between 10 and 15 km beneath the Polochic and the Motagua faults as well as beneath the graben area (south of the Motagua fault) and beneath the NS-trending folds (north of the Polochic fault). Although not directly comparable, the locking depth of ~20 km found in modeling strain accumulation on the Motagua fault (Lyon-Caen *et al.* 2006; Franco 2008) is consistent with this finding.

While both the Polochic and the Motagua faults appear subvertical above 15 km depth, we cannot constrain their deeper geometry. However, based on pure geometrical arguments, it is quite unlikely that these faults, which are separated by about 50 km at the surface, will merge below 15 km depth, a situation comparable to the San Andreas fault system. Implications for the driving and evolution of such fault systems are outside the scope of this paper but will need to be investigated.

The mapped seismicity reveals an overall evolution from dominant E-W strike-slip motion across the Polochic and the Motagua faults to a dominant E-W extension across one of the Pliocene or Pleistocene grabens south of the Motagua fault. This present stress regime is consistent with strain deduced from GPS observations (Lyon-Caen *et al.* 2006; Franco *et al.* 2008). However, the east-west extension zone seems here to extend further eastward than observed by Lyon-Caen *et al.* (2006) in agreement with new observations from Honduras (Rodriguez *et al.* 2009). In addition, contrary to seismological observations, GPS data do not show any evidence of compression across the NS-trending folds north of the Polochic, but GPS observations are too sparse there to really be conclusive.

According to the geodetic studies cited above, the elastic strike-slip deformation across the fault system is mainly accommodated by the Motagua fault. The Polochic fault shows, however, similar morphology and historical and present seismicity (Table 2, Figure 4). Despite the inability of our receiver functions study to properly resolve the trade-off between crustal thickness variation and *Vp*/*Vs* variation, our data suggest that both the Polochic and the Motagua faults are major structural boundaries between the Maya, Sierra de las Minas, and Chortis blocks. As previously observed on the San Andreas fault system (*e.g.*, Chéry 2007) or on the Altyn Tagh fault (*e.g.*, Jolivet *et al.* 2008), a lateral rheological variation of the crust could induce an asymmetric deformation pattern across the faults. However, in the case of the Polochic fault, such a hypothesis does not really help to explain the apparent lack of deformation accumulation on the Polochic (Franco 2008). Alternatively, the apparent contradiction between the GPS observations and the activity of the Polochic fault could reveal transient mechanisms where deformation accumulation jumps from one fault to the other during the seismic cycle. The results presented in this paper represent a first step toward a better understanding of this active fault system. Important questions remain open and further studies will be necessary. Future comparison with the San Andreas fault system should be quite interesting.

ACKNOWLEDGMENTS

Funding for this work came from the Dyeti program of INSU-CNRS. Instruments belong to the French national pool of mobile seismic instruments Sismob (INSU-CNRS). We thank the French embassy in Guatemala for its help in shipping the equipment. We also thank the numerous people who helped us in the field.

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STOP 2.3 – North Motagua Serpentinite Mélange

I was able to find a couple of short write-ups for this stop:

DERTS (Diamond Exploration and Research Training School), 2019, Ancient and Modern subduction and modern Volcanism in Guatemala. Field Trip Guidebook, 17 pgs.

Stop 8: Serpentinized peridotite of the El Tambor Complex.

Location: Roadside outcrop near El Progresso at 14.904400N, 90.163070W.

Observations summary: Orthopyroxene-rich serpentinized peridotites (Fig 2.4). Some areas are highly serpentinized.

Figure 2-4 Roadside outcrop exposing orthopyroxene-rich serpentinized peridotites.

Martens, U., Solari, L., Siison, V. Harlow, G., Torres de Leon, R. Ligorria, J. P., Tsujimori, T., Ortega, F., Brueckner, H., Giunta, G., and Lallemant, H.A., 2007, High Pressure Belts of Central Guatemala: The Motagua Suture and the Chuacus Complex. Field Trip Guide of the IGCP 546 – "Subduction Zones of the Caribbean," 32 pgs.

"Stop 10 (60 minutes) North Motagua Serpentinite mélange along highway CA-14.
Presenter: George Harlow, Jinny Sisson.

The outcrop at this stop is one of the largest continuous sections of serpentinites exposed in Guatemala. The lower part of the exposure is antigorite rock, with lower temperature varieties of serpentinite on the surface of blocks and cracks. Relict textures of original peridotites are visible. Rocks are strongly tectonized and show abundant fault fibers. Going upwards along the blocks allows observing exotic meter-scale blocks of mafic rocks contained in serpentinite.

Baja Verapaz Ultramafic

The Baja Verapaz ultramafic was thrust faulted over the Maya Block. It was emplaced mainly over Mesozoic evaporitic-terrigenous-carbonaceous deposits of the Todos Santos, Coban and Campur formations. Similarly, the Sierra de Santa Cruz unit, which outcrops ~70 km NE of Baja Verapaz, was thrust faulted over the Late Cretaceous-Eocene carbonaceous-terrigenous sequences of the Sepur formation. Mafic and ultramafic rocks in Baja Verapaz and the Sierra de Santa Cruz of somewhat serpentinized mantle harzburgites, layered gabbros, dolerites, and andesitic basalts, with an island-arc tholeiite to calc-alkaline magmatic affinity. Little petrologic and geochemical work has been done on the ultramafic rocks of Baja Verapaz. Petrographic examination reveals recrystallized olivine, large orthopyroxene crystals with minor exsolved clinopyroxene, and fresh chromitic spinel. Some samples exhibit a very low degree of serpentinization (<10%; see Fig. 9)."

STOP 2.4 – Baja Verapaz Ophiolite Complex

I was able to find a couple of short write-ups for this stop:

DERTS (Diamond Exploration and Research Training School), 2019, Ancient and Modern subduction and modern Volcanism in Guatemala. Field Trip Guidebook, 17 pgs.

Stop 7: Baja Verapaz ophiolite complex.

Location: Large harzburgite quarry along the side of the road at 15.227100N 90.221945W.

Observations summary: Ultra-fresh orthopyroxene-rich massive harzburgite. Large lateral extent indicated by abundant outcrops for many km's along roadsides (Fig. 2.3). Fresh olivine that has not been serpentinized can be observed in reddish (rusty) blocks in the quarry.

See Section 7: Baja Verapaz ophiolitic complex for additional info.

Figure 2-3 Ultra-fresh orthopyroxene-rich massive harzburgite observed at roadside quarry near Purulha.

Martens, U., Solari, L., Siison, V. Harlow, G., Torres de Leon, R. Ligorria, J. P., Tsujimori, T., Ortega, F., Brueckner, H., Giunta, G., and Lallemant, H.A., 2007, High Pressure Belts of Central Guatemala: The Motagua Suture and the Chuacus Complex. Field Trip Guide of the IGCP 546 – "Subduction Zones of the Caribbean," 32 pgs.

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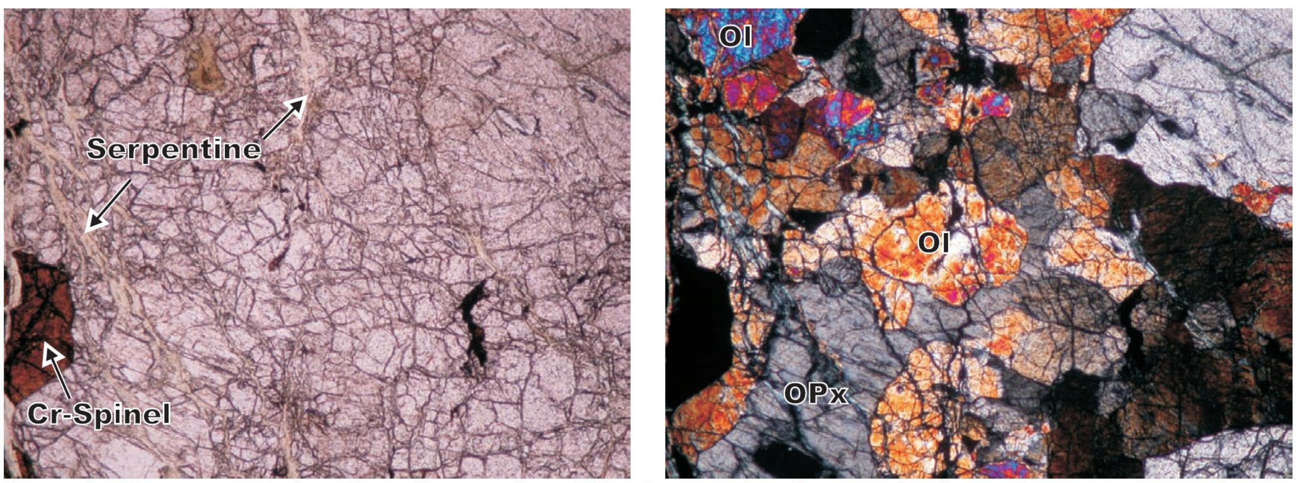


Figure 9. Photomicrographs of Baja Verapaz Spinel Harzburgite. Left photograph taken with plane-polarized light, right photograph under crossed polars. Degree of serpentinization is <10%.

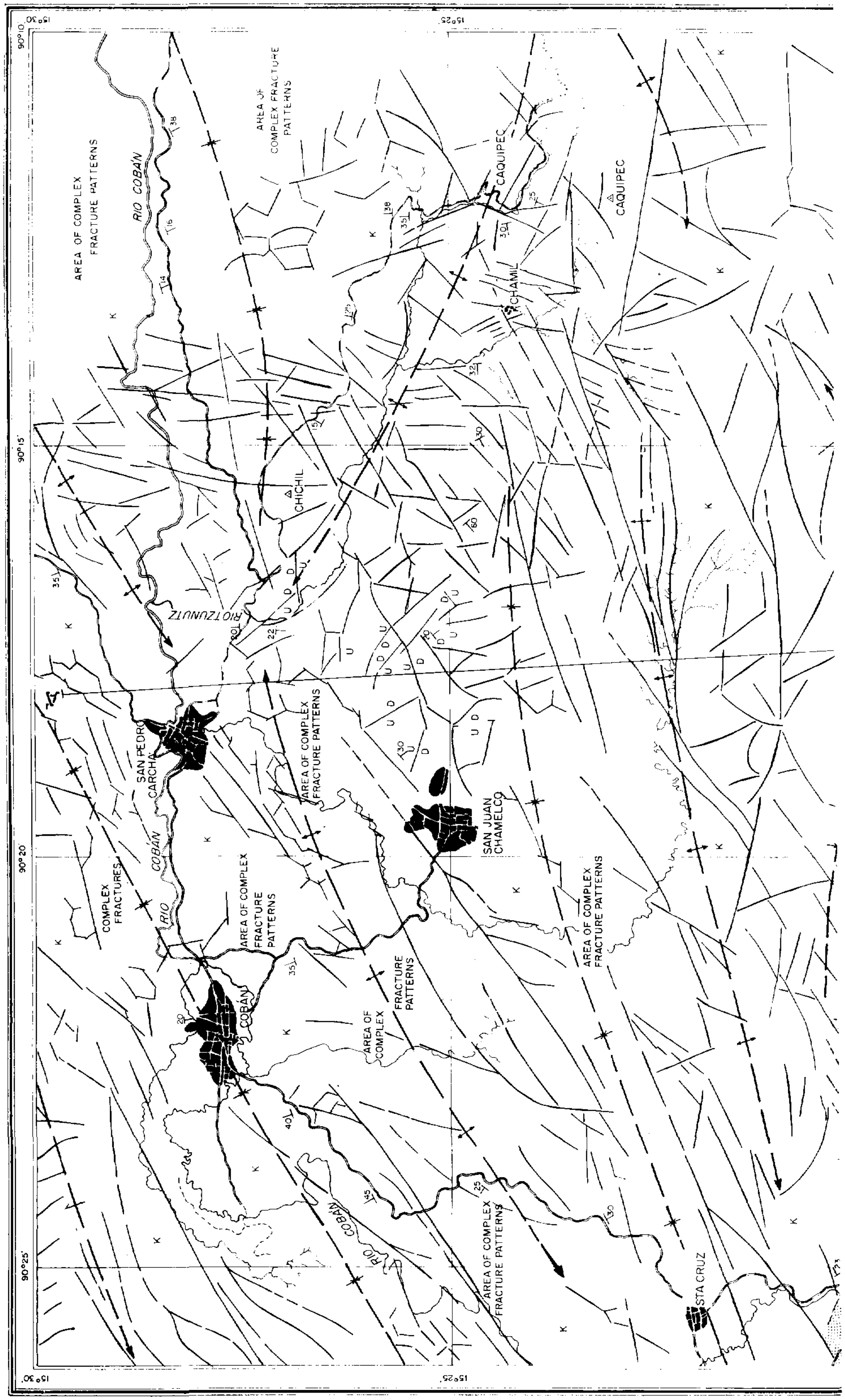
STOP 2.5 – Coban

This older paper had good details on the stratigraphy:

Walper, J.L., 1960, Geology of the Coban-Purulha Area, Alta Verapaz, Guatemala. Bulletin of the American Association of Petroleum Geologists, v. 44, no. 8, pp. 1273-1315.

Stratigraphic Column of Cobán-Purulhá Area

Alluvium, chiefly volcanic ash	Small, isolated patches of reddish brown ash	Quaternary
	Unconformity	
Cobán formation 1,730+ feet thick	Massive, gray to black limestone and dolomite	Cretaceous
Ixcoy formation 3,820+ feet thick	Massive, gray to black limestone and dolomite with thin-bedded zone of argillaceous limestone at top	
Todos Santos formation 2,100± feet thick	Red to brown shale and sandstone and conglomerate composed of limestone and metamorphic rock fragments	Cretaceous and Upper Jurassic
	Unconformity	
Serpentine	Dark green serpentine in fault contact with Cretaceous strata. Intrusive relations not visible in report area	Jurassic or Triassic (?)
	Unconformity	
Chochal formation 2,100+ feet thick	Massive limestone and dolomite with minor shale	Permian
Tactic formation 1,500+ feet thick	Black shale with minor limestone beds in upper part	



90°10'
90°15'
90°20'
90°25'
15°30'
15°25'
AREA OF COMPLEX FRACTURE PATTERNS
RIO COBAN
CAQUIPEC
CHAMIL
CHICHIL
RIO TZUNUTZ
SAN PEDRO CARCHA
SAN JUAN CHAMELCO
COMPLEX FRACTURES
RIO COBAN
AREA OF COMPLEX FRACTURE PATTERNS
COBAN
AREA OF COMPLEX FRACTURE PATTERNS
STA CRUZ

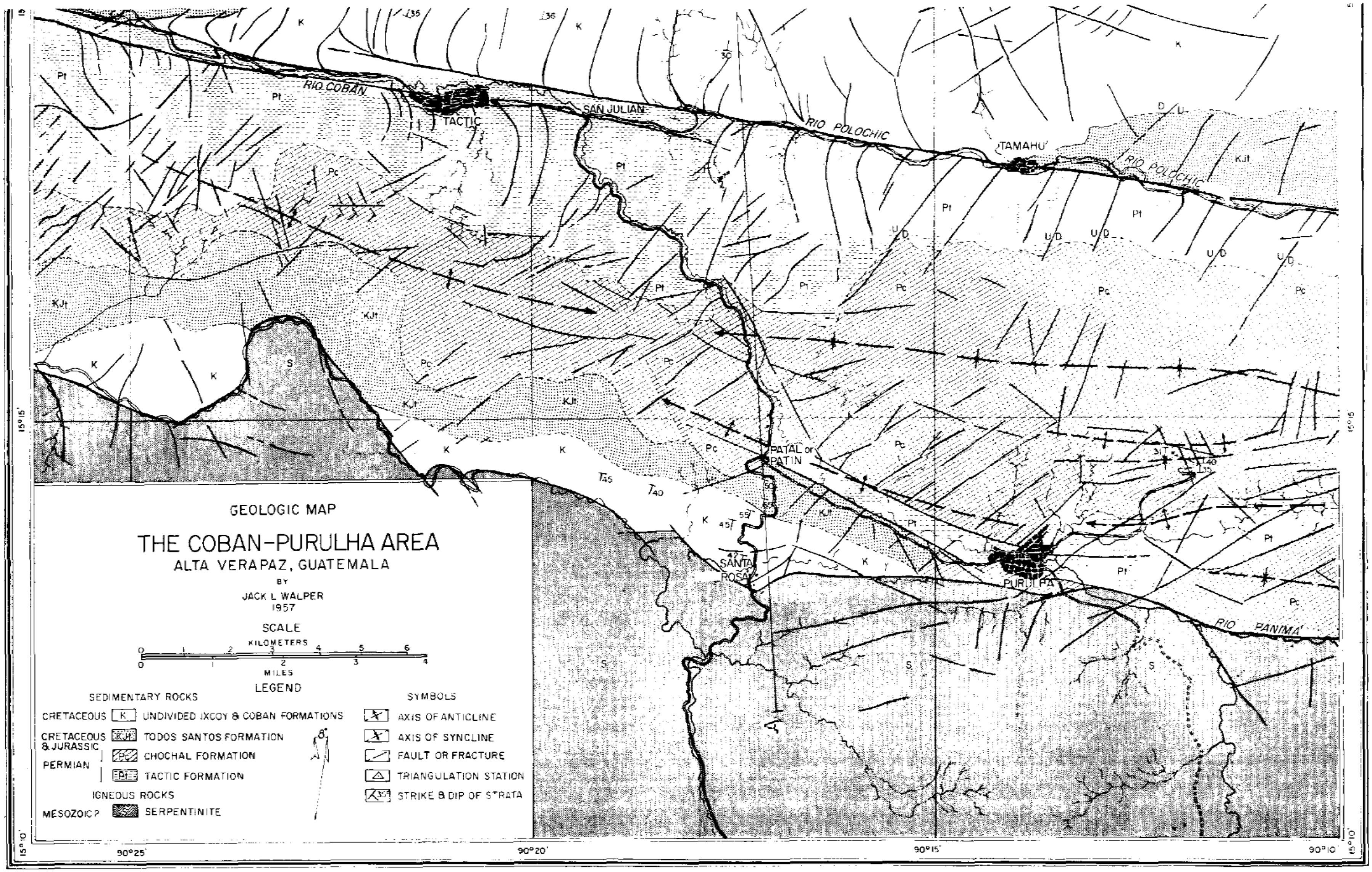


Fig. 5.—Geologic map of Cobán-Purulhá area, Alta Verapaz, Guatemala.

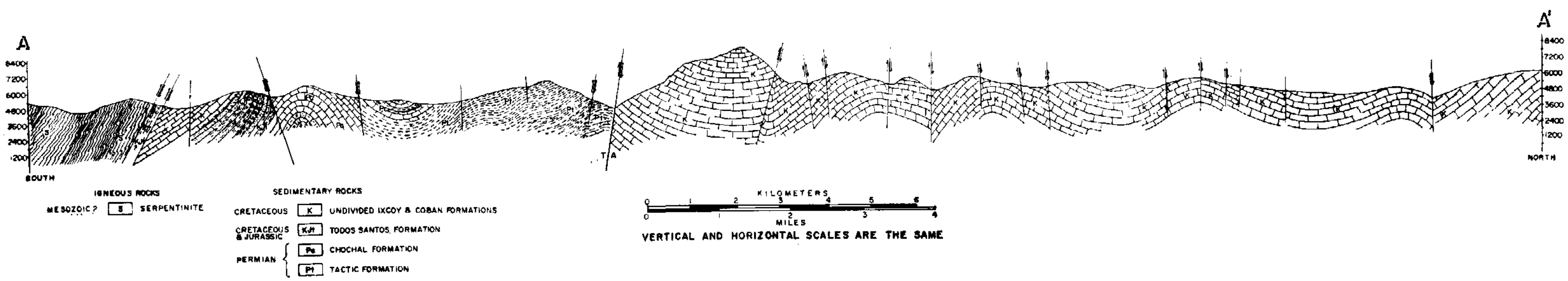
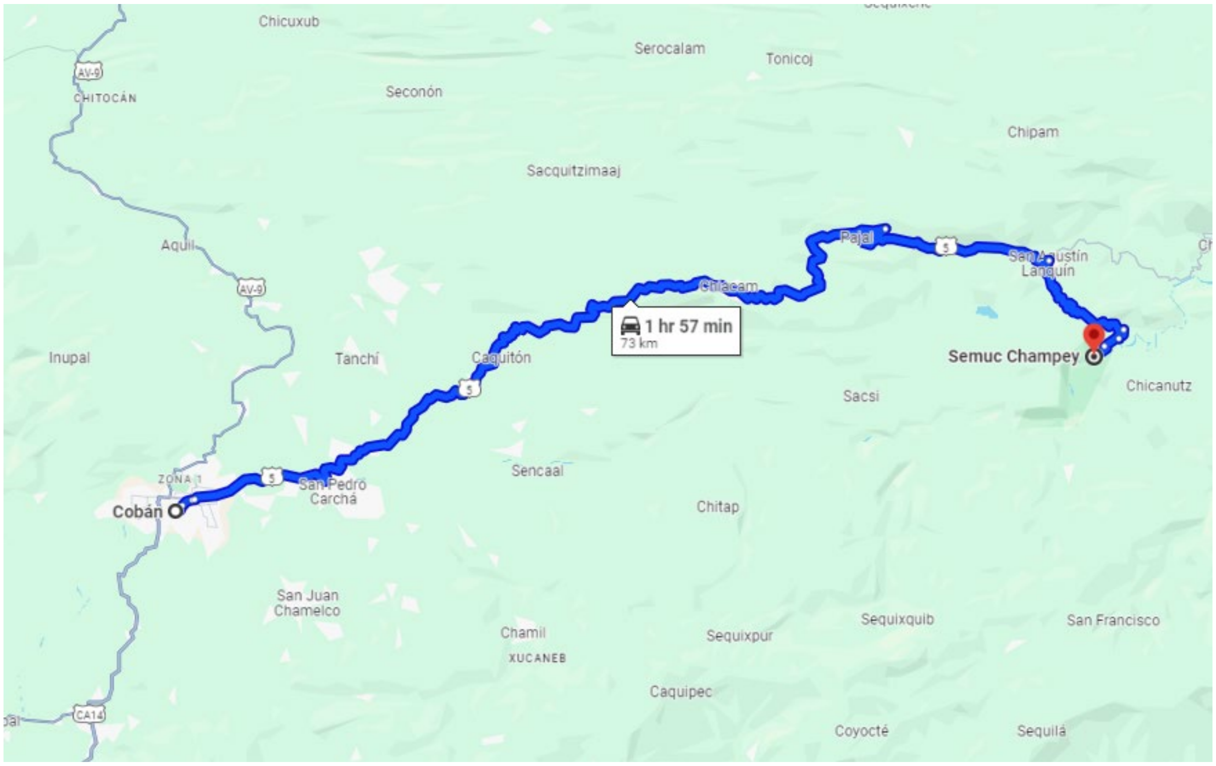


FIG. 6.—Generalized structure section A-A', Cobán-Purulhá area, Alta Verapaz, Guatemala.

Day 3: Sunday, March 2nd, 2025 – Semuc Champey

7:00AM: Wake up, breakfast not included at hotel. What time does the restaurant open?
9:00AM: Load the bus
11:00AM: Arrive at Semuc Champey
12:00PM: Grocery store lunch,
4:00PM: Return to Coban and the Don Francisco Hotel



maybe next time I will add a section on karst stuff….

STOP 3.1 – Semuc Champey: *This write-up is from that Stanford Field Guide:*

Stanford Alpine Project, 2005, Field Guide to Guatemalan Geology. Stanford University, Department of Geological and Environmental Sciences, 62 pgs.

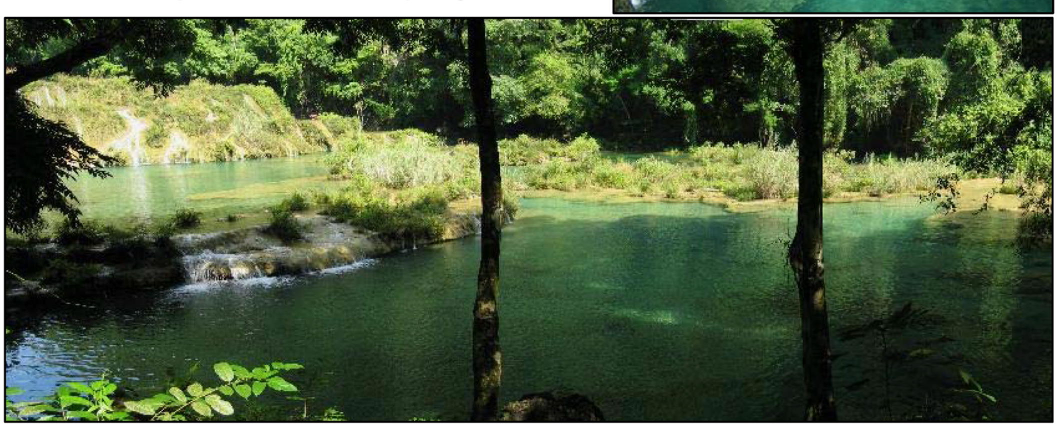
Day 13 – Semuc Champey and Grutas de Lanquín

Today we will visit both Semuc Champey and the Grutas de Lanquín, which are separated by a short drive along a bumpy, dirt road. Both are spectacular geomorphic features unique to carbonate rocks. The driving is minimal in distance, but the road between Lanquín and Semuc Champey is very rough and slow, 4WD vehicles with high clearance are strongly recommended. The Grutas Lanquín are the first left turn as you enter the town of Lanquín, while Semuc Champey is 11 km past town on the road towards Cahabón. The two attractions are separated by about a half hour's drive and both are easy to find as they are well marked with signs.

Stop 13.1: 9:00 – Semuc Champey.

Semuc Champey is said to be one of the most beautiful places in all of Guatemala (and possibly the world), and for good reason. Here, in the heart of karst country, the Río Cahabón has incised a deep canyon through the limestone bedrock. Above the level of the river are springs, the cool waters of which are saturated with carbonates. At the emergence of these springs, the mineral *travertine* is deposed, which slowly builds the spring out away from the rock and over the river. A this location, nature has built a substantial dam ("travertine bridge") across the Río Cahabón. The river flows in a raging torrent deep under the extensive bridge before re-emerging on the downstream side. The bridge itself spans more than 300 m of the river's length and is pocketed with crystal-clear freshwater pools ideally warm enough and deep enough for diving and swimming.

Semuc Champey opens at 6:00, so if you want the place to yourself, get there early and spend as much of the day as possible enjoying the various pools and scenery. It starts getting crowded around 11:00 when the sun heats up and the cool spring water is



that much more inviting. Bring some food and enough water to keep you going: swimming works up an appetite! Entrance fee is Q. 20.00.

Although this will be a relatively mellow time, a stringent warning is in order: ***be very careful*** *around the upstream edge of the bridge, one wrong step could be fatal.* If you fall into the river, you will be dragged under; a park guard may be on duty to help prevent such fatalities.

Stop 13.2: 14:00 – Grutas de Lanquín II: the caves.

If you were not scared off by the thousands of bats from the previous night, it is time to have a look inside the caves. They run several kilometers into the earth and, after the first paved and lit section are relatively untouched, though getting to the greater and darker depths of the caves is rather difficult. Still, the speleothems in the lit portion of the cave are spectacular in size and shape; plus if you hunt around you may find some spectacular sparry calcite.

Just below the entrance to the cave is the birthplace of the Lanquín River where it emerges from underground. If you listen carefully as you enter the cave you can hear the rush of flowing water beneath you. In Spanish the place is known as *Nacimiento del Río Lanquín.* The other attraction of the Grutas de Lanquín are the thousands of bats that exit at dusk each day for their evening meal (see previous day).

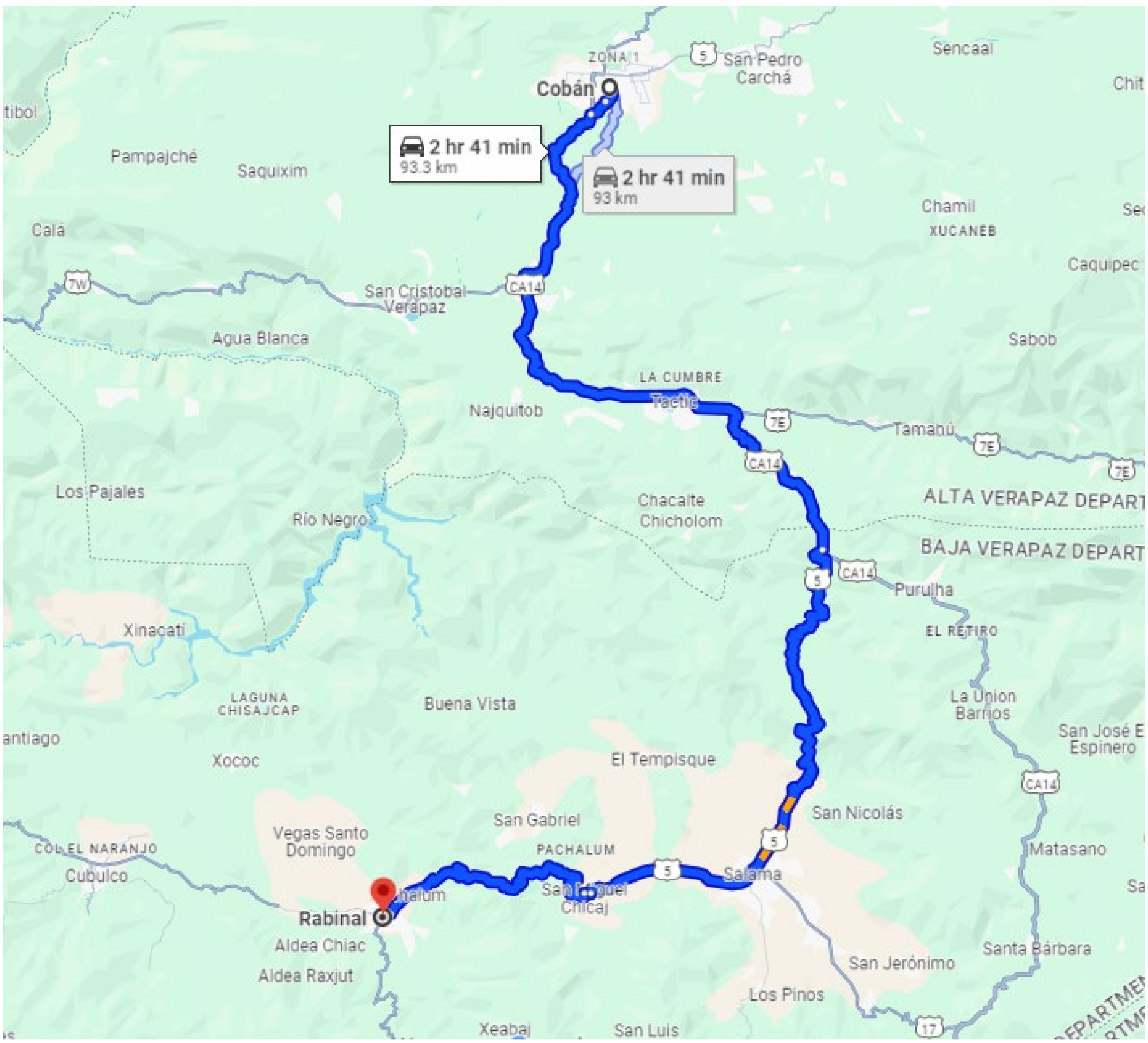
Stop 13.3: 18:00 – Cobán.

After retracing the first 11 km of treacherous, winding dirt road up out of the Lanquín valley, the 50 km stretch of road to Cobán is well paved, though still quite curvy. The whole trip takes slightly less than two hours.

Day 4: Monday, March 3rd, 2025 – Rabinal

7:00AM: Wake up, breakfast not included at hotel, pack up, and load into the buses.
8:00AM: Leave the hostel and drive to Rabinal
Go to grocery store for lunch supplies for Day 4 and Day 5
9:00AM: Could be some interesting things heading South on the 5 road. There's a quarry east of Salama that is greenschist meta-sediments, probably part of the Maya Block pre suture.
4:00PM: Reach the guesthouse
5:30PM: Check-in at the guesthouse
Hotel y Restaurante Maria De Los Angeles
(https://www.facebook.com/hotelmariadelosangeless/)
3ra Calle 6-80 zona 2, Rabinal, Guatemala
Email: hotelmariangel@hotmail.com Phone: +502 7938 8919

6:00PM: Group dinner at the guesthouse



STOP 4.1 – San Gabriel Sequence and the Rabinal Granite:

Martens, U., Solari, L., Siison, V. Harlow, G., Torres de Leon, R. Ligorria, J. P., Tsujimori, T., Ortega, F., Brueckner, H., Giunta, G., and Lallemant, H.A., 2007, High Pressure Belts of Central Guatemala: The Motagua Suture and the Chuacus Complex. Field Trip Guide of the IGCP 546 – "Subduction Zones of the Caribbean," pg. 18

Stops in the Salamá-San Miguel Chicaj-Rabinal area will focus on the intrusive relationships of the Rabinal granite suite into the San Gabriel sequence, and the unconformably overlying sheared conglomerates that possibly correlate with the Sacapulas Formation, which represent the basal unit of the Santa Rosa Group. We will also have a look to the superimposed shearing that is widespread on Rabinal and San Gabriel sequence, as well as on the conglomerates, and that we interpret as an evidence for activity of the Baja Verapaz Shear Zone.

The Rabinal - Salamá area lies between the Baja Verapaz and Polochic faults (Fig. 4). Geological mapping of this area (Ortega-Obregón, 2005, Fig. 10) revealed the presence of three units: (i) the San Gabriel unit (Salamá sequence of van den Boom, 1972, redefined), which is intruded by (ii) the Rabinal granite suite (Gomberg et al., 1968 calculated U-Pb discordant ages for this granite using very large zircon fractions, with intercepts of 1075 ± 25 Ma and 345 ± 20 Ma, interpreted as either inheritance and intrusion, or as crystallization of hosting gneisses and metamorphism); and (iii) the Santa Rosa Group (Sacapulas formation of van den Boom, 1972).

San Gabriel unit

The San Gabriel unit consists of low grade, interbedded sandstone, arkose, greywacke, phyllite (Fig. 11), slate, and mafic-felsic lavas and tuffs. These lithologies indicate a continental, possibly shallow marine environment of deposition. Petrographically, the metasedimentary rocks contain quartz, feldspar, muscovite, epidote, chlorite, scarce biotite, and clay minerals. The mafic volcanic rocks are made up of albite-oligoclase, green amphibole (rare hornblende and, more often, tremolite), epidote and chlorite set in a cryptocrystalline matrix, whereas felsic rocks contain feldspar and quartz. The mineral associations found in metasediments and metabasites suggest that these rocks were metamorphosed under greenschist facies conditions. There are no continuous sections across the unit, and this, combined with the folding and discontinuous outcrop, makes it impossible to measure a type section. Although it is difficult to estimate the real thickness of the San Gabriel unit, we argue that it is at least 200 m thick, based on the continuous and undeformed section outcropping along the San Miguel – Rabinal paved road. The best exposures are on the road between San Miguel Chichaj and San Gabriel and Rabinal (Figs. 10a and 10b, and STOP 14).

No independent age constraints are available for this unit, however an Ordovician upper limit is provided by the Rabinal granite suite, which is intrusive into the unit. The San Gabriel unit shows striking similarities with low-grade metasediments cropping out south of Huehuetenango, in western Guatemala, where detrital zircon geochronology yielded Precambrian ages bracketed between ~ 920 and ~ 1,000 Ma (Solari et al., in press).

Rabinal granite suite

The Rabinal granite (STOPS 13 and 14) and its associated minor intrusions and pegmatites intrude the San Gabriel unit, which locally preserves sedimentary (primary) features, such

Rabinal granite suite

The Rabinal granite (STOPS 13 and 14) and its associated minor intrusions and pegmatites intrude the San Gabriel unit, which locally preserves sedimentary (primary) features, such as graded and/or cross stratification. It is locally weakly foliated, and composed of K-feldspar (orthoclase and rare perthite), plagioclase (oligoclase), quartz, muscovite, accessory apatite, zircon, titanite, and opaque minerals. Secondary sericite and chlorite are replacing biotite. Modal analyses show a range from granite to granodiorite. The dikes contain quartz, microcline, and biotite, and the pegmatites are made up of quartz, K-feldspar, and muscovite. The lack of contact metamorphism suggests that intrusion occurred into sediments at shallow depths with crystallization of magmatic muscovite occurring at a minimum depth of ~ 10 km (Chatterjee and Johannes, 1974; Wyllie, 1977).

Chemically the granite has a SiO_2 content of 72-76%, high-K, and calc-alkaline/peraluminous affinity. Normalized against primitive mantle, the analyzed trace elements show enrichment in high field strength elements, low Nb, P and Ti anomalies, and high K and Pb. Normalized against chondrites, the REE pattern is slightly enriched in light rare earth elements. On discriminant diagrams, they plot in the volcanic arc field, straddling in part the fields of within plate and syn-collisional granites (Fig. 12).

Three granite samples and three pegmatite samples were dated by U-Pb zircon and K-Ar geochronology. All of the zircons yielded discordant analyses, and chords through analyses from each sample yielded lower intercepts of 496 ± 26 Ma, 462 ± 11 Ma, and 417 ± 23 Ma and an upper intercept of 483 ± 7 Ma (Ortega-Obregón et al., in press). The best fit chord is through the analyses of three zircons from a pegmatite sample. One of these analyses is nearly concordant, and is regarded as most closely constraining the age of intrusion at 462 ± 11 Ma. Upper intercepts of three of four dated samples (Gt0457b, Gt03115, and PEG; see Fig. 10) range from 1312 ± 76 Ma through 1351 ± 110 Ma, to 1736 ± 190 Ma.

Muscovite from two pegmatites cutting the San Gabriel unit yielded K-Ar ages of 453 ± 4 Ma and 445 ± 5 Ma. As these pegmatites represent the last crystallization phase of the Rabinal granite, their K-Ar cooling ages provide a younger limit for the age of intrusion. Furthermore, as the granite appears to be a relatively high level intrusion (~ 10 km), the K-Ar ages probably closely post-date intrusion. Thus, together with the least discordant, U-Pb zircon age, the granite was probably intruded between ~462 and 445 Ma, i.e. Upper Ordovician. In view of this interpretation, the ~417 Ma, U-Pb, lower intercept age is probably due to lead loss. On the other hand, the Middle Proterozoic, U-Pb, upper intercept ages possibly reflect inheritance from the source terrane.

Santa Rosa Group

Sheared conglomerate and sandy conglomerate containing cobbles of metasandstone, phyllite, and granite similar to the Rabinal granite suite crop out in the Salamá area (e.g., STOP 12). In the Cerro Mumús (Fig. 10), these rocks are accompanied with shale and limestone containing crinoids and the conodont Siphonella sp. (Ed Landing, written communication, 2005), which dates the base of the unit as Tournaisian (Lower Mississippian). The limited outcrop and structural complexities make it impossible to provide a measured type section. The lithologies indicate a continental to shallow marine environment of deposition. They correlate with the Santa Rosa Group in the Maya block (cf. Bohnenberger, 1966; Anderson et al., 1973). The lowest conglomerate beds in the Rabinal-Salamá area

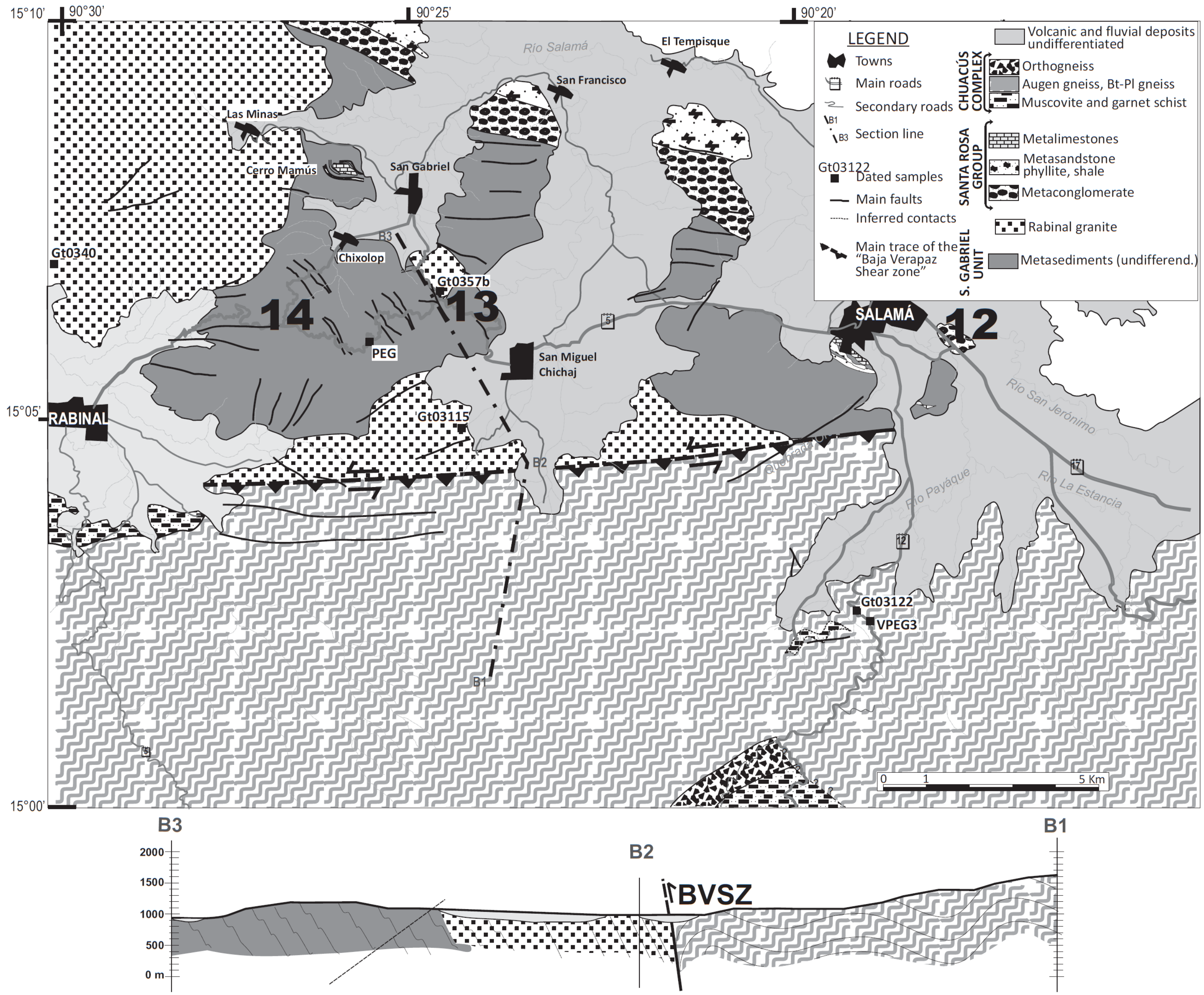


Fig 10. Simplified geologic map of the Rabinal Salamá area. Modified from Ortega-Obregón et al., 2007. Bold numbers indicate the stops.

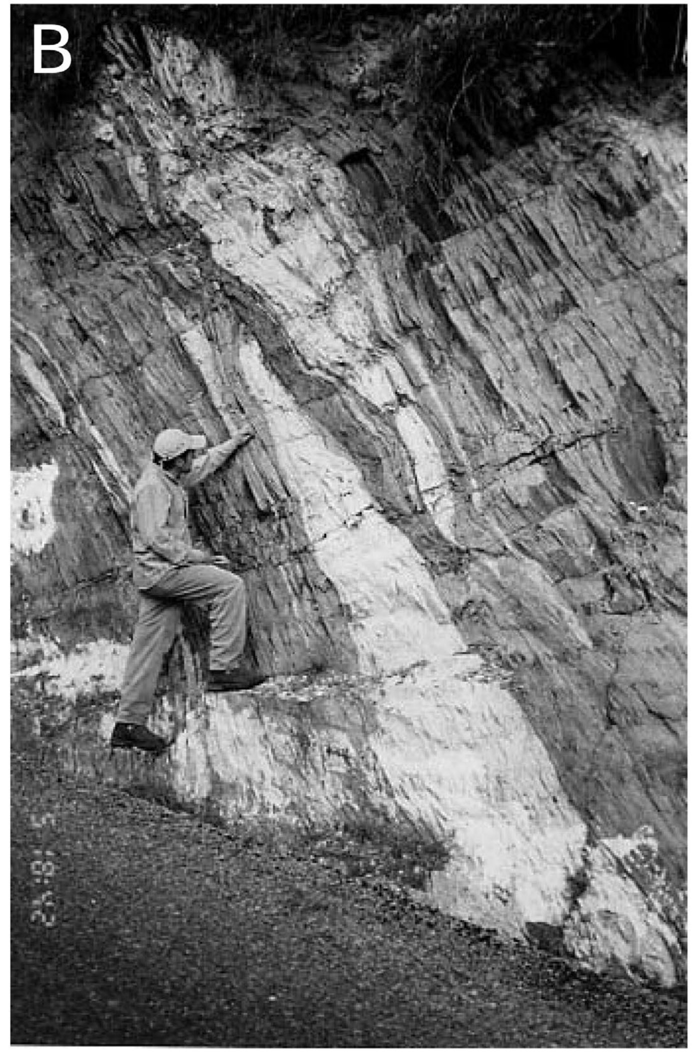


Figure 11.
A) Phyllite bands of the San Gabriel sequence embedded in the Rabinal granite. Tectonic foliation, subvertical in this picture, is refracted and primary structures can be seen in these sedimentary bands.

B)Tectonic relationships between the Rabinal granite and the San Gabriel sequence metaarkoses. Both Rabinal granite and San Gabriel sequence underwent deformation in low grade metamorphic conditions, represented by the intense shearing, dated at Late Cretaceous.

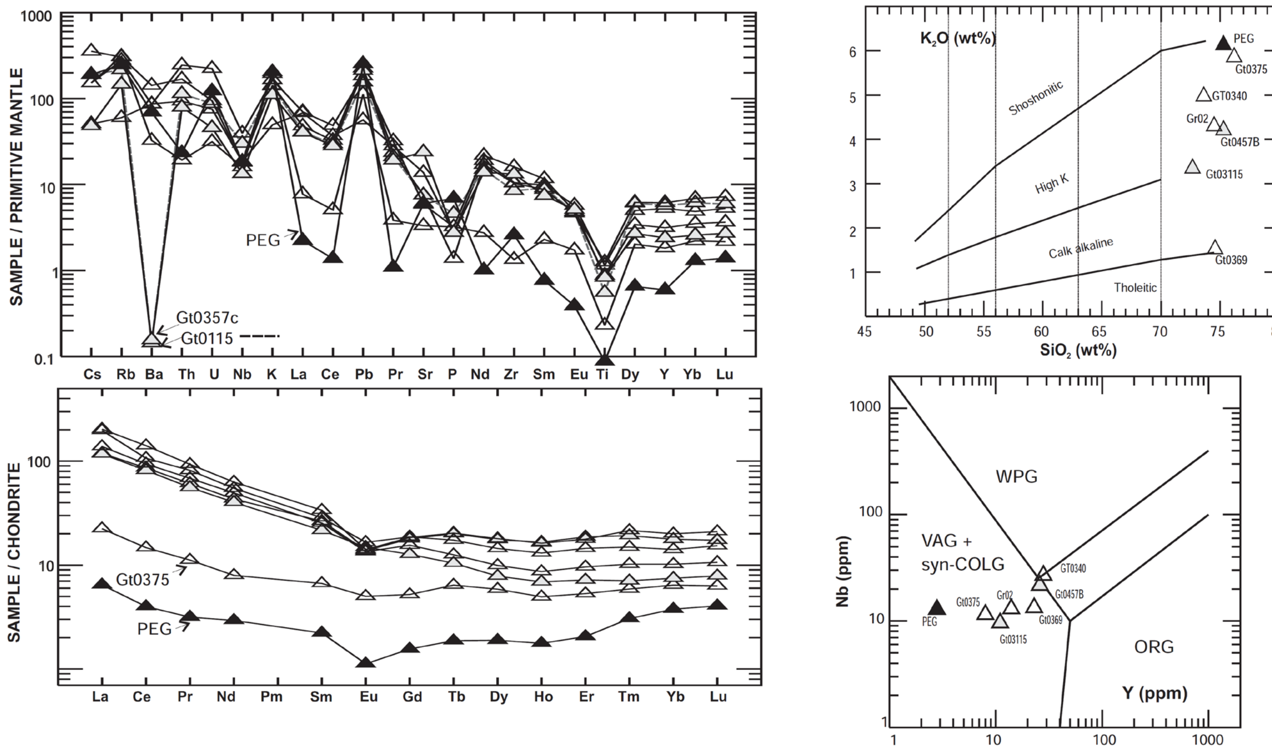


Fig 12. Geochemical characteristics of the Rabinal granite. Modified from Ortega-Obregón et al., in press.

(named the Sacapulas formation, Forth, 1971), are in fault contact with the San Gabriel unit and Rabinal granite suite (Ortega-Obregón et al., in press).

Implications

Taken altogether the geological, geochemical and geochronological data of the Rabinal-Salamá area suggest that:

1. The (actual) southern Maya block margin is made up of pre-Ordovician sediments, here named San Gabriel sequence, affected by a very low metamorphic grade. It is intruded by Mid-Ordovician granites, which geochemistry suggest they produced by crustal melting (i.e., they are S-type granites).

2. On top of such sequence it rests a sedimentary sequence that goes from conglomerated to sandstone, pelites and carbonates. The latter has been dated at the Tournasian (345 Ma). His sequence can be tentatively associated to the Santa Rosa Group.

3. Both San Gabriel and Rabinal granites, as well as the basal conglomerates of the Santa Rosa Group, show a low grade, top-to –the NNE shearing, with a reverse kinematics. The age of this shearing is restricted to the Late Cretaceous, and tectonically associated with the collision of the southern Maya block with either the Greater Antillan arc or the Chortís block, the obduction of El Tambor Group and the Baja Verapaz, Sierra de Santa Cruz and San Juán de Paz ophiolites and ultramafics. Such age also coincide with the exhumation and accretion of the Sierra de Chuacús metamorphic rocks.

4. Current data suggest that difference in metamorphic grade, lithotectonic associations, presence versus absence of the overlying Santa Rosa sediments, as well as ages, constitute major arguments against the inclusion of the Sierra de Chuacús metamorphic rocks into the Maya block. We propose that the Baja Verapaz Shear Zone should be considered as the southern tectonic limit of the Maya block and, in general, the north America plate.

Stop 12 (20 minutes) Sacapulas Formation of the Santa Rosa Group in Salamá. Presenter:

Luigi Solari.

Conglomerates of the Sacapulas Fm. Road El Rancho – Salamá, approaching Salamá (Fig. 10). Deformed conglomerates, metamorphosed under greenschist facies conditions, are exposed at this locality. They constitute the base of the Santa Rosa Group in the studied area, and are correlated with the Sacapulas Fm. of Forth (1971). Main foliation is gently to moderately SW dipping, NW to WNW-trending, whereas a moderately SW-plunging stretching lineation is sometimes visible on foliation planes. Kinematic indicators are generally well observed, as rotated clasts (mainly granites to quartzites), as well as S-C foliation in the sheared matrix. Both kinematic indicators suggest a top-to the NE sense of shearing, indicative of the BVSZ activity in the outcrop.

Stop 13 (30 minutes) San Gabriel Sequence and Rabinal Granite, Cumbre de San Gabriel. Presenter: Luigi Solari.

Rabinal granite. Quarry at the intersection between San Miguel Chicaj – Rabinal and S. Gabriel roads. In this outcrop it is possible to observe the mineralogy and tectonic relationships of one of the granites we included in the Rabinal granite suite. Particularly, the sample we dated at 417 ± 23 Ma (lower intercept) belongs to this outcrop. Intrusive relationships are evident just few tens of meters before the intersection, along the main road. Locally the granite is weakly foliated, and kinematic indicators, indicating a top-to-the NE sense of shearing, are visible in the quarry outcrops.

Stop 14. (30 minutes). San Gabriel sequence, and intrusive Rabinal granite, Cumbre de Rabinal. Presenter: Luigi Solari.

Contact relationships between the sheared metasediments of the San Gabriel sequence, and intruding dikes of the Rabinal granite, are exposed in this outcrop. S to SW moderately dipping foliation is clearly visible in the outcrop, and affecting both metasediments and interlayered granites. Although shearing is in part transposing the primary contacts between the two units, some metasedimentary bands inside the granite indicate the original intrusive nature of the latter. Quartz stretching lineation is generally SW-NE trending, gently to moderately SW plunging.

Gneiss-hosted Eclogites in the Sierra de Chuacús

The Chuacús Complex (Ortega-Gutiérrez et al., 2004) is an elongated metamorphic belt that stretches throughout central and eastern Guatemala for a length of ~ 220 km (McBirney 1963; Kesler et al. 1970; van den Boom 1972; Anderson et al. 1973; Roper 1978; Donnelly et al. 1990; Giunta et al. 2002; Ortega-Gutiérrez et al. 2004) (Fig. 4). To the north, the Chuacús terrane is bounded by low-grade greenschist-facies schists along the south-dipping high-angle Baja Verapaz shear zone. The MFZ puts the Chuacús Complex in contact with serpentinite mélange of Motagua Valley. Most gneissose rocks show compositional banding and contain both mafic amphibolite and quartzofeldspathic gneiss. Ortega-Gutiérrez et al. (2004) first described relict eclogite preserved in mafic epidote-amphibolite of the banded quartzofeldspathic gneiss in the El Chol area of the central Sierra de Chuacús. The retrograded eclogite is characterized by a relict eclogitic assemblage garnet + omphacite + rutile + quartz and overprinted by an epidote-amphibolitic assemblage of hornblende + epidote + albite + titanite; omphacite contains up to 45 mol.% jadeite component. Garnet grains exhibiting radial fractures around quartz inclusions were recognized and eclogite-facies conditions were estimated at 2.2-2.4 GPa and 730-750 °C (Ortega-Gutiérrez et al. 2004; Martens et al.. 2007).

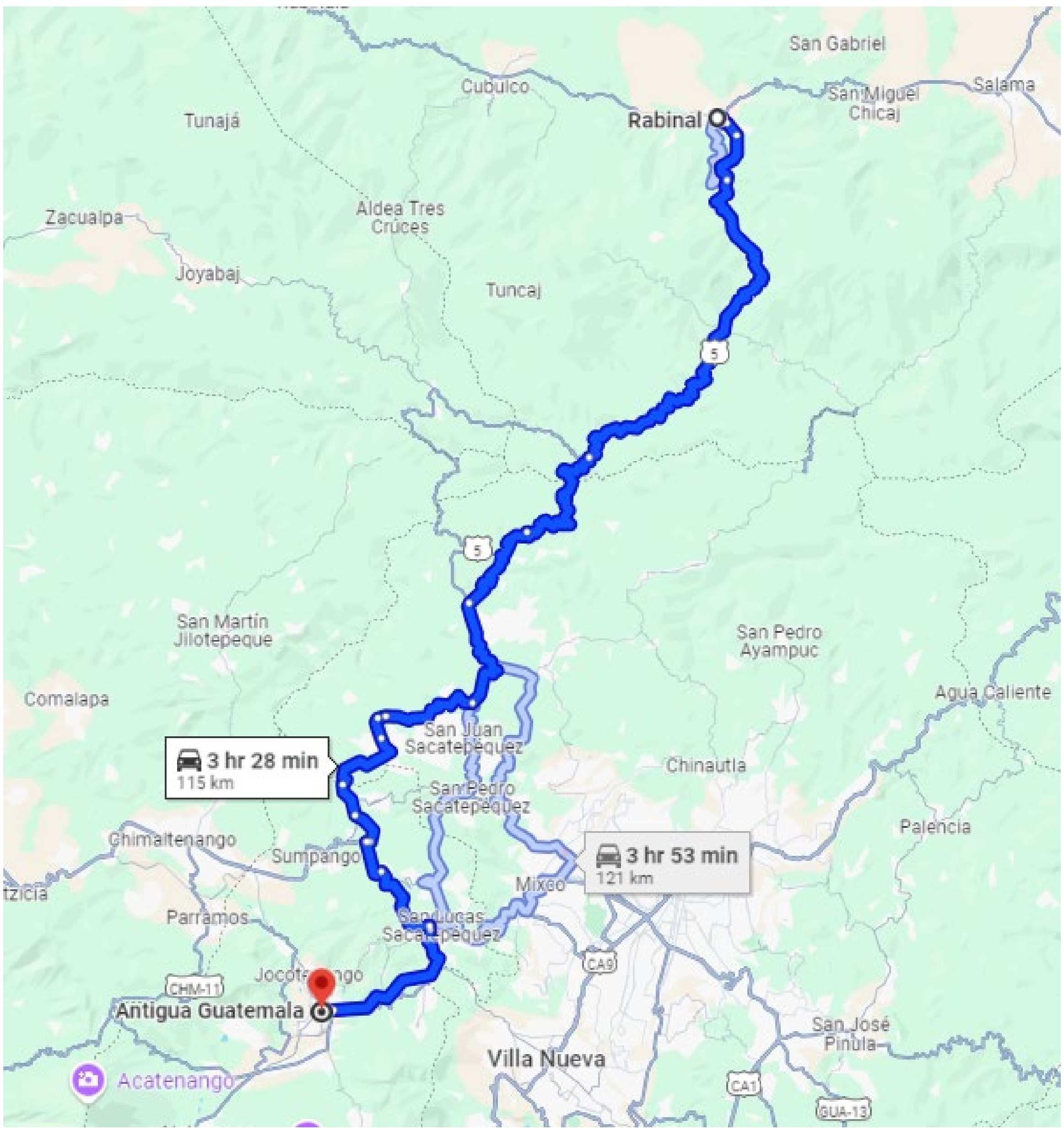
Field relations suggest that the protolith of orthogneiss was intruded by mafic dikes, subsequently subjected to eclogite-facies conditions, and finally strongly overprinted at epidote-amphibolite conditions. Cathodoluminescence images, Th/U, U/Pb and REE patterns of Agua Caliente gneiss zircon cores indicate magmatic crystallization between 217 – 229 Ma of at least part of the orthogneisses. Refolding and conventional U-Pb geochronology of zircons from banded gneiss at El Chol yields early Paleozoic upper intercept ages and Carboniferous lower intercept ages, indicating that some of the units of the Chuacús Complex are older than Mesozoic. Bright CL metamorphic zircon rims from both samples contain low U (<60 ppm), and yield a weighted mean U238/Pb206 age of 75 ± 3 Ma (n = 7). Ages between 215 and 80 Ma are compatible with partial recrystallization of magmatic zircon or mixed analyses. Zircon rims of orthogneiss show less steep heavy REE patterns suggestive of growth in equilibrium with garnet, and are enriched in light REE. Eu anomalies in REE patterns indicate that cores and rims grew stable with plagioclase, and that neither represents the eclogite-facies event. This implies the ca. 75 Ma metamorphic age represents the epidote-amphibolite overprint, and constrains the high-pressure event to have occurred after the Triassic and before the Late Cretaceous.

Day 5: Tuesday, March 4th, 2025 – Antigua

7:00AM: Wake up, breakfast not included at hotel. Hotel does have a restaurant.
8:30AM: Depart from the hostel Drive to Antigua. Dirt road initially and then very windy.
10:30AM: North of El Chol there's a stop with Gneisses, amphiboles, garnets, feldpars, micas. Possible eclogite? Multiple phases of folding.
12:30AM: South of Granados we'd recross the Motagua and see the Subinal on top of the El Tambor again.
4:30PM: Check-in at the guesthouse

Selah Hotel y Coffee, Antigua
(https://hotel-selah.guatemalaantiguahotels.com/en/)
6ta Calle Poniente Casa No.58-1A, Antigua Guatemala, Guatemala
Email: selahotelantigua@gmail.com Phone: +502 7832 5063

6:00PM: Fend for yourself for dinner



STOP 5.1 – El Tambor Ophiolite:

Stops taken from this guidebook:

DERTS (Diamond Exploration and Research Training School), 2019, Ancient and Modern subduction and modern Volcanism in Guatemala. Field Trip Guidebook, 17 pgs.

Stops 1, 2, and 3: Sedimentary, mafic, and ultramafic rocks of the El Tambor ophiolite complex.

Location: Abundant roadside outcrops from south of Estensia Garcia on unnamed road at 14.878733N, 90.573160W to north of Estensia Garcia at 14.892488N, 90.565117W on RN-5.

Observations summary: Dismembered upper and possibly lower portion of the El Tambor ophiolite complex north of the Motagua fault zone. These outcrops consist of a melange of sheered mafic and marine carbonate blocks on a decimeter scale (Fig. 2.1A), sheered serpentinites (Fig. 2.1B to C), and more competent mafic blocks cut by pegmatitic dykes that are parallel to the Motagua Fault zone. These form portions of the El Tambor complex that is sandwiched between the North American and Caribbean plates along the Motagua fault zone.

Stop 4: Eclogite facies boulders of the Chuacus complex.

Location: Entrance to small creek by bridge on RN-5 at 14.895970N, 90.565156W.

Observations summary: Meter-scale intercalated layers of phengite-garnet metasediments, garnet-calcsilicates, and eclogites of the Chuacus complex (Fig 2.1F). Some outcrops exist, but for the most part these are boulders. The eclogite facies rocks are quite spectacular and the group spent some time here.

Stops 5 and 6: Orthogneisses and amphibolitized eclogites at Rio Agua Caliente and El Chol (Chuacús Complex).

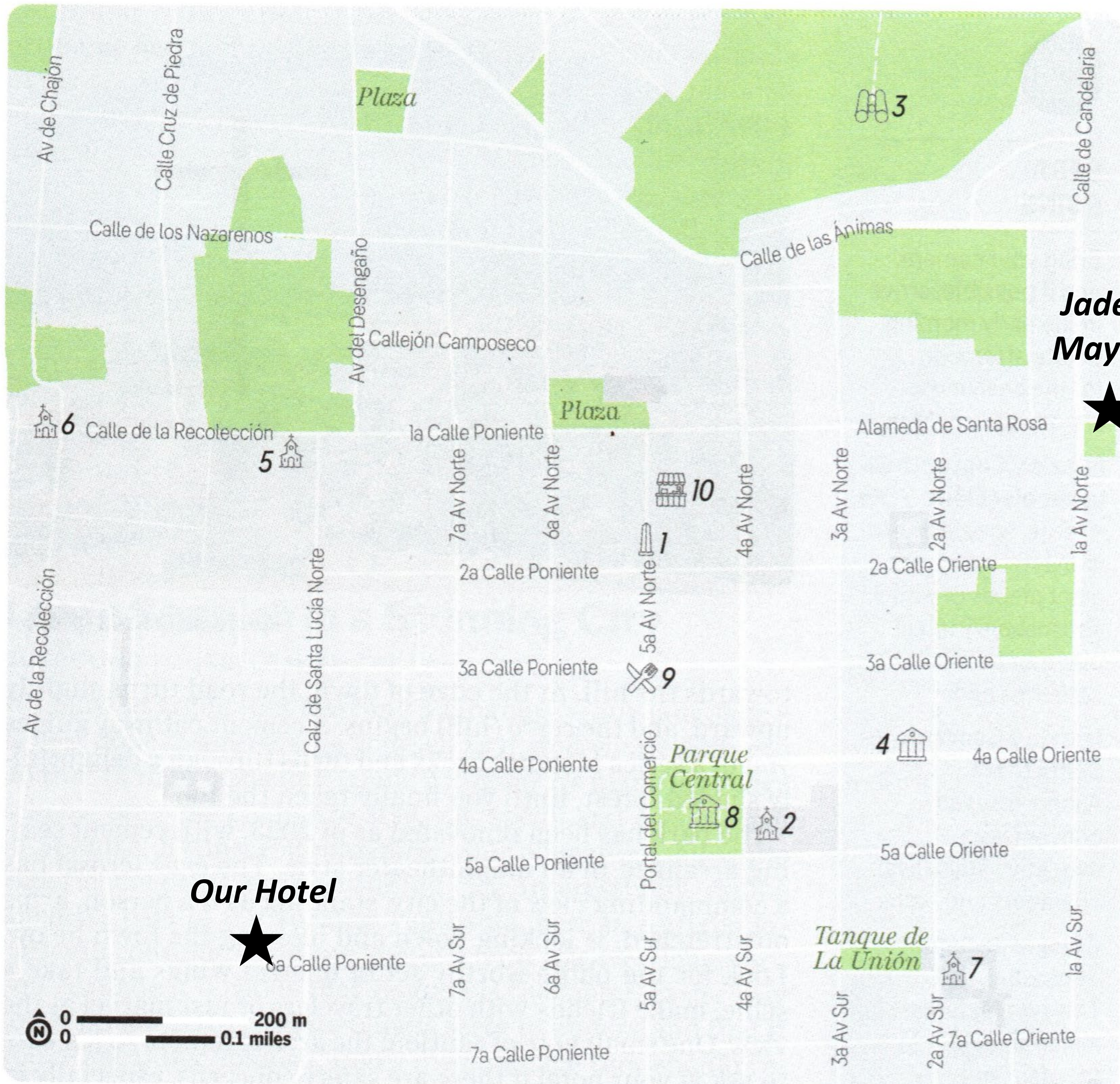
Location: At Rio Agua the entrance the river is at 14.934569N, 90.502123W and hiking NW along river for about 1km to outcrops. At El Chol these outcrops are located at creek in town at 14.964783N, 90.486764W.

Observations summary: Orthogneisses with garnet amphibolite lenses (Fig2.2). The amphibolite lenses contain remnants of omphacite and are interpreted to be retrogressed eclogites (Ortega-G, 2004).

Figure 2-1. Outcrops and hand samples from stops 1-4.
A) stop 1, tectonically intercalated carbonate and mafic blocks of the El Tambor ophiolite. B to D). Mafic block in a serpentinite melange of the El Tambor Complex, stop 2. E) Stop 4, garnet calcsilicate of the Chuacus complex. F) Eclogite from the Chuacus complex.

Figure 2-2 Orthogneisses and amphibolitized eclogites at Rio Agua Caliente and El Chol (Chuacús Complex).

STOP 5.2 – Antigua Map



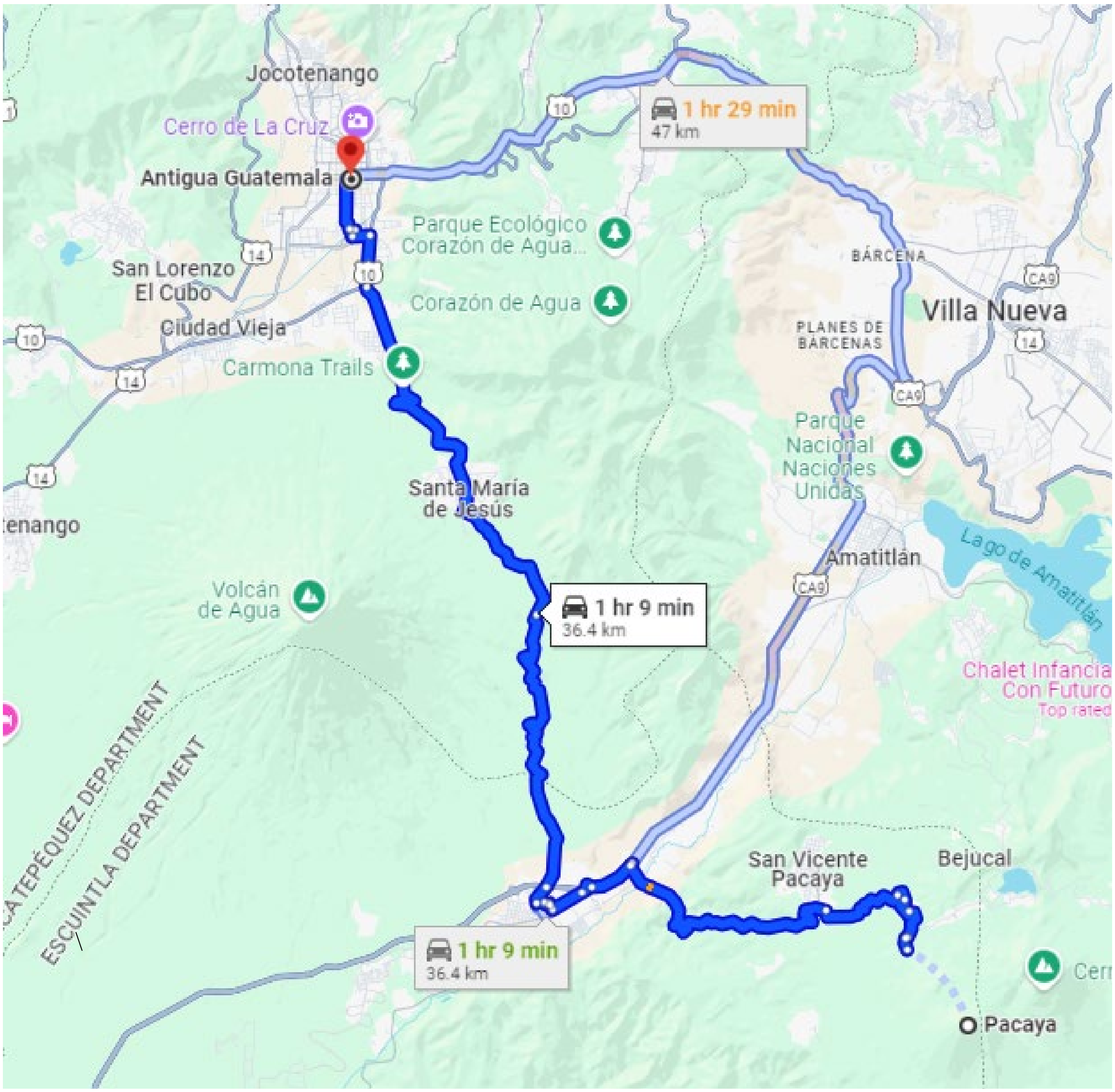
SIGHTS
1 Arco de Santa Catalina
2 Catedral de San José
3 Cerro de la Cruz
4 Choco Museo
5 Colegio de San Jerónimo
6 Iglesia y Convento de la Recolección
7 Iglesia y Convento de Santa Clara
8 Parque Central

EATING
9 Casa Troccoli

SHOPPING
10 Nim Po't

Day 6: Wednesday, March 5th, 2025 – Volcan Pacaya and Antigua

6:00AM: Wake-up, breakfast included at the guesthouse
7:00AM: Depart for Pacaya
8:30AM: Hike Volcan Pacaya
2:00PM: Return to Antigua – free day in the city
Suggestion: Looks like there is a Jade Lapidary workshop in Antigua that does tours, that might be cool. **Jade Maya, 4a Calle Ote. 34, Antigua Guatemala, Guatemala**
Looks Walkable



STOP 6.1 – Antigua UNESCO World Heritage Site:

This write-up was taken from the UNESCO website:

United Nations Educational, Scientific and Cultural Organization (UNESCO), World Heritage Listing for Antigua, Guatemala. https://whc.unesco.org/en/list/65/ accessed February, 15, 2025.

Antigua Guatemala

Antigua, the capital of the Captaincy-General of Guatemala, was founded in the early 16th century. Built 1,500 m above sea-level, in an earthquake-prone region, it was largely destroyed by an earthquake in 1773 but its principal monuments are still preserved as ruins. In the space of under three centuries the city, which was built on a grid pattern inspired by the Italian Renaissance, acquired a number of superb monuments.

Outstanding Universal Value

Brief Synthesis

Built 1,530.17 m above sea level in an earthquake-prone region, Antigua Guatemala, the capital of the Captaincy-General of Guatemala, was founded in 1524 as Santiago de Guatemala. It was subsequently destroyed by fire caused by an uprising of the indigenous population, re-established in 1527 and entirely buried as a result of earthquakes and an avalanche in 1541. The third location, in the Valley of Panchoy or Pacán, was inaugurated in March 1543 and served for 230 years. It survived natural disasters of floods, volcanic eruptions and other serious tremors until 1773 when the Santa Marta earthquakes destroyed much of the town. At this point, authorities ordered the relocation of the capital to a safer location region, which became Guatemala City, the county's modern capital. Some residents stayed behind in the original town, however, which became referred to as "La Antigua Guatemala".

Antigua Guatemala was the cultural, economic, religious, political and educational centre for the entire region until the capital was moved. In the space of under three centuries the city acquired a number of superb monuments.

The pattern of straight lines established by the grid of north-south and east-west streets and inspired by the Italian Renaissance, is one of the best examples in Latin American town planning and all that remains of the 16th-century city. Most of the surviving civil, religious, and civic buildings date from the 17th and 18th centuries and constitute magnificent examples of colonial architecture in the Americas. These buildings reflect a regional stylistic variation known as Barroco antigueño. Distinctive characteristics of this architectural style include the use of decorative stucco for interior and exterior ornamentation, main facades with a central window niche and often a deeply carved tympanum, massive buildings, and low bell towers designed to withstand the region's frequent earthquakes. Among the many significant historical buildings, the Palace of the Captains General, the Casa de la Moneda, the Cathedral, the Universidad de San Carlos, Las Capuchinas, La Merced, Santa Clara, among others, are worth noting.

The city lay mostly abandoned for almost a century until the mid-1800s when increased agricultural production, particularly coffee and grain, brought new investment to the region. The original urban core is small, measuring approximately 775 metres from north to south and 635 metres east to west, covering 49.57 hectares.

Criterion (ii): Antigua Guatemala contains living traces of Spanish culture with its principal monuments, built in the Baroque style of the 18th century preserved today as ruins. Antigua Guatemala was a centre for the exportation of religious images and statues to the rest of the American continent and to Spain during the 17th and 18th centuries.

Criterion (iii): Antigua Guatemala is one the earliest and outstanding examples of city planning in Latin America in which the basic grid plan, dating from 1543, has been maintained. Its religious, private and government buildings are outstanding evidences of Spanish colonial architecture in Antigua.

Criterion (iv): The many churches and monasteries in Antigua Guatemala testify to the influence of the Christian church, during the colonial period, on every aspect of daily life in the city. Barroco antigueño developed in this area, a regional adaptation of the Baroque style designed to withstand the earthquakes common in the region.

Integrity

Antigua Guatemala has retained the integrity of its 16th-century layout and the physical integrity of most of its built heritage. The relocation transfer of the capital after the 1773 earthquake and the abandonment of the area by most of its population permitted the preservation of many of its monumental Baroque-style buildings as ruins. In addition to vulnerability to natural disasters, including earthquakes, volcanic eruptions and hurricanes, the conditions of integrity for the property are threatened by tourist exploitation and uncontrolled growth. Further concerns on potential erosion of integrity include the illegal construction and gentrification as well as increased traffic through the historic district.

Authenticity

Due to the partial abandonment of the city in 1776, and the regulations prohibiting the repair and construction of new buildings, the city's 16th-century Renaissance grid pattern and Baroque-style monumental buildings and ruins have survived along with cobblestone streets, plazas with fountains, and domestic architecture.

While some of the original residences have been fully restored, new construction in recent years has followed a neo-colonial or "Antigua Style", which impacts the conditions of authenticity. Additional concerns relate to new development that has been inserted into existing ruins. For example, the modern hotel (Casa Santo Domingo) was constructed within the ruins of the Santo Domingo church and monastery, which also impact the form and function of buildings. Adaptative re-use of historic buildings, driven by tourism development pressures, is also a matter of concern to be addressed through the enforcement of regulations and development of adequate conservation guidelines.

Protection and management requirements

Legal protection for Antigua Guatemala was established in 1944, when the city was declared a national monument with the intention to protect it from uncontrolled industrial and urban development. However, as responsibility was not given to a specific institution, the actual enforcement of protective and regulatory measures was minimal. The Pan-American Institute of Geography and History declared it an American Historical Monument in 1965 which took affect four years later with the approval of Article 61 of the Constitution of the Republic of Guatemala, Legislative Decree 60-69 (Law for the Protection of the City of La Antigua Guatemala). The establishment of the "National Council for the Protection of Antigua Guatemala" in 1972 created an institution responsible for this protection and restoration of the city's monuments.

Modern development pressure and increased tourism in the area have required more protection for the historic area and certain initiatives, at both the community and legislative levels, have been undertaken. These include recently developed tools for promoting local awareness, the participation by the community association Salvemos Antigua (Save Antigua), as well as a public education campaign (with a newsletter, schoolchildren programs etc.) supported by the Japanese government. The revision of Antigua's Protection Law, which requires approval of Congress, has also been promoted to adequately respond to existing factors and threats. Sustaining the Outstanding Universal Value of the property will require not only the updating and enforcement of legislative and regulatory measures, but also the definition and efficient protection of a the buffer zone and the sustained implementation of a master plan. The latter will need to include provisions for risk preparedness and disaster risk management, particularly in light of the vulnerability of the property. Comprehensive visitor management and clear conservation guidance and policies, will also be crucial for the property.

STOP 6.2 – Volcan Pacaya

For this stop, I just grabbed the Wikipedia page:
Wikipedia, https://en.wikipedia.org/wiki/Pacaya, Accessed February 15, 2025

Pacaya Volcano

Pacaya is an active complex volcano in Guatemala, which first erupted approximately 23,000 years ago and has erupted at least 23 times since the Spanish conquest of Guatemala. It rises to an elevation of 2,552 metres (8,373 ft).[1] After being dormant for over 70 years, it began erupting vigorously in 1961 and has been erupting frequently since then. Much of its activity is Strombolian, but occasionally Plinian eruptions also occur, sometimes showering the area of the nearby Departments with ash.[1]

Pacaya is a popular tourist attraction. It is even the home to the popular Guatemala Impact Marathon which pioneered the use of a running route across the lava field created by the 2010 eruption and supports the local communities through runners endeavouring to complete the challenge.[2] It lies 30 kilometers (19 miles) southwest of Guatemala City and close to Antigua.[3] The volcano sits inside the Escuintla Department.[3][4] Volcano Boarding is also practiced on the craters of Pacaya.[5]

Villagers near Pacaya ignored an evacuation request as the volcano threw ash into the air in March 2021.[6]

Geological history

The Pacaya volcano is a part of the Central American Volcanic Arc, a chain of volcanoes stretching from the northwest to the southeast along the Pacific coast of Central America, formed by the tectonic subduction of the Cocos Tectonic Plate beneath the Caribbean Plate. Pacaya lies on the southern edge of a sizable volcanic caldera formed in the Pleistocene age which contains Lago de Amatitlán. This caldera has been the source of at least nine very large explosions over the past 300,000 years, erupting a total of about 70 cubic kilometres (17 cu mi) of magma.[1][7]

After the last caldera-forming eruption 23,000 years ago, several smaller vents within and around the caldera have seen eruptive activity. Pacaya is the largest post-caldera volcano, and has been one of Central America's most active volcanoes over the last 500 years. It has erupted at least 23 times since the Spanish conquest,[1][8] producing basalt and basaltic andesite.[9]

About 1,100 years ago the volcano's edifice collapsed, causing a huge landslide. Deposits from the landslide travelled about 25 kilometres (16 mi) from the volcano down to the Pacific coastal plain. The landslide left a large crater, within which the current active cone has grown. The presence of a magma chamber at shallow depths beneath Pacaya means that distortion of the cone leading to instability and future landslides remains a hazard to the surrounding areas.[1]

Recent eruptions

With its almost continuous activity, the volcano has been a popular location for tourism, and is easily accessible from Guatemala City and from Antigua. Pacaya and the surrounding area now lie within the Pacaya National Park, which was created to supervise and protect tourism in this region. The Pacaya Park generates its income from tour groups who are charged a fee of about100 Quetzales to enter the park.[10]

In 1998, several explosive eruptions emitted lava, debris and ash columns with a height of 1,500 m (4,900 ft) to 5,000 m (16,000 ft). The ash fall affected nearby cities including Guatemala city and La Aurora International Airport.[8]

During 2006, a slight increase in Pacaya's volcanic activity brought about the creation of several lava rivers that slowly flowed down its slope.[11] Word about these phenomena spread, and local tourism increased significantly.

May 2010 eruption

On May 27, 2010, the Pacaya volcano erupted, followed by several tremors. At approximately 20:00 hours there was a strong eruption ejecting debris and ash columns up to 1,500 metres (4,900 ft). Ash rained down in many Guatemalan cities to the northwest of the volcano, including Guatemala City.[12] The volcanic ash fall pelted Guatemala City, and the international airport, La Aurora. The National Coordinator for Disaster Reduction (CONRED) declared a red alert for the communities near the volcano and recommended the evacuation of some of them. Noti7 reporter Anibal Archila, one of the first to cover the event, was reportedly killed by volcanic debris.[13]

President Álvaro Colom declared a state of calamity in the region adjacent to the volcano, and the Ministry of Education closed the schools in the departments of Guatemala, Escuintla, and Sacatepequez. Heavy rainfall from Tropical Storm Agatha worsened the emergency situation, causing lahars, landslides and widespread flooding across the country. However, people working in coffee fields considered the rain brought by the storm to be helpful, removing ash from their trees.[14]

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Day 7: Thursday, March 6th, 2025 – Volcanoes around Lake Atitlan

7:00AM: Wake-up, breakfast included at hotel, pack our things, and load the vans.
8:00AM: Drive to San Pedro La Laguna, Laka Atitlan. Take the Southern Route down the RN14 with views of Fuego volcano.

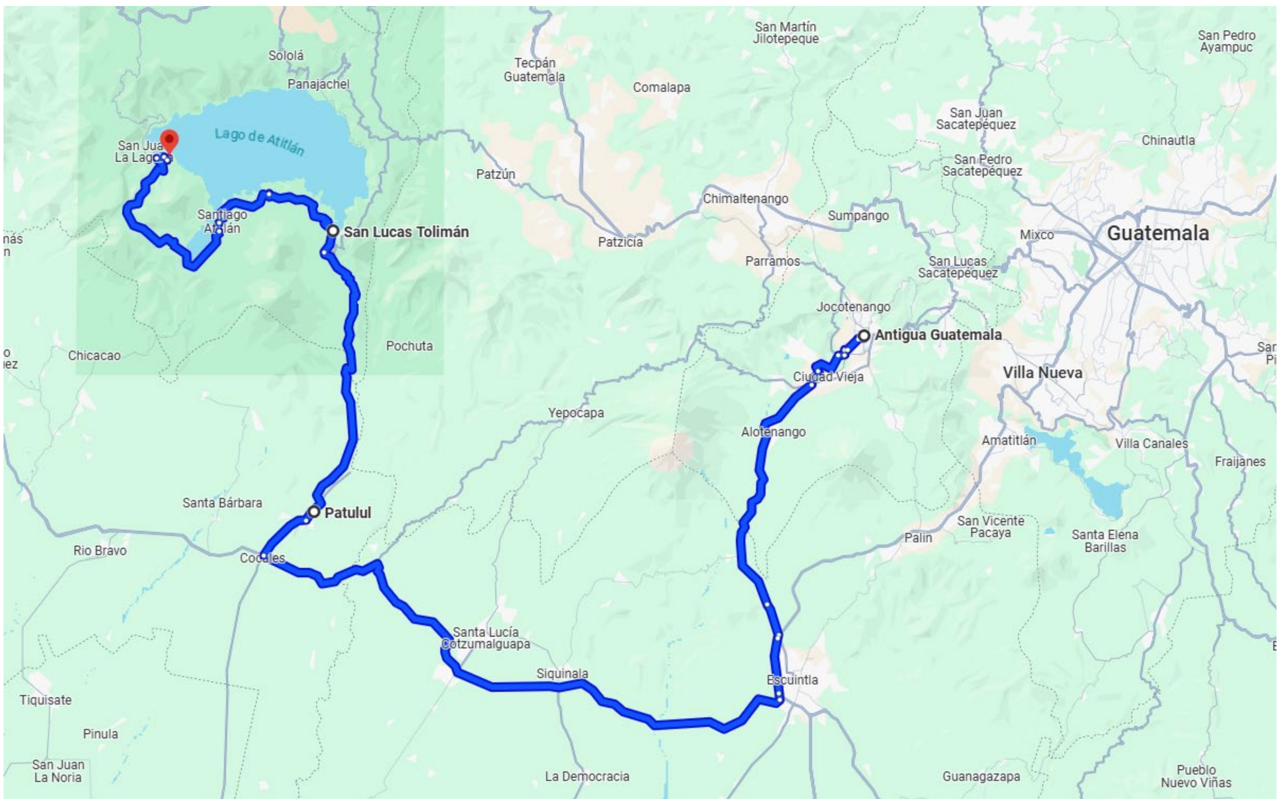
Discuss 2018 eruption.

Possible stop at quarry North of San Miguel Los Lotes to see PDC deposits that destroyed the town.

Lunch SantaLu Mall.

4:00PM: Arrive in Mikaso in San Pedro

Rest of the Day: Enjoy San Pedro and Lake Atitlan, you are on your own.



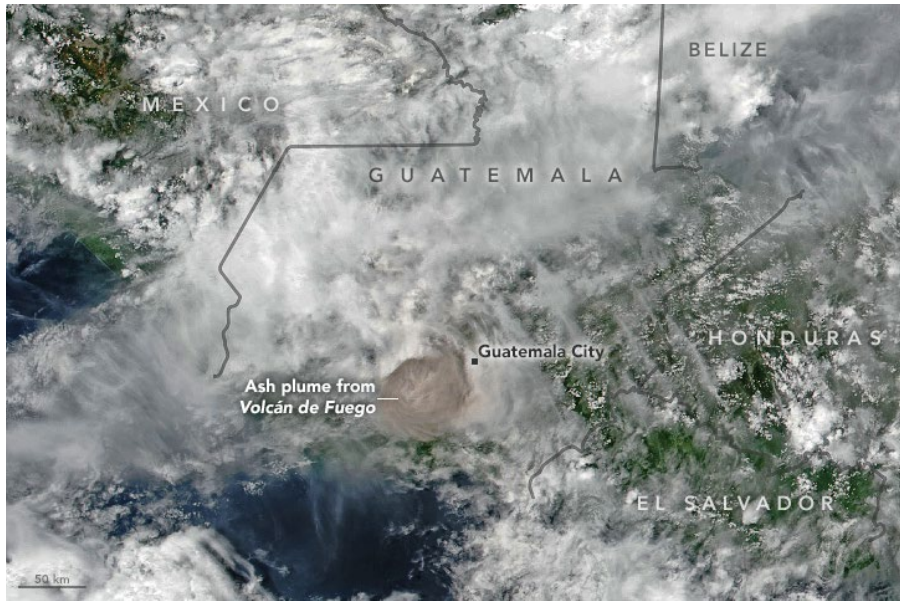
STOP 7.1 – Volcan Fuego

For this stop, I just grabbed the Wikipedia page:

Wikipedia, https://en.wikipedia.org/wiki/2018_Volc%C3%A1n_de_Fuego_eruption, Accessed February 15, 2025

2018 Volcán de Fuego eruption

The eruption produced a large ash plume fed by continuous explosions, pyroclastic flows, and lahars. Pyroclastic flows descended the Las Lajas ravine and overspilled its confines, causing the death of officially nearly 200 people. This was the deadliest eruption in Guatemala since the eruption of Volcán Santiaguito in 1902.



Ash plume from Volcan de Fuego during the eruption on 3 June

Background

Volcán de Fuego (Spanish for "Volcano of Fire") is one of the most active volcanoes in the world and is located 44 kilometres (27 mi) from Guatemala City.[2] It is a stratovolcano that has had more than 60 eruptions since 1524, including a major eruption in 1974 which produced pyroclastic flows and ashfall that destroyed the region's winter harvest and caused roof collapse and infrastructure damages in nearby towns.[3] The 3 June 2018 eruption is one of several eruptions of Guatemalan volcanoes that have caused many deaths, including the Santa María eruption of 1902[4] and the Santiaguito dome collapse of 1929, which killed hundreds.[5][6]

The most recent eruptive phase of Fuego began in 1999 and continues to the present day.[7] Since 1999, Fuego has had several large eruptions, including an eruption on 13 September 2012, in which authorities recommended the evacuation of 33,000 people.[8] In fact, approximately 5,000 people evacuated, and there were no reported deaths.[7] The last eruption of Fuego prior to 3 June 2018 happened on 31 January - 1 February 2018.[9]

The population around the volcano is estimated to be 54,000 within 10 kilometres (6.2 mi) and more than 1 million within 30 kilometres (19 mi).[10]

Events of eruption

Fuego began to show increased explosive activity from around 06:00 on the morning of Sunday 3 June 2018. The eruption continued to get stronger throughout the morning of 3 June, as explosions produced an ash plume that reached 15.2 km altitude and pyroclastic flows descended several of the ravines around the volcano.[9] Most of the injuries and fatalities happened in the towns of San Miguel Los Lotes and El Rodeo, located south-east of Fuego's summit in the Escuintla department.[11][12][13] San Miguel Los Lotes, located 2 kilometres (1.2 mi) north of El Rodeo, was covered with ash and rocks from pyroclastic flows.[4][14] The eruption prompted the evacuation of about 3,100 people from nearby areas. Ashfall forced the shutdown of La Aurora International Airport, Guatemala's primary airport,[15][4] where members of the Guatemalan military were deployed to remove ash off the runway;.[16] Although some flights were canceled, the airport was reopened on 4 June.[17]

The eruption produced an ash column approximately 15 kilometres (9.3 mi) in height.[18] Pyroclastic flows—fast-moving clouds of hot gas and volcanic matter[19]—caused many of the casualties and crop damage.[20][21] INSIVUMEH, Guatemala's national scientific monitoring agency, warned on 4 June that further pyroclastic flows and lahars (volcanic mudflows) were possible.[4] Heavy rainfall during and after the eruption produced large and fast-moving lahars. Volcanic material buried several of the affected villages and cut off roadways.[4] The poor weather and volcanic deposits complicated the recovery operation, and all rescue efforts were suspended overnight on 3 June.[22] The volcanic material also destroyed an estimated 21,000 acres (8,500 hectares) of corn, bean, and coffee crops.[23]

Continued volcanic activity in June

On 5 June, a second eruption occurred and prompted additional evacuations.[24] On 8 June, new volcanic flows prompted more evacuations of rescue workers and residents of the town of El Rodeo, who had recently returned to their homes and were told to leave once again.[25] On 9 June, additional lahars prompted preventive evacuations in Santa Lucía Cotzumalguapa.[26]

Later eruptions of Fuego in 2018

An eruption of Fuego occurred on 12–13 October 2018, producing lava fountaining and a lava flow reaching 1 km from the volcano's summit.[27] On 18 November 2018, Volcán de Fuego entered a new eruptive and violent phase that prompted preventive evacuations of approximately 4,000 people from communities near the volcano.[28] CONRED issued a red alert in the area that closed main roads and suspended flights at the La Aurora International Airport.[29]

Victims

At least 190 people were killed,[30] 57 injured, and 256 remained missing as of 30 July 2018[31]—including a number of children, a CONRED officer,[32] firefighters,[33] and a policeman[34]—although local residents estimate that approximately 2,000 people are buried[34] and a local organization said that up to 2,900 may have died.[35] Due to the intense heat and burn injuries, many bodies were planned to be identified with anthropological methods and DNA.[36][37] As of 18 June 2018, up to 159 cases entered the morgues,[38] with 85 of the victims having been identified.[39]

Animals

Animals such as dogs, cats, chickens, monkeys, donkeys and other species were found by rescuers with burns or blinded by the eruption.[40] In many cases urgent veterinary care was required to treat eye infections, respiratory problems, and burns caused by dust, hot ash and gas from the eruption.[41][42] In one instance, a dog led rescuers towards its destroyed owners' home, where his owner, and the rest of people in the house, had been killed.[43]

Response

Former President Jimmy Morales ordered three days of national mourning in response to the disaster[4] and visited some of the affected towns and villages in person on 4 June.[44] Messages of support, solidarity, and offers of assistance were given by various world leaders.[16]

The Coordinadora Nacional para la Reducción de Desastres (CONRED), Guatemala's disaster relief agency, reported that more than 1.7 million people have been affected by the eruption and its ashfall.[12] A state of emergency was declared in the departments of Escuintla, Chimaltenango, and Sacatepéquez.[45]

Organizations such as GoFundMe, Cruz Roja Guatemalteca, and The National Federation of Cooperatives are being used to raise physical and monetary donations to be dispersed to those affected by the eruption.[46] GoFundMe created a centralized hub for all verified campaigns that are providing aid to those affected.[47]

Severely wounded individuals are scheduled to receive medical attention in the United States and Mexico, and an emergency medical team from Shriners Hospitals for Children would travel from the United States.[48]

Recovery

The Guatemalan Mountain Rescue Brigade were already searching for a missing person when they suddenly realized that the volcano's activity had increased. Firefighters have been deployed in order to help evacuate residents and recover bodies.[49] Family members who grew tired of waiting for organized efforts by the government organized their own groups of recovery operations and defied police roadblocks to dig at the debris.[50]

A member of a firefighter support organization stated, "Basically there's no houses left, and to my assumption there's nobody left there... except the people doing the search and rescue." A volunteer firefighter added that the ground was very unstable and that breathing was difficult and firefighters' boot soles had been torn off because of the heat.[51]

Firefighters have stated that after 72 hours the chance of finding anyone alive would be nonexistent.[52]

Controversy

On 7 June, opposition politician Mario Taracena, in an address to Congress, accused the executive secretary of the National Coordination for Disaster Reduction (CONRED) of mismanaging the disaster warnings. The director of the National Institute for Seismology, Vulcanology, Meteorology and Hydrology also came under criticism for mismanagement and lack of warnings, a claim they refuted.[53] Taracena also called for a government investigation into potential criminal negligence.[54] A lawmaker told reporters that seismologists warned of the eruption eight hours before the main eruption, however, three hours later the national disaster agency CONRED called for voluntary evacuations only.[55][56] Mandatory evacuations were ordered at 3pm local time, after some communities were already covered by volcanic flow.[57]

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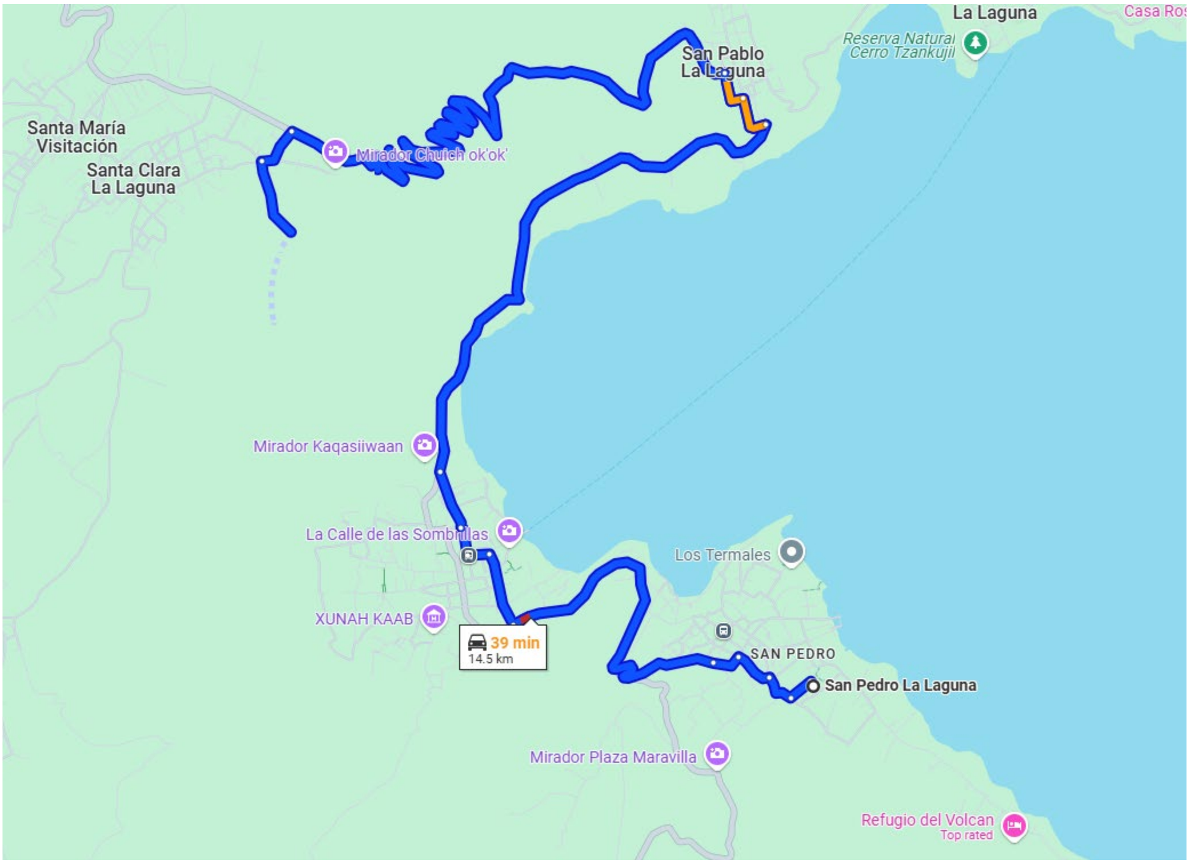
Day 8: Friday, March 7th, 2025 – Lake Atitlan and the Mayan Face

7:00AM: Wake-up, breakfast not included at the guesthouse – breakfast options close by Idea Connection
9:00AM: Depart for Mayan Face hike
1:30PM: Lunch San Juan
3:00PM: Women weaving collective in San Juan



STOP 8.1 – Lake Atitlan

For this stop, I just grabbed the Wikipedia page (I'm getting pretty lazy about this guidebook….):
Wikipedia, https://en.wikipedia.org/wiki/Lake_Atitl%C3%A1n, Accessed February 15, 2025

Lake Atitlán

Lake Atitlán (Spanish: Lago de Atitlán, [atiˈtlan]) is a lake in the Guatemalan Highlands of the Sierra Madre mountain range. The lake is located in the Sololá Department of southwestern Guatemala. It is known as the deepest lake in Central America.

Name

Atitlán means "between the waters". In the Nahuatl language, "atl" is the word for water,[2] and "titlan" means between.[3] The "tl" at the end of the word "atl" is dropped (because it is a grammatical suffix) and the words are combined to form "Atitlán".

Geography

The lake has a maximum depth of about 340 metres (1,120 ft)[1] and an average depth of 154 metres (505 ft).[4] Its surface area is 130.1 km2 (50.2 sq mi).[1] It is approximately 18 km × 8 km (11.2 mi × 5.0 mi) with around 20 km3 (4.8 cu mi) of water. Atitlán is an endorheic lake, fed by two nearby rivers and not draining into the ocean. It is shaped by deep surrounding escarpments and three volcanoes on its southern flank. The lake basin is volcanic in origin, filling an enormous caldera formed by a supervolcanic eruption 84,000 years ago.[citation needed] The culture of the towns and villages surrounding Lake Atitlán is influenced by the Maya people. The lake is about 50 kilometres (31 mi) west-northwest of Antigua. It should not be confused with the smaller Lake Amatitlán.

Lake Atitlán is renowned as one of the most beautiful lakes in the world, and is one of Guatemala's most important national and international tourist attractions.[4] German explorer and naturalist Alexander von Humboldt called it "the most beautiful lake in the world,"[5] and Aldous Huxley famously wrote of it in his 1934 travel book Beyond the Mexique Bay: "Lake Como, it seems to me, touches on the limit of permissibly picturesque, but Atitlán is Como with additional embellishments of several immense volcanoes. It really is too much of a good thing."[6]

The area around San Marcos has particularly tall cliffs abutting the lake and in recent years has become renowned for cliff diving.[7]

A view across Lake Atitlán from Panajachel to Volcán San Pedro

Agriculture

The area supports extensive coffee and avocado orchards and a variety of farm crops, most notably corn and onions. Significant agricultural crops include: corn, onions, beans, squash, tomatoes, cucumbers, garlic, chile verde, strawberries and pitahaya fruit. The lake itself is a significant food source for the largely indigenous population.

Geological history

Panorama view of the lake as seen from the top of Volcán San Pedro, or from the top towards the bottom of the satellite photo on the top of this page

The first volcanic activity in the region occurred about 11 million years ago, and since then the region has seen four separate episodes of volcanic growth and caldera collapse, the most recent of which began about 1.8 million years ago and culminated in the formation of the present caldera. The lake now fills a large part of the caldera, reaching depths of up to 340 m (1,120 ft).

The caldera-forming eruption is known as Los Chocoyos eruption and ejected up to 300 km3 (72 cu mi) of tephra. The enormous eruption dispersed ash over an area of some 6,000,000 square kilometres (2,300,000 sq mi): it has been detected from Florida to Ecuador, and can be used as a stratigraphic marker in both the Pacific and Atlantic oceans (known as Y-8 ash in marine deposits).[8] A chocoyo is a type of bird which is often found nesting in the relatively soft ash layer.

Since the end of Los Chocoyos, continuing volcanic activity has built three volcanoes in the caldera. Volcán Atitlán lies on the southern rim of the caldera, while Volcán San Pedro and Volcán Tolimán lie within the caldera. San Pedro is the oldest of the three and seems to have stopped erupting about 40,000 years ago. Tolimán began growing after San Pedro stopped erupting and probably remains active, although it has not erupted in historic times. Atitlán has developed almost entirely in the last 10,000 years and remains active, its most recent eruption having occurred in 1853.

On February 4, 1976, a very large earthquake (magnitude 7.5) struck Guatemala, killing more than 26,000 people. The earthquake fractured the lake bed and caused subsurface drainage from the lake, allowing the water level to drop two metres (6 ft 7 in) within one month.[9][10]

Ecological history

In 1955, the area around Lake Atitlán became a national park. The lake was mostly unknown to the rest of the world, and Guatemala was seeking ways to increase tourism and boost the local economy. It was suggested by Pan American World Airways that stocking the lake with a fish prized by anglers would be a way to do just that.[11] As a result, an exotic non-native species, the black bass, was introduced into the lake in 1958. The bass quickly took to its new home and caused a radical change in the species composition of the lake. The predatory bass caused the elimination of more than two-thirds of the native fish species in the lake and contributed to the extinction of the Atitlan grebe, a rare bird that lived only in the vicinity of Lake Atitlán.[12]

A unique aspect of the climate is what is referred to as Xocomil (of the Kaqchickel language meaning "the wind that carried away sin"). This wind is common late morning and afternoon across the lake; it is said to be the encounter of warm winds from Pacific meeting colder winds from the North. The winds can result in violent water turbulence, enough to capsize boats.[13]

In August 2015 a thick bloom of algae known as Microcystis cyanobacteria re-appeared in Lake Atitlan; the first major occurrence was in 2009. Bureaucratic red tape has been blamed for the lack of action to save the lake. If current activities continue unchecked, the toxification of the lake will make it unsuitable for human use.[14]

Culture

The lake is surrounded by many villages in which Maya culture is still prevalent and traditional dress is worn. The Maya people of Atitlán are predominantly Tz'utujil and Kaqchikel. During the Spanish conquest of the Americas, the Kaqchikel initially allied themselves with the invaders to defeat their historic enemies, the Tz'utujil and K'iche' Maya, but were themselves conquered and subdued when they refused to pay tribute to the Spanish.

San Pedro la Laguna and Volcán San Pedro

Santiago Atitlán is the largest of the lakeside communities, and it is noted for its worship of Maximón, an idol formed by the fusion of traditional Mayan deities, Catholic saints, and conquistador legends. The institutionalized effigy of Maximón is under the control of a local religious brotherhood and resides in various houses of its membership during the course of a year, being most ceremonially moved in a grand procession during Semana Santa. Several towns in Guatemala have similar cults, most notably the cult of San Simón in Zunil.

View from Hotel Atitlán near Panajachel

While Maya culture is predominant in most lakeside communities, Panajachel has been overwhelmed over the years by Guatemalan and foreign tourists. It attracted many hippies in the 1960s, and although the civil war caused many foreigners to leave, the end of hostilities in 1996 saw visitor numbers boom again, and the town's economy is almost entirely reliant on tourism today.

Several Mayan archeological sites have been found at the lake. Sambaj, located approximately 55 feet below the current lake level, appears to be from at least the pre-classic period.[15] There are remains of multiple groups of buildings, including one particular group of large buildings that are believed to have been the city center.[15]

A project titled "Underwater archeology in the Lake Atitlán. Sambaj 2003 Guatemala" was recently approved by the Government of Guatemala in cooperation with Fundación Albenga and the Lake Museum in Atitlán. Because of the concerns of a private organization as is the Lake Museum in Atitlán the need to start the exploration of the inland waters in Guatemala was analyzed.[16]

There is no road that circles the lake. Communities are reached by boat or roads from the mountains that may have brief extensions along the shore. Jaibalito can only be reached by boat. Santa Catarina Palopó and San Antonio Palopó are linked by road to Panajachel. Main places otherwise are Santa Clara La Laguna, San Juan La Laguna, and San Pedro La Laguna in the west; Santiago Atitlán in the south; Cerro de Oro in the southeast; and San Lucas Tolimán in the east.

Recent studies indicate that a ceremonial site named Samabaj was located on an island about 500 metres (1,600 ft) long in Lake Atitlán. The site was revered for its striking connection to the Popol Wuj of the K'iche' Mayan peoples.

Lake Atitlán, from Tzam Poc Hotel near Santa Catarina Palopó

Guatemalan civil war

During the Guatemalan Civil War (1960 - 1996), the lake was the scene of many terrible human rights abuses, as the government pursued a scorched earth policy.[17][18] Indigenous people were assumed to be universally supportive of the guerrillas who were fighting against the government, and were targeted for brutal reprisals.[17][18] Some believe that hundreds of Maya from Santiago Atitlán have disappeared during the conflict.[19][20]

Two events of this era made international news. One was the assassination of Stanley Rother, a missionary from Oklahoma, in the church at Santiago Atitlán in 1981.[21] In 1990, a spontaneous protest march to the army base on the edge of town was met by gunfire, resulting in the death of 11 unarmed civilians.[22] International pressure forced the Guatemalan government to close the base and declare Santiago Atitlán a "military-free zone". The memorial commemorating the massacre was damaged in the 2005 mudslide.

Hurricane

Torrential rains from Hurricane Stan caused extensive damage throughout Guatemala in early October 2005, particularly around Lake Atitlán. A massive landslide buried the lakeside village of Panabaj, causing the death of as many as 1,400 residents, leaving 5,000 homeless, and many bodies buried under tonnes of earth. Following this event, Diego Esquina Mendoza, the mayor of Santiago Atitlán, declared the community a mass gravesite: "Those buried by the mudslide may never be rescued. Here they will stay buried, under five meters of mud. Panabáj is now a cemetery."[23]

Four and a half years after Hurricane Stan, Tropical Storm Agatha dropped even more rainfall causing extensive damages to the region[24] resulting in dozens of deaths between San Lucas Tolimán and San Antonio Palopó. Since then roads have been reopened and travel to the region has returned to normal.

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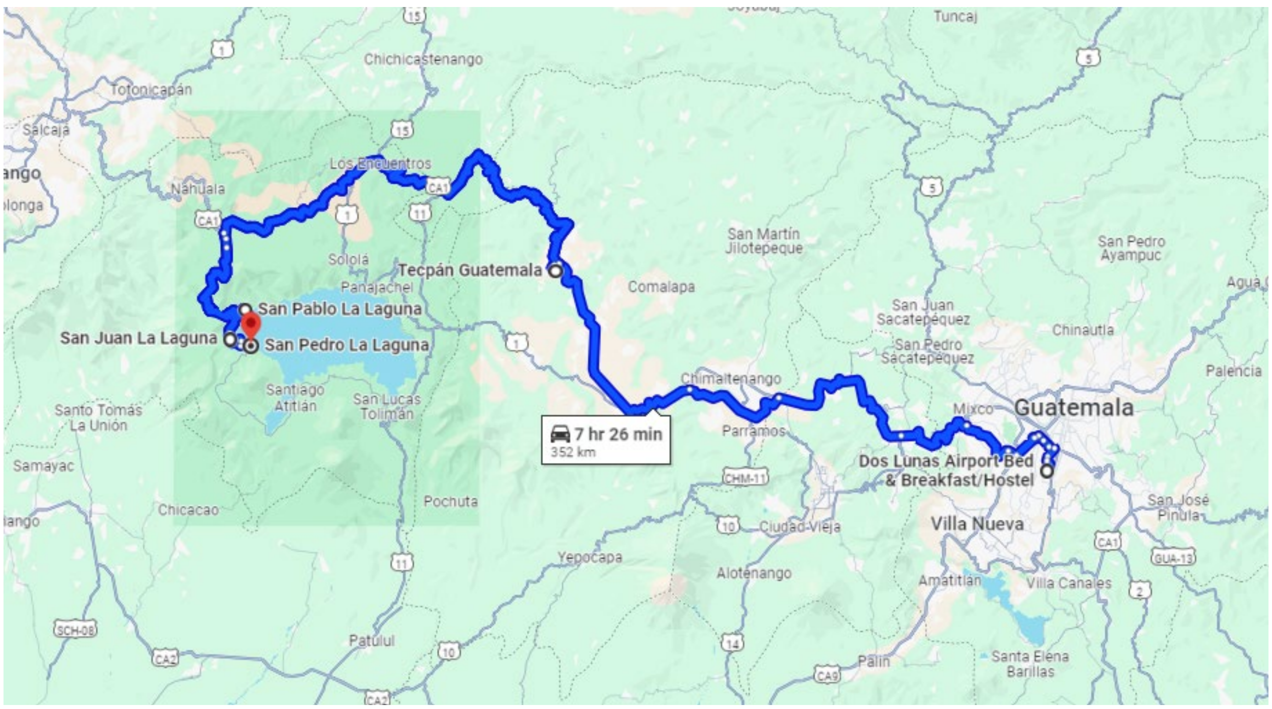
Day 9: Saturday, March 8th, 2025 – Geology and Archeology Stops on our way back to the airport

7:30AM: Wake-up, breakfast not included at hotel
8:30AM: Depart the hotel
One stop outside of San Juan La Laguna. Massive intrusive (Atitlan 2 Caldera leftovers?), fault breccia on top, massive pumice deposits. Co-Atitlan 3 Caldera formation?
Stop on the CA1 at massive Atitlan 3 Ignimbrite deposits. Near Maria Tecun
1:00PM: Grocery store lunch Maybe at Iximche ruins
4:00PM: Leave Iximche Ruins
7:00PM: Dinner close to the airport
9:00PM: Arrive at the airport

+502 3168 8625



STOP 8.1 – Atitlan intrusives, fault breccias, & massive pumice deposits
I need to get some details for this stop

STOP 8.2 – Massive Atitlan 3 ignimbrite deposits
I need to get some details for this stop

STOP 8.3 – Iximche Ruins

For this stop, I grabbed what was posted on the "Mayan Ruins Website":

Mayan Ruins Website, https://www.themayanruinswebsite.com/iximche.html, Accessed February 15, 2025

IXIMCHE-Chimaltenango Department, Guatemala

DESCRIPTION

Iximche is a late Post Classic (1250-1525) capital of the Kaqchikel Maya. Its name means "Place of the Maize/Ramon tree". It is located in the Central Guatemalan Highlands at an elevation of around 7,4723 feet/2,277 meters. In common with other Highland Postclassic sites, it is defensively situated on a modified plateau surrounded by deep ravines.

The site is a well-planned urban center featuring six plazas and over 170 structures set on an NW/SE axis. Most of the structures at the site possess finely worked masonry and exhibit a Central Mexico Talud-Tablero style. The construction techniques and the ceramics recovered are similar to those observed at the sites of Zacelau and Mixco Viejo.

Iximché is located in the municipality of Tecpán, in Chimaltenango Department, 25 miles/40 km from the departmental capital, and 56 miles/91 km from Guatemala City. From the Capital take Highway CA1, driving to western Guatemala through Chimaltenango. Once in the town of Tecpán follow the main road southwest out of town for 2.5 miles/3.8 kilometers until you reach the archaeological site. The site today is considered a pilgrimage/ceremonial site for many Maya, inculding shamans and aj q'ijab/daykeepers.

HOURS:8 A.M.-4 P.M, everyday
ENTRANCE FEE: $6.50/50 Quetzals
GUIDES: no official guides on site, though informal guides can be found outside the gate, and in Tecpán
SERVICES: Bathrooms, Service kiosk
ON-SITE MUSEUM: small on-site museum
ACCOMMODATIONS: Tecpán, Chimaltenango, day trip from the Capital
GPS: 14d 44' 8" N, 90d 59' 46" W

HISTORY AND EXPLORATION

Ceramic evidence points to a minor presence back to the Late Pre-Classic (300 B.C-250 A.D). The history of the site as it is seen today, while brief, is well documented as the site was a thriving city at the time of the Spanish onslaught. A Colonial document, The Annals of the Cakchikuels, provides a written history of the Kaqchikel people from their beginnings through the Spanish conquest. Spanish chronicles also provide information about the site. One of the most important sources of Mayan theology, and history of the K'iche, a related group, comes from the 16th century book, Popol Vuh.

The Kaqchikel were in an alliance with, and subordinate to, the neighboring K'iche Kingdom. After disagreements with these K'iche lords, the Kaqchikel left the K'iche capital of Q'umarkaj and founded their own capital and Kingdom at Iximche in 1470.

Iximche was administered by four clan leaders, with the two senior clan lineage leaders acting as co-rulers. The first among equals was a lord of the Sotz'il clan, Hun-Toh. The second co-ruler was Wuqu Batz of the Xahil clan. The other two lesser clans were the K'alel Achi and Ahuchan.

Intra-tribal and clan warfare was continuous, and left the Kaqchikel and K'iche people in a weakened state upon the arrival of the Spanish in 1524. After foolishly becoming allies of the Spanish, the Kaqchikel eventually revolted against them with the inevitable result; Iximche was abandoned in 1525, and later destroyed by the Spanish in 1526.

Iximche was first reported on by the soldier-chronicler Bernal Diaz del Castillo in1526, and later published in his memoirs. Francisci de Fuentes y Guzman wrote an informative report in 1690. The next visitors of note were that dynamic duo of John L. Stephens and Frederick Catherwood in 1840. Next came Alfred Maudslay in1887. Modern research began in 1956 under Janos de Szecsy followed by George Guillemin in a multi-year investigation from 1959-1972. Restorations and consolidations have continued.

STRUCTURES

Site Plan

Iximche is made up of six plazas that contain one or more pyramids, altars, sub-plazas, courtyards, and numerous raised platforms for residences and civic/ceremonial structures. Two of these plazas also have a ballcourt. It would seem that each plaza formed an individual complex that was devoted to one of the clans that administered the city. The streets linking each plaza were well-defined. A moat at one time bisected the city that was utilized for drainage and defense. There are two structural groups that may have been of a communal nature, and several small residential areas and complexes that developed as the city grew.

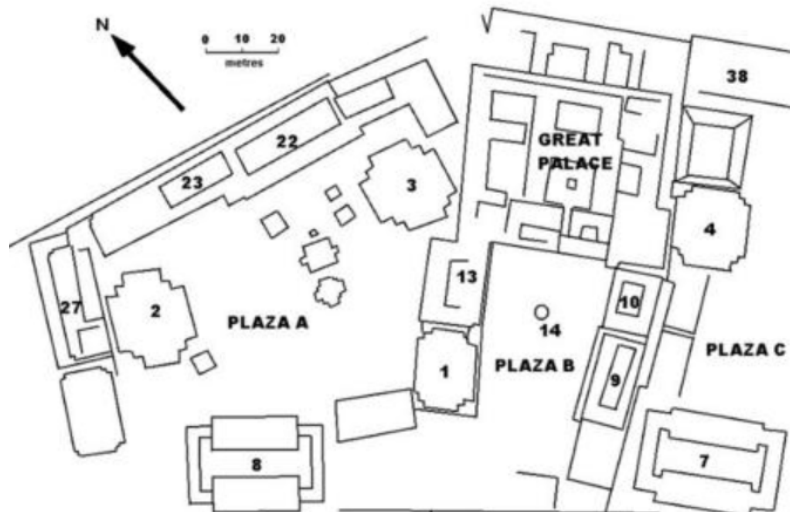
The pyramidal structures were of a rubble core finished with well-cut ashlar stone facades covered with a stucco coating, some of which remains. Both the central stairways and the corners were inset, a trait common to the Central Guatemala Highlands. The temples atop the pyramids were composed of adobe walls, with some stone columns, and wood beam roofs. The exterior and interior walls were covered with brightly painted murals, little of which survives today. Many of these structures exhibit multiple construction phases, as was typical with the Maya.

The other civic, administrative, religious and residential areas were all built atop raised platforms. These too had adobe wall and wood roofed structures which, unfortunately, have all been destroyed with the passage of time. Only their foundation outlines atop the solid stone platforms remain.

The first two structural groups seen upon entering the site are divided by the original entry pathway. These are called here the Northwest Group and the Northeast Group. The Northeast Group is bounded completely on the north side by a long mound 167 feet/51 meters in length. Its height is about 8-10 feet/2.5-3.75 meters. The plaza expands out from there 181 feet/55 meters. An unexcavated, small platform is in the center.

The Northwest Group has been considered by some to be a marketplace. It is composed of several sub-plazas that run the length of the entry pathway, and then on behind Ballcourt 1. Numerous raised platforms and small pyramid mounds are located here. The entry pathway itself ends at Structure 8/Ballcourt 1, in Plaza A.

Plaza A, along with Plaza B, is considered to have been the domain of the Sotz'il clan. Plaza A has two pyramidal structures, a ballcourt, and a number of platforms that once housed structures of a perishable nature. The main structure here is Structure 2.



Structure 2 is a multi-tiered pyramid with a single, inset, central stairway that leads up from the plaza. It has only been partially excavated and restored, with an original height of about 26 feet/8 meters. The temple atop the pyramid contained a large chamber entered through three doorways. Vivid murals once graced the columns and interior walls. A small shrine room was at the rear of the structure. A violent earthquake destroyed this temple in1976. It is located on the west side of the plaza.

In front of Structure 2 is a platform that may have been used in dance or ceremonial purposes. A cache of skulls was recovered from the structure leading some to compare it to the central Mexican skull platforms known as a Tzompantli. Immediately behind Structure 2 is a low mound wherein a significant burial, 27A, of an elite personage was found. This burial contained numerous items of obsidian, jade, shell, and gold reflecting the high degree of trade that Iximche engaged in.

Structure 3 is a pyramidal structure located across the plaza from Structure 2. It has been mostly excavated though not completely restored. It reaches a height of 23 feet/7 meters. A single chamber once crowned the summit. Fragments of two large incense burners were located here. In front of this structure are two small platforms and one circular altar.

Next to Structure 3 on the east side of the plaza are the back sides of two structures that are part of Plaza B. In the center of the plaza are two very low platforms that have an outline similar to Structures 2 and 3.

The north side of the plaza is taken up by a long platform that houses Structures 22 and 23. The remains of these single-story structures indicate they may have been of a civic/administrative nature. Three sets of steps extend down to the plaza floor.

The ballcourt, Ballcourt 1, is located on the south side of the plaza. It incorporates closed end zones with elevated stairways upon both. While the adobe superstructures have collapsed, the ballcourt itself has been nicely restored. No markers or ballcourt rings have been discovered.

Plaza B is adjacent to Plaza A, and is entered from the northwest. It is in the shape of a squared horseshoe with the south side open. There are two principal structures here; Structure 1, and the Grand Palace.

The Grand Palace is built atop a large platform base, about 10 feet/3 meters in height, and is thought to have been the principle residential area of the Sotz'il clan. This area consists of eight interconnected courtyards that held twenty-five structures of a perishable nature. Sunken hearths and benches have been identified within the structures with altars in the center of the courtyards. The residential area was increased over time as the city grew, and is located on the east side of the plaza. Its final area has been calculated at 32,292 sq feet/3,000 sq meters.

Structure 1 is a fully restored, truncated, stepped pyramid. A central stairway leads up from the plaza to a small raised platform that most likely held a temple structure now disintegrated. Its height is 16 feet/5 meters, and is located on the southwest corner of the plaza.

Structure 13 is next to Structure 1 and is a large platform accessed by a single, central stairway. Both these structures have their back to Plaza A.

On the opposite side of the plaza are found Structures 9 and 10, both sharing the same platform base, and believed to have been of a civic/administrative nature. A circular altar is located in the center of the plaza. Backing onto Structures 9, 10 and the Grand Palace, is Plaza C. Plaza C is thought to have been under the control of the Xajil clan. It combines the structural components found in Plazas A and B, and is the largest plaza at the site.

There are three pyramidal structures, Structures 4-6, that ring the plaza. They are about 20-26 feet/6-8 meters in height, and all have inset corners and central, recessed stairways that face onto the plaza. Structure 4 shows the most restoration work, though none of the summits that once held a temple structure have been restored.

Structure 4 is located on the northwest side of the plaza, with Structure 5 directly across from it on the northeast side. Structure 6 found on the southwest side of the plaza. Behind it is Structure7/Ballcourt 2.

Structure 7 is similar in design to Ballcourt 1. It has been mostly excavated, though the playing field has not been cleared. No ballcourt markers or rings have been recovered.

The southeast corner of the plaza is taken up by a large residential area called the Small Palace/Grand Palace II, and is similar in layout to the Grand Palace in Plaza B. There are a number of low platforms that surround sunken courtyards and which once housed nineteen adobe structures. The remains of an altar are located within each courtyard.

The north side of Plaza C is taken up by a long, low platform, Structure 38, that measures about 198 feet/61 meters in length. It once incorporated three structures of a perishable material, with each structure having its own set of steps to the plaza. These structures may have functioned in a similar civic/administrative manner as Structures 22 and 23 in Plaza A.

Plazas D-F contain mostly smaller, unexcavated mounds and are similar in layout to the preceding plazas. Plaza D has been cleared of the forest and undergrowth. Plaza F is the farthest from the entrance, and contains a small, partially excavated structure that is used by modern K'iche Maya for ceremonial purposes. There are some smaller groups of residential/ceremonial areas that hug the edges of the plateau, especially on the south side.

STOP 8.4 – Restaurant near the Airport

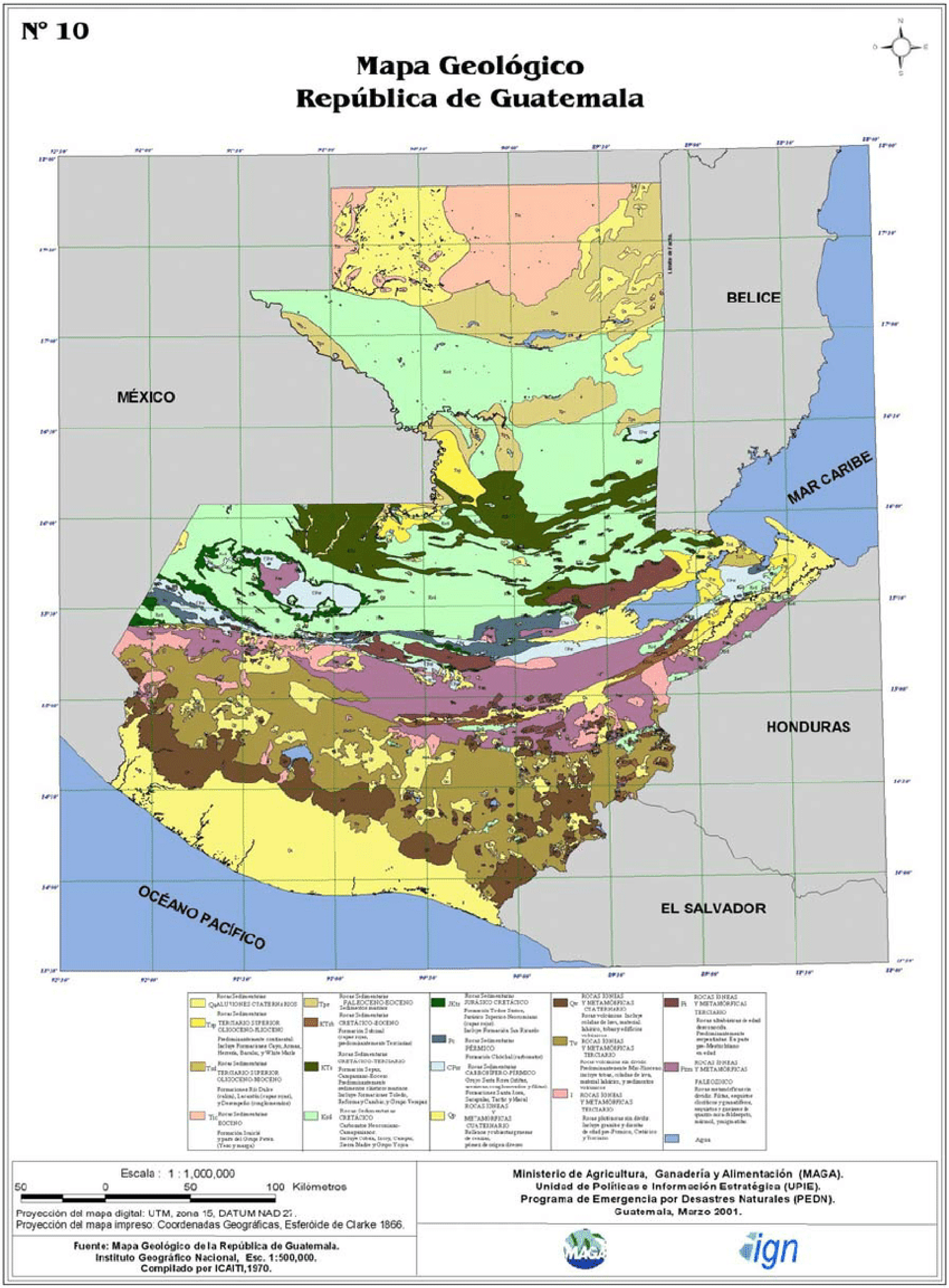
We'll have a nice dinner before getting to the airport at 9 PM for our midnight flight.

Day 10: Sunday, March 9th, 2025 – In transit and Return home

Flight #1: <u>*Departure:*</u> United Airlines, UA 1562, Sun 28 Mar 2025, 12:05 AM, La Aurora International Airport, Guatemala City (GUA)
<u>*Arrival:*</u> Sun 9 Mar 2025, 6:15 AM, Washington Dulles International (IAD)

Flight #2: <u>*Departure:*</u> United Airlines, UA 5046, Sun 9 Mar 2025, 12:35 PM, Washington Dulles International (IAD)
<u>*Arrival:*</u> Sun 9 Mar 2025, 1:32 PM, John Murtha Johnstown-Cambria County Airport (JST)

GEOLOGIC MAP OF GUATEMALA



GEOLOGIC SAMPLES FOR THE PITT-JOHNSTOWN COLLECTION

Number	Sample	Description & Location
GUA25-001		
GUA25-002		
GUA25-003		
GUA25-004		
GUA25-005		
GUA25-006		
GUA25-007		
GUA25-008		
GUA25-009		
GUA25-010		

Number	Sample	Description & Location
GUA25-011		
GUA25-012		
GUA25-013		
GUA25-014		
GUA25-015		
GUA25-016		
GUA25-017		
GUA25-018		
GUA25-019		
GUA25-020		

GLOSSARY OF GEOLOGIC TERMS

Most of the definitions were taken from Wikipedia or random locations on the internet.

Aa: Hawaiian word used to describe a lava flow whose surface is broken into rough angular fragments.
Accessory: A mineral whose presence in a rock is not essential to the proper classification of the rock.
Accidental: Pyroclastic rocks that are formed from fragments of non-volcanic rocks or from volcanic rocks not related to the erupting volcano.
Accretionary Lava Ball: A rounded mass, ranging in diameter from a few centimeters to several meters, [carried] on the surface of a lava flow (e.g., 'a'a) or on cinder-cone slopes [and formed] by the molding of viscous lava around a core of already solidified lava.
Acid: A descriptive term applied to igneous rocks with more than 60% silica (SiO_2).
Active Volcano: A volcano that is erupting. Also, a volcano that is not presently erupting, but that has erupted within historical time and is considered likely to do so in the future.
Agglutinate: A pyroclastic deposit consisting of an accumulation of originally plastic ejecta and formed by the coherence of the fragments upon solidification.
Alkalic: Rocks which contain above average amounts of sodium and/or potassium for the group of rocks for which it belongs. For example, the basalts of the capping stage of Hawaiian volcanoes are alkalic. They contain more sodium and/or potassium than the shield-building basalts that make the bulk of the volcano.
Andesite: Volcanic rock (or lava) characteristically medium dark in color and containing 54 to 62 percent silica and moderate amounts of iron and magnesium.
Ankaramite: is volcanic rock type of mafic composition. It is a dark porphyritic variety of basanite containing abundant pyroxene and olivine phenocrysts. It contains minor amounts of plagioclase and accessory biotite, apatite, and iron oxides. An ankaramite is a pyroxene-rich basalt and is the pyroxene equivalent of a picrite.
Ash: Fine particles of pulverized rock blown from an explosion vent. Measuring less than 1/10 inch in diameter, ash may be either solid or molten when first erupted. By far the most common variety is vitric ash (glassy particles formed by gas bubbles bursting through liquid magma).
Ashfall (Airfall): Volcanic ash that has fallen through the air from an eruption cloud. A deposit so formed is usually well sorted and layered.
Ash Flow: A turbulent mixture of gas and rock fragments, most of which are ash-sized particles, ejected violently from a crater or fissure. The mass of pyroclastics is normally of very high temperature and moves rapidly down the slopes or even along a level surface.
Asthenosphere: The shell within the earth, some tens of kilometers below the surface and of undefined thickness, which is a shell of weakness where plastic movements take place to permit pressure adjustments.
Aquifer: A body of rock that contains significant quantities of water that can be tapped by wells or springs.
Avalanche: A large mass of material or mixtures of material falling or sliding rapidly under the force of gravity. Avalanches often are classified by their content, such as snow, ice, soil, or rock avalanches. A mixture of these materials is a debris avalanche.
Basalt: Volcanic rock (or lava) that characteristically is dark in color, contains 45% to 54% silica, and generally is rich in iron and magnesium.
Basement: The undifferentiated rocks that underlie the rocks of interest in an area.
Basic: A descriptive term applied to igneous rocks (basalt and gabbro) with silica (SiO_2) between 44% and 52%.

Bench: The unstable, newly-formed front of a lava delta.

Blister: A swelling of the crust of a lava flow formed by the puffing-up of gas or vapor beneath the flow. Blisters are about 1 meter in diameter and hollow.

Block: Angular chunk of solid rock ejected during an eruption.

Bomb: Fragment of molten or semi-molten rock, 2 1/2 inches to many feet in diameter, which is blown out during an eruption. Because of their plastic condition, bombs are often modified in shape during their flight or upon impact.

Caldera: The Spanish word for cauldron, a basin-shaped volcanic depression; by definition, at least a mile in diameter. Such large depressions are typically formed by the subsidence of volcanoes. Crater Lake occupies the best-known caldera in the Cascades.

Capping Stage: Refers to a stage in the evolution of a typical Hawaiian volcano during which alkalic, basalt, and related rocks build a steeply, sloping cap on the main shield of the volcano. Eruptions are less frequent, but more explosive. The summit caldera may be buried.

Central Vent: A central vent is an opening at the Earth's surface of a volcanic conduit of cylindrical or pipe-like form.

Central Volcano: A volcano constructed by the ejection of debris and lava flows from a central point, forming a more or less symmetrical volcano.

Cinder Cone: A volcanic cone built entirely of loose fragmented material (pyroclastics.)

Cirque: A steep-walled horseshoe-shaped recess high on a mountain that is formed by glacial erosion.

Cleavage: The breaking of a mineral along crystallographic weak lattice planes that reflect weaknesses in a crystal structure.

Composite Volcano: A steep volcanic cone built by both lava flows and pyroclastic eruptions.

Compound Volcano: A volcano that consists of a complex of two or more vents, or a volcano that has an associated volcanic dome, either in its crater or on its flanks. Examples are Vesuvius and Mont Pelee.

Compression Waves: Earthquake waves that move like a slinky. As the wave moves to the left, for example, it expands and compresses in the same direction as it moves.

Conduit: A passage followed by magma in a volcano.

Continental Crust: Solid, outer layers of the earth, including the rocks of the continents.

Continental Drift: The theory that horizontal movement of the earth's surface causes slow, relative movements of the continents toward or away from one another.

Country Rocks: The rock intruded by and surrounding an igneous intrusion.

Crater: A steep-sided, usually circular depression formed by either explosion or collapse at a volcanic vent.

Craton: A part of the earth's crust that has attained stability and has been little deformed for a prolonged period.

Curtain of Fire: A row of coalescing lava fountains along a fissure; a typical feature of a Hawaiian-type eruption.

Dacite: Volcanic rock (or lava) that characteristically is light in color and contains 62% to 69% silica and moderate a mounts of sodium and potassium.

Debris Avalanche: A rapid and unusually sudden sliding or flowage of unsorted masses of rock and other material. As applied to the major avalanche involved in the eruption of Mount St. Helens, a rapid mass movement that included fragmented cold and hot volcanic rock, water, snow, glacier ice, trees, and some hot pyroclastic material. Most of the May 18, 1980 deposits in the upper valley of the North Fork Toutle River and in the vicinity of Spirit Lake are from the debris avalanche.

Debris Flow: A mixture of water-saturated rock debris that flows downslope under the force of gravity (also called lahar or mudflow).

Detachment Plane: The surface along which a landslide disconnects from its original position.
Diatreme: A breccia filled volcanic pipe that was formed by a gaseous explosion.
Dike: A sheet-like body of igneous rock that cuts across layering or contacts in the rock into which it intrudes.
Dome: A steep-sided mass of viscous (doughy) lava extruded from a volcanic vent (often circular in plane view) and spiny, rounded, or flat on top. Its surface is often rough and blocky as a result of fragmentation of the cooler, outer crust during growth of the dome.
Dormant Volcano: Literally, "sleeping." The term is used to describe a volcano which is presently inactive but which may erupt again. Most of the major Cascade volcanoes are believed to be dormant rather than extinct.
Drainage Basin: The area of land drained by a river system.
Ejecta: Material that is thrown out by a volcano, including pyroclastic material (tephra) and lava bombs.
En Echelon: Set of geologic features that are in an overlapping or a staggered arrangement (e.g., faults). Each is relatively short, but collectively they form a linear zone in which the strike of the individual features is oblique to that of the zone as a whole.
Episode: An episode is a volcanic event that is distinguished by its duration or style.
Eruption: The process by which solid, liquid, and gaseous materials are ejected into the earth's atmosphere and onto the earth's surface by volcanic activity. Eruptions range from the quiet overflow of liquid rock to the tremendously violent expulsion of pyroclastics.
Eruption Cloud: The column of gases, ash, and larger rock fragments rising from a crater or other vent. If it is of sufficient volume and velocity, this gaseous column may reach many miles into the stratosphere, where high winds will carry it long distances.
Eruptive Vent: The opening through which volcanic material is emitted.
Evacuate: Temporarily move people away from possible danger.
Extinct Volcano: A volcano that is not presently erupting and is not likely to do so for a very long time in the future.
Extrusion: The emission of magmatic material at the earth's surface. Also, the structure or form produced by the process (e.g., a lava flow, volcanic dome, or certain pyroclastic rocks).
Fault: A crack or fracture in the earth's surface. Movement along the fault can cause earthquakes or--in the process of mountain-building--can release underlying magma and permit it to rise to the surface.
Fault Scarp A steep slope or cliff formed directly by movement along a fault and representing the exposed surface of the fault before modification by erosion and weathering.
Felsic: An igneous rock having abundant light-colored minerals.
Fire fountain: See also: lava fountain.
Fissures: Elongated fractures or cracks on the slopes of a volcano. Fissure eruptions typically produce liquid flows, but pyroclastics may also be ejected.
Flank Eruption: An eruption from the side of a volcano (in contrast to a summit eruption.)
Fluvial: Produced by the action of flowing water.
Formation: A body of rock identified by lithic characteristics and stratigraphic position and is map able at the earth's surface or traceable in the subsurface.
Fracture: The manner of breaking due to intense folding or faulting.
Fumarole: A vent or opening through which issue steam, hydrogen sulfide, or other gases. The craters of many dormant volcanoes contain active fumaroles.
Geothermal Energy: Energy derived from the internal heat of the earth.
Geothermal Power: Power generated by using the heat energy of the earth.
Graben: An elongate crustal block that is relatively depressed (down dropped) between two fault systems.

Guyot: A type of seamount that has a platform top. Named for a nineteenth-century Swiss-American geologist.

Hardness: The resistance of a mineral to scratching.

Harmonic Tremor: A continuous release of seismic energy typically associated with the underground movement of magma. It contrasts distinctly with the sudden release and rapid decrease of seismic energy associated with the more common type of earthquake caused by slippage along a fault.

Heat transfer: Movement of heat from one place to another.

Heterolithologic: Material is made up of a heterogeneous mix of different rock types. Instead of being composed on one rock type, it is composed of fragments of many different rocks.

Holocene: The time period from 10,000 years ago to the present. Also, the rocks and deposits of that age.

Horizontal Blast: An explosive eruption in which the resultant cloud of hot ash and other material moves laterally rather than upward.

Horst: A block of the earth's crust, generally long compared to its width that has been uplifted along faults relative to the rocks on either side.

Hot Spot: A volcanic center, 60 to 120 miles (100 to 200 km) across and persistent for at least a few tens of million of years, that is thought to be the surface expression of a persistent rising plume of hot mantle material. Hot spots are not linked to arcs and may not be associated with ocean ridges.

Hot-spot Volcanoes: Volcanoes related to a persistent heat source in the mantle.

Hyaloclastite: A deposit formed by the flowing or intrusion of lava or magma into water, ice, or water-saturated sediment and its consequent granulation or shattering into small angular fragments.

Hydrothermal Reservoir: An underground zone of porous rock containing hot water.

Hypabyssal: A relatively shallow intrusive consisting of magma or the resulting solidified rock.

Hypocenter: The place on a buried fault where an earthquake occurs.

Ignimbrite: The rock formed by the widespread deposition and consolidation of ash flows and nuees ardentes. The term was originally applied only to densely welded deposits but now includes non-welded deposits.

Intensity: A measure of the effects of an earthquake at a particular place. Intensity depends not only on the magnitude of the earthquake, but also on the distance from the epicenter and the local geology.

Intermediate: A descriptive term applied to igneous rocks that are transitional between basic and acidic with silica ($SiO2$) between 54% and 65%.

Intrusion: The process of emplacement of magma in pre-existing rock.

Intrusive: A term that refers to igneous rock mass formed at depth within surrounding rock.

Joint: A surface of fracture in a rock.

Jökulhlaup: is a type of glacial outburst flood. It is an Icelandic term that has been adopted in glaciological terminology in many languages. It originally referred to the well-known subglacial outburst floods from Vatnajökull, Iceland, which are triggered by geothermal heating and occasionally by a volcanic subglacial eruption, but it is now used to describe any large and abrupt release of water from a subglacial or proglacial lake/reservoir.

Juvenile: Pyroclastic material derived directly from magma reaching the surface. Also a term used to describe CM's approach to teaching Geology and life in general.

Kame: a steep-sided mound of sand and gravel deposited by a melting ice sheet.

Kipuka: An area surrounded by a lava flow.

Laccolith: A body of igneous rocks with a flat bottom and domed top. It is parallel to the layers above and below it.

Lahar: A torrential flow of water-saturated volcanic debris down the slope of a volcano in response to gravity. A type of mudflow.

Landsat: A series of unmanned satellites orbiting at about 706 km (438 miles) above the surface of the earth. The satellites carry cameras similar to video cameras and take images or pictures showing features as small as 30 m or 80 m wide, depending on which camera is used.
Lapilli: Literally, "little stones." Round to angular rock fragments, measuring 1/10 inch to 2 1/2 inches in diameter, which may be ejected in either a solid or a molten state.
Lava: Magma which has reached the surface through a volcanic eruption. The term is most commonly applied to streams of liquid rock that flow from a crater or fissure. It also refers to cooled and solidified rock.
Lava Dome: Mass of lava, created by many individual flows, that has built a dome-shaped pile of lava.
Lava Flow: An outpouring of lava onto the land surface from a vent or fissure. Also, a solidified tongue like or sheet-like body formed by outpouring lava.
Lava Fountain: A rhythmic vertical fountain like eruption of lava.
Lava Lake (Pond): A lake of molten lava, usually basaltic, contained in a vent, crater, or broad depression of a shield volcano.
Lava Shields: A shield volcano made of basaltic lava.
Lava Tube: A tunnel formed when the surface of a lava flow cools and solidifies while the still-molten interior flows through and drains away.
Limu O Pele (Pele Seaweed): Delicate, translucent sheets of spatter filled with tiny glass bubbles.
Lithic: Of or pertaining to stone.
Lithosphere: The rigid crust and uppermost mantle of the earth. Thickness is on the order of 60 miles (100 km). Stronger than the underlying asthenosphere.
Luster: The reflection of light from the surface of a mineral.
Maar: A volcanic crater that is produced by an explosion in an area of low relief, is generally more or less circular, and often contains a lake, pond, or marsh.
Mafic: An igneous composed chiefly of one or more dark-colored minerals.
Magma: Molten rock beneath the surface of the earth.
Magma Chamber: The subterranean cavity containing the gas-rich liquid magma which feeds a volcano.
Magmatic: Pertaining to magma.
Magnitude: A numerical expression of the amount of energy released by an earthquake, determined by measuring earthquake waves on standardized recording instruments (seismographs.) The number scale for magnitudes is logarithmic rather than arithmetic. Therefore, deflections on a seismograph for a magnitude 5 earthquake, for example, are 10 times greater than those for a magnitude 4 earthquake, 100 times greater than for a magnitude 3 earthquake, and so on. Energy release is roughly 27 times greater for each successive Richter scale increase.
Mantle: The zone of the earth below the crust and above the core.
Matrix: The solid matter in which a fossil or crystal is embedded. Also, a binding substance (e.g., cement in concrete).
Miocene: An epoch in Earth's history from about 24 to 5 million years ago. Also refers to the rocks that formed in that epoch.
Móberg Mountain: The Icelandic name for a flat-topped mountain produced by the subglacial eruption of a central vent volcano.
Moho: Also called the Mohorovicic discontinuity. The surface or discontinuity that separates the crust from the mantle. The Moho is at a depth of 5-10 km beneath the ocean floor and about 35 km below the continents (but down to 60 km below mountains). Named for Andrija Mohorovicic, a Croatian seismologist and wild blender aficionado.
Monogenetic: A volcano built by a single eruption.

Mudflow: A flowage of water-saturated earth material possessing a high degree of fluidity during movement. A less-saturated flowing mass is often called a debris flow. A mudflow originating on the flank of a volcano is properly called a lahar.

Myth: A fictional story to explain the origin of some person, place, or thing. Also a useful term to describe CM's technical publications.

Nuees Ardentes: A French term applied to a highly heated mass of gas-charged ash which is expelled with explosive force and moves hurricane speed down the mountainside.

Obsidian: A black or dark-colored volcanic glass usually composed of rhyolite.

Oceanic Crust: The earth's crust where it underlies oceans.

Pahoehoe: A Hawaiian term for lava with a smooth, billowy, or ropy surface.

Palagonite: an alteration product from the interaction of water with volcanic glass of chemical composition similar to basalt. Palagonite can also result from the interaction between water and basalt melt. The water flashes to steam on contact with the hot lava and the small fragments of lava react with the steam to form the light colored palagonite tuff cones common in areas of basaltic eruptions in contact with water. Palagonite can also be formed by a slower weathering of lava into palagonite, resulting in a thin, yellow-orange rind on the surface of the rock. The process of conversion of lava to palagonite is called palagonitization.

Palagonite soil is a light yellow-orange dust, comprising a mixture of particles ranging down to sub-micrometer sizes, usually found mixed with larger fragments of lava. The color is indicative of the presence of iron in the +3 oxidation state, embedded in an amorphous matrix.

Palagonite tuff is a tuff composed of sideromelane fragments and coarser pieces of basaltic rock, embedded in a palagonite matrix. A composite of sideromelane aggregate in palagonite matrix is called hyaloclastite.

Pali: Hawaiian word for steep hills or cliffs.

Pele Hair: A natural spun glass formed by blowing-out during quiet fountaining of fluid lava, cascading lava falls, or turbulent flows, sometimes in association with Pele tears. A single strand, with a diameter of less than half a millimeter, may be as long as two meters.

Pele Tears: Small, solidified drops of volcanic glass behind which trail pendants of Pele hair. They may be tearshaped, spherical, or nearly cylindrical.

Peralkaline: Igneous rocks in which the molecular proportion of aluminum oxide is less than that of sodium and potassium oxides combined.

Phenotypes: it is commonly impossible to determine a representative mineralogical mode of significantly aphanitic rocks, even in thin-section. If it is impossible to recognize the mineralogy of the matrix, a mode must be based on the phenocrysts. The IUGS recommends that rocks identified in such a manner be called phenotypes and have the prefix "pheno-" inserted before the name (e.g., pheno-latite).

Phenocryst: A conspicuous, usually large, crystal embedded in porphyritic igneous rock.

Phreatic Eruption (Explosion): An explosive volcanic eruption caused when water and heated volcanic rocks interact to produce a violent expulsion of steam and pulverized rocks. Magma is not involved.

Phreatomagmatic: An explosive volcanic eruption that results from the interaction of surface or subsurface water and magma.

Picrite Basalt (Picrobasalt): is a variety of high-magnesium olivine basalt that is very rich in the mineral olivine. It is dark with yellow-green olivine phenocrysts (20 to 50%) and black to dark brown pyroxene, mostly augite.

Pillow lava: Interconnected, sack-like bodies of lava formed underwater.

Pipe: A vertical conduit through the Earth's crust below a volcano, through which magmatic materials have passed. Commonly filled with volcanic breccia and fragments of older rock.

Pit Crater: A crater formed by sinking in of the surface, not primarily a vent for lava.
Plastic: Capable of being molded into any form, which is retained.
Plate Tectonics: The theory that the earth's crust is broken into about 10 fragments (plates,) which move in relation to one another, shifting continents, forming new ocean crust, and stimulating volcanic eruptions.
Pleistocene: An epoch in Earth history from about 2-5 million years to 10,000 years ago. Also refers to the rocks and sediment deposited in that epoch.
Plinian Eruption: An explosive eruption in which a steady, turbulent stream of fragmented magma and magmatic gases is released at a high velocity from a vent. Large volumes of tephra and tall eruption columns are characteristic.
Plug: Solidified lava that fills the conduit of a volcano. It is usually more resistant to erosion than the material making up the surrounding cone, and may remain standing as a solitary pinnacle when the rest of the original structure has eroded away.
Plug Dome: The steep-sided, rounded mound formed when viscous lava wells up into a crater and is too stiff to flow away. It piles up as a dome-shaped mass, often completely filling the vent from which it emerged.
Pluton: A large igneous intrusion formed at great depth in the crust.
Polygenetic: Originating in various ways or from various sources.
Precambrian: All geologic time from the beginning of Earth history to 570 million years ago. Also refers to the rocks that formed in that epoch.
Pumice: Light-colored, frothy volcanic rock, usually of dacite or rhyolite composition, formed by the expansion of gas in erupting lava. Commonly seen as lumps or fragments of pea-size and larger, but can also occur abundantly as ash-sized particles.
Pyroclastic: Pertaining to fragmented (clastic) rock material formed by a volcanic explosion or ejection from a volcanic vent.
Pyroclastic Flow: Lateral flowage of a turbulent mixture of hot gases and unsorted pyroclastic material (volcanic fragments, crystals, ash, pumice, and glass shards) that can move at high speed (50 to 100 miles an hour.) The term also can refer to the deposit so formed.
Quaternary: The period of Earth's history from about 2 million years ago to the present; also, the rocks and deposits of that age.
Relief: The vertical difference between the summit of a mountain and the adjacent valley or plain.
Renewed Volcanism State: Refers to a state in the evolution of a typical Hawaiian volcano during which --after a long period of quiescence--lava and tephra erupt intermittently. Erosion and reef building continue.
Repose: The interval of time between volcanic eruptions.
Rhyodacite: An extrusive rock intermediate in composition between dacite and rhyolite.
Rhyolite: Volcanic rock (or lava) that characteristically is light in color, contains 69% silica or more, and is rich in potassium and sodium.
Ridge, Oceanic: A major submarine mountain range.
Rift System: The oceanic ridges formed where tectonic plates are separating and a new crust is being created; also, their on-land counterparts such as the East African Rift of Africa or Southwest Rift of Hawaii.
Rift Zone: A zone of volcanic features associated with underlying dikes. The location of the rift is marked by cracks, faults, and vents.
Ring of Fire: The regions of mountain-building earthquakes and volcanoes which surround the Pacific Ocean.
Scoria: A bomb-size (> 64 mm) pyroclast that is irregular in form and generally very vesicular. It is usually heavier, darker, and more crystalline than pumice.

Seafloor Spreading: The mechanism by which new seafloor crust is created at oceanic ridges and slowly spreads away as plates are separating.
Seamount: A submarine volcano.
Seismograph: An instrument that records seismic waves; that is, vibrations of the earth.
Seismologist: Scientists who study earthquake waves and what they tell us about the inside of the Earth.
Seismometer: An instrument that measures motion of the ground caused by earthquake waves.
Shearing: The motion of surfaces sliding past one another.
Shear Waves: Earthquake waves that move up and down as the wave itself moves. For example, to the left.
Shield Volcano: A gently sloping volcano in the shape of a flattened dome and built almost exclusively of lava flows.
Shoshonite: A trachyandesite composed of olivine and augite phenocrysts in a groundmass of labradorite with alkali feldspar rims, olivine, augite, a small amount of leucite, and some dark-colored glass. Its name is derived from the Shoshone River, Wyoming and given by Iddings in 1895.
Silica: A chemical combination of silicon and oxygen.
Sill: A tabular body of intrusive igneous rock, parallel to the layering of the rocks into which it intrudes.
Skylight: An opening formed by a collapse in the roof of a lava tube.
Solfatara: A type of fumarole, the gases of which are characteristically sulfurous.
Spatter Cone: A low, steep-sided cone of spatter built up on a fissure or vent. It is usually of basaltic material.
Spatter Rampart: A ridge of congealed pyroclastic material (usually basaltic) built up on a fissure or vent.
Specific Gravity: The density of a mineral divided by the density of water.
Spines: Horn-like projections formed upon a lava dome.
Stalactite: A cone shaped deposit of minerals hanging from the roof of a cavern.
Stratigraphic: The study of rock strata, especially of their distribution, deposition, and age.
Stratovolcano: A volcano composed of both lava flows and pyroclastic material.
Streak: The color of a mineral in the powdered form.
Strike-Slip Fault: A nearly vertical fault with side-slipping displacement.
Strombolian Eruption: A type of volcanic eruption characterized by jetting of clots or fountains of fluid basaltic lava from a central crater.
Subduction Zone: The zone of convergence of two tectonic plates, one of which usually overrides the other.
Surge: A ring-shaped cloud of gas and suspended solid debris that moves radially outward at high velocity as a density flow from the base of a vertical eruption column accompanying a volcanic eruption or crater formation.
Talus: A slope formed at the base of a steeper slope, made of fallen and disintegrated materials.
Tephra: Materials of all types and sizes that are erupted from a crater or volcanic vent and deposited from the air.
Tephrochronology: The collection, preparation, petrographic description, and approximate dating of tephra.
Tholeiite: are a chemical sub-type of basalt defined on their silica content. Basalts that are silica saturated are known as olivine tholeiites, those that are silica oversaturated are termed quartz tholeiites. Tholeiites lack feldspathoids. Silica undersaturated basalts are termed alkali basalts.
Tilt: The angle between the slope of a part of a volcano and some reference. The reference may be the slope of the volcano at some previous time.
Trachyandesite: An extrusive rock intermediate in composition between trachyte and andesite.
Trachybasalt: An extrusive rock intermediate in composition between trachyte and basalt.

Trachyte: A group of fine-grained, generally porphyritic, extrusive igneous rocks having alkali feldspar and minor mafic minerals as the main components, and possibly a small amount of sodic plagioclase.

Tremor: Low amplitude, continuous earthquake activity often associated with magma movement.

Tsunami: A great sea wave produced by a submarine earthquake, volcanic eruption, or large landslide.

Tuff: Rock formed of pyroclastic material.

Tuff Cone: A type of volcanic cone formed by the interaction of basaltic magma and water. Smaller and steeper than a tuff ring.

Tuff Ring: A wide, low-rimmed, well-bedded accumulation of hyaloclastic debris built around a volcanic vent located in a lake, coastal zone, marsh, or area of abundant ground water.

Tumulus: A doming or small mound on the crest of a lava flow caused by pressure due to the difference in the rate of flow between the cooler crust and the more fluid lava below.

Tuya: a flat-topped, steep-sided volcano formed when lava erupts through a thick glacier or ice sheet. They are rare worldwide, being confined to regions which were covered by glaciers and had active volcanism during the same period.

Ultramafic: Igneous rocks made mostly of the mafic minerals: hypersthene, augite, and/or olivine.

Unconformity: A substantial break or gap in the geologic record where a rock unit is overlain by another that is not next in stratigraphic succession, such as an interruption in continuity of a depositional sequence of sedimentary rocks or a break between eroded igneous rocks and younger sedimentary strata. It results from a change that caused deposition to cease for a considerable time, and it normally implies uplift and erosion with loss of the previous formed record.

Vent: The opening at the earth's surface through which volcanic materials issue forth.

Vesicle: A small air pocket or cavity formed in volcanic rock during solidification.

Viscosity: A measure of resistance to flow in a liquid (water has low viscosity while honey has a higher viscosity.)

Volcano: A vent in the surface of the Earth through which magma and associated gases and ash erupt; also, the form or structure (usually conical) that is produced by the ejected material.

Volcanic Arc: A generally curved linear belt of volcanoes above a subduction zone, and the volcanic and plutonic rocks formed there.

Volcanic Complex: A persistent volcanic vent area that has built a complex combination of volcanic landforms.

Volcanic Cone: A mound of loose material that was ejected ballistically.

Volcanic Neck: A massive pillar of rock more resistant to erosion than the lavas and pyroclastic rocks of a volcanic cone.

Vulcan: Roman god of fire and the forge after whom volcanoes are named.

Vulcanian: A type of eruption consisting of the explosive ejection of incandescent fragments of new viscous lava, usually on the form of blocks.

Water Table: The surface between where the pore space in rock is filled with water and where the pore space in rock is filled with air.

Xenocrysts: A crystal that resembles a phenocryst in igneous rock, but is a foreign to the body of rock in which it occurs.

Xenoliths: A foreign inclusion in an igneous rock.

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BUDGET INFORMATION

(as of 02/14/25)

2025 - Guatemala

Total Cost of the Trip: ……………………………………………………………$18,888.54

Cost per person for the trip (9 students)…………………………………….…………$750
Cost per person for the trip (3 faculty)…………………………………….……....$1,100
Cost per person for the trip (2 non-UPJ spouse)……………………………….……..$1,550
Contribution from Student Activities: ………………………………………………..$6,500

Breakdown

1.	Airfare – Iceland Air	$	8,387.54
2.	Guided Geology Tour through GeoTravel Guatemala	$	9,213.00
	The guided tour covers the following:		
	a. Transportation		
	b. Hotels		
	c. Personal Geology Guide throughout the trip		
	a. Fees for parks and local guides		
3.	Group Fund for Food	$	1,219.46
4.	Miscellaneous		
	a. Guidebook (to be paid to the UPJ print shop)	$	280.00

BOOKING RECEIPTS
AIRFARE

We've received your request and updated your group booking to reflect the information shown below. If the booking information below does not accurately reflect your request, please contact United's Group Department immediately at the phone number or e-mail address below.

Group Name: JOHNSTOWN PITT GEOLOGY CLUB

RYAN KERRIGAN X1741284
205 COLLEGIATE DR
JOHNSTOWN PA 15904

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/LOCATOR                                                  TAX/     US TAX
                                BASE/NET FARE            SRCHG
* FRW3F5                         484.00                    70.71   44.40
   UA 5034T 28FEB FR JSTIAD HK13  6:30A 7:35A
   UA 1524T 28FEB FR IADIAH HK13  8:25A 11:00A
   UA 1902T 28FEB FR IAHGUA HK13  8:20P 11:14P
   UA 1562T 09MAR SU GUAIAD HK13 12:05A 6:15A
   UA 5046T 09MAR SU IADJST HK13 12:55P 1:52P

   ISABELLERENE    BOYER
   DEBORAHPIETRANTONIO    DONAHUE
   AVA    FREED
   DOMINICPASCAL    FREED
   TYLERMCALESTER    SMITH
   GABRIELLANADINE    HODGSON
   JESSICANICOLE    HOLLAN
   RYANJASON    KERRIGAN
   TERESAKOHLER    MCCONNELL
   TRINITYANN    MCELRAVY
   EMILYGRACE    MIKESIC
   JESSICALYNN    MILLER
   JORDANTHOMAS    PREMOZIC

* JSSYZT                         894.00                    75.91   44.40
   UA  350W 28FEB FR DENIAH HK1 11:45A 3:15P
   UA 1902W 28FEB FR IAHGUA HK1  8:20P 11:14P
   UA 1562W 09MAR SU GUAIAD HK1 12:05A 6:15A
   UA  468W 09MAR SU IADDEN HK1  8:30A 10:35A

   KARENCLAIRE    KOHLER
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If you need to make any changes to your group booking, such as names or seats, please contact the group desk as soon as possible using the phone number below.

Our group department hours are Monday - Friday 7:00am - 8:00pm Central time.

United Groups
1-800-426-1122
unitedgroups@united.com

PREVIOUS SPRING BREAK GROUPS

SPRING BREAK 2024 – PORTUGAL

Picture taken from Forte de São Miguel Arcanjo, Nazare

L-R: Ryan Kerrigan, Terry McConnell, Marilyn Lindberg, Steve Lindberg, Deb Donahue, Ilia Galasso, Luka Hodgson, Jessica Hollan, Ryan Kelly, Donovan Stanley-Reeves, Trinity Chynoweth, Avery Freed, Nick Scelsi, Tyler Smith, Jordan Premozic, Pedro Barreto (Guide), Jessica Miller

SPRING BREAK 2023 – ICELAND

Picture taken from Reynisfjara Beach

Back Row (L-R): Avery Freed, Jessica Miller, Jade Smith, Olivia Weaver, Aleya Shreckengost, Holly Garrett, Nick Smith, Chris Howard, Tyler Smith; *Front Row (L-R)*: Ryan Kerrigan, Ryan Kelly, Courtney Roxby, Trish Garing (random UPJ Alum), Nick Scelsi, Ann Schaefer, Karan Kohler, Ilia Galasso – *not pictured* Terry McConnell (*she's taking the picture*)

SPRING BREAK 2022 – HAWAII

Picture taken on top Papakōlea beach (Green Sand Beach)

L-R: Steve Lindberg, Marilyn Lindberg, Elliot Finney, Terry McConnell, Alex Kijowski, Aleya Shreckengost, Cian Williamson-Rea, Olivia Weaver, Ryan Kerrigan, Jessica Miller, Delaney D'Amato, Nick Scelsi, Holly Garrett, Courtney Roxby, and Avery Freed

SPRING BREAK 2021 – COVID STRIKES AGAIN!!!

SPRING BREAK 2020 – ICELAND (CANCELLED - STUPID COVID)

SPRING BREAK 2019 – ECUADOR

Picture taken in front of ash flow from Mount Chimborazo

L-R: Jen Hlivko, Kyle Molnar, Ryan Kerrigan, Jessica Miller, Abby Wess, Alex Hockensmith, Susan Ma, Kyle Sarver, Jake Marsh, Tyler Newell, and Kim Waltermire

SPRING BREAK 2018 – SCOTLAND
Picture taken in front of Edinburgh Castle
L-R: Ryan Kerrigan, Jessica Miller, Terry McConnell, Steve Lindberg, Marilyn Lindberg, Sam Louderback, Jake Marsh, Lauren Raysich, Kim Waltermire, and Katie Roxby
Not Pictured: Bill McConnell

SPRING BREAK 2017 – HAWAII
Picture taken at the rim of Mauna Ulu in Volcanoes National Park
L-R: Jacob Williamson-Rea, Tyler Norris, Kris Miller, Allie Marra, Luke Layton, Matt Leger, Katie Roxby, and Ryan Kerrigan

SPRING BREAK 2016 – ICELAND
Picture taken on columnar joints at Reynisfjara Beach, Iceland
Top Row: Tyler Norris, Lorin Simboli, Allie Marra, Luke Layton; *Bottom Row:* Catie Bert, Matt Leger; *Not Pictured:* Ryan Kerrigan, Terry McConnell, and Steve Lindberg

SPRING BREAK 2015 – NORTH CAROLINA
Picture taken at Ray Mine Pegmatite mine, Spruce Pine, NC
Left to Right: Kris Miller, Luke Layton, Leah Marko, Andrew Barchowsky, Matt Gerber, and Ryan Kerrigan

NOTES