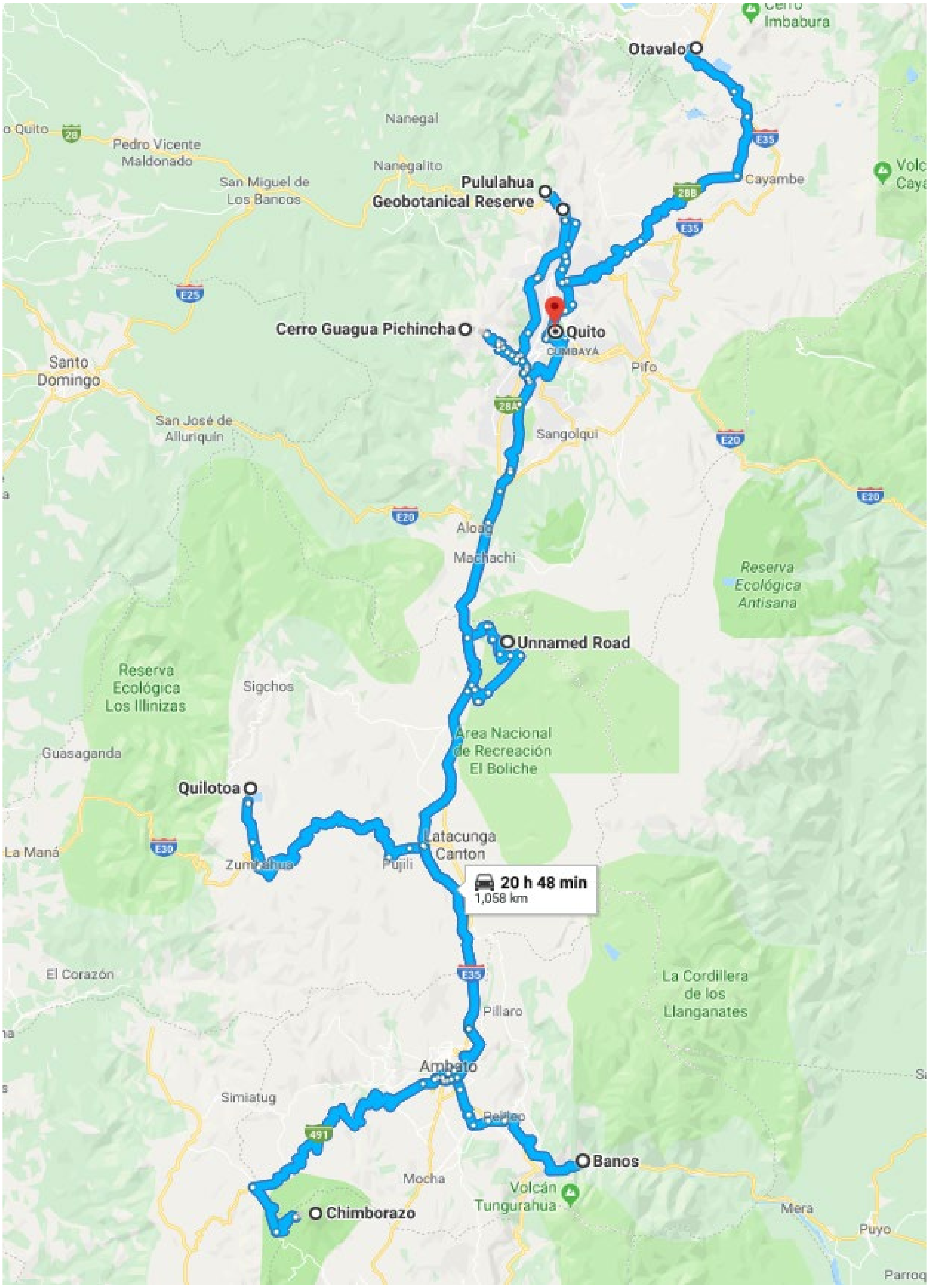
SPRING BREAK TRIP 2019

UNIVERSITY OF PITTSBURGH AT JOHNSTOWN
DEPARTMENT OF ENERGY AND EARTH RESOURCES

Ecuador!!



Cerro Imbabura
Otavalo
Nanegal
Quito
Pedro Vicente Maldonado
Nanegalito
San Miguel de Los Bancos
Pululahua Geobotanical Reserve
Cayambe
Cerro Guagua Pichincha
Quito
CUMBAYÁ
Pifo
Santo Domingo
San José de Alluriquín
Sangolquí
Aloag
Machachi
Reserva Ecológica Antisana
Unnamed Road
Reserva Ecológica Los Illinizas
Sigchos
Área Nacional de Recreación El Boliche
Guasaganda
Quilotoa
Latacunga Canton
La Maná
Pujilí
20 h 48 min
1,058 km
El Corazón
La Cordillera de los Llanganates
Pillaro
Ambato
Simiatug
Pelileo
Banos
Mocha
Volcán Tungurahua
Chimborazo
Mera
Puyo

The following was compiled by Ryan Kerrigan, Assistant Professor at University of Pittsburgh a Johnstown, Johnstown, PA in the winter of 2018-2019 as supporting material for the Pitt-Johnstown Geology Club Spring Break Trip to Ecuador on March 9th to 17th, 2019.

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

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LOGISTICS AND BASICS

Flight

Flight	Departs	Arrives
Copa Airlines, Flight 357	Washington, DC-Dulles (IAD) **9:08 am** Sat, Mar 9th	Panama City (PTY) **2:10 pm** Sat, Mar
Copa Airlines, Flight 159	Panama City (PTY) **3:33 pm** Sat, Mar 9	Quito (UIO) **5:31 pm** Sat, Mar 9
Duration: 8 hours 23 minutes		
Copa Airlines, Flight 210	Quito (UIO) **6:12 am** Sun, Mar 17	Panama City (PTY) **8:14 am** Sun, Mar 17
Copa Airlines, Flight 304	Panama City (PTY) **9:15 am** Sun, Mar 17	Washington, DC-Dulles (IAD) **3:05 pm** Sun, Mar 17
Duration: 7 hours 53 minutes		

A tour group is handling much of our trip logistics:
Ecuador Expat Journeys (http://www.ecuadorexpatjourneys.com/)

Jonathan Hall is the contact man handling much of the logistics for the trip. His contact information is juanzec@yahoo.com

Ecuador Basics

In case of an emergency, the following phone numbers can be of great importance.

Emergency: 911 (only in major cities)
Police: 101
Ambulance: 131
Fire: 102

- *Currency:* US Dollar – it can be hard for Ecuadorians to get $2 bills, so bring a bunch and they will go crazy for them.
- *Cell Phones:* Lonely Planet says, “Cell and mobile numbers are preceded by 09. Bring your phone and purchase a SIM card (called a ‘chip,’ costing $5 to $10) from a local network. Add credit at convenience stores and supermarkets.”
- *Tipping:* yeah, you should probably tip, just like 5% less than what you would in the US
- *Time zone:* Eastern Standard Time, no difference from ours
- *Daylight:* Ecuador is pretty homogeneous year-round, 6AM to 6PM.
- *Immunizations:* Ecuador does not require any immunization for entry, however, CDC and WHO recommend some. Please talk with your physician to make this decision.

Basic Spanish

The following is from:

Lonely Planet, 2018, Ecuador and the Galápagos Islands. Lonely Planet Global Limited, Oakland, CA, 414 pgs. ISBN: 978-1-78657-062-8

BASICS

Hello.	*Hola.*	o·la
Goodbye.	*Adiós.*	a·dyos
How are you?	*¿Qué tal?*	ke tal
Fine, thanks.	*Bien, gracias.*	byen gra·syas
Excuse me.	*Perdón.*	per·don
Sorry.	*Lo siento.*	lo syen·to
Please.	*Por favor.*	por fa·vor
Thank you.	*Gracias.*	gra·syas
You're welcome.	*De nada.*	de na·da
Yes.	*Sí.*	see
No.	*No.*	no

My name is ...
Me llamo ... — me ya·mo ...

What's your name?
¿Cómo se llama Usted? — ko·mo se ya·ma oo·ste (pol)
¿Cómo te llamas? — ko·mo te ya·mas (inf)

Do you speak English?
¿Habla inglés? — a·bla een·gles (pol)
¿Hablas inglés? — a·blas een·gles (inf)

I don't understand.
Yo no entiendo. — yo no en·tyen·do

ACCOMMODATIONS

I'd like a ... room.	*Quisiera una habitación ...*	kee·sye·ra oo·na a·bee·ta·syon ...
single	*individual*	een·dee·vee·dwal
double	*doble*	do·ble

How much is it per night/person?
¿Cuánto cuesta por noche/persona? — kwan·to kwes·ta por no·che/per·so·na

Does it include breakfast?
¿Incluye el desayuno? — een·kloo·ye el de·sa·yoo·no

campsite	*terreno de cámping*	te·re·no de kam·peeng
hotel	*hotel*	o·tel
guesthouse	*pensión*	pen·syon
(small) hotel/ country inn	*hostal/ hostería*	os·tal/ os·te·ree·a
youth hostel	*albergue juvenil*	al·ber·ge khoo·ve·neel
air-con	*aire acondicionado*	ai·re a·kon·dee·syo·na·do
bathroom	*baño*	ba·nyo
bed	*cama*	ka·ma
window	*ventana*	ven·ta·na

DIRECTIONS

Where's ...?
¿Dónde está ...? — don·de es·ta ...

What's the address?
¿Cuál es la dirección? — kwal es la dee·rek·syon

Could you please write it down?
¿Puede escribirlo, por favor? — pwe·de es·kree·beer·lo por fa·vor

Can you show me (on the map)?
¿Me lo puede indicar (en el mapa)? — me lo pwe·de een·dee·kar (en el ma·pa)

at the corner	*en la esquina*	en la es·kee·na
at the traffic lights	*en el semáforo*	en el se·ma·fo·ro
behind ...	*detrás de ...*	de·tras de ...
far	*lejos*	le·khos
in front of ...	*enfrente de ...*	en·fren·te de ...
left	*izquierda*	ees·kyer·da
near	*cerca*	ser·ka
next to ...	*al lado de ...*	al la·do de ...
opposite ...	*frente a ...*	fren·te a ...
right	*derecha*	de·re·cha
straight ahead	*todo recto*	to·do rek·to

EATING & DRINKING

Can I see the menu, please?
¿Puedo ver el menú, por favor? — pwe·do ver el me·noo por fa·vor

What would you recommend?
¿Qué recomienda? — ke re·ko·myen·da

Do you have vegetarian food?
¿Tienen comida vegetariana? — tye·nen ko·mee·da ve·khe·ta·rya·na

I don't eat (red meat).
No como (carne roja). — no ko·mo (kar·ne ro·kha)

That was delicious!
¡Estaba buenísimo! — es·ta·ba bwe·nee·see·mo

Cheers!
¡Salud! — sa·loo

The bill, please.
La cuenta, por favor. — la kwen·ta por fa·vor

I'd like a table for ...	*Quisiera una mesa para ...*	kee·sye·ra oo·na me·sa pa·ra ...
(eight) o'clock	*las (ocho)*	las (o·cho)
(two) people	*(dos) personas*	(dos) per·so·nas

THINGS YOU SHOULD BRING

Most Important:

- Passport
- Driver's License

Personal Items:

- Toiletries (including lotion/sunscreen)
- Van/Plane Entertainment (iPod, books, cards, small board games, etc.)
- Backpack for day hikes

Clothes:

- Good hiking boots
- Sneakers
- Rain jacket & Rain pants
- Wool socks (good for long days of walking or hikes)
- Some warm clothes, think polyester and gore-tex (It will be wet and chilly, count on it), I tend to wear layers rather than big bulky stuff
- Bathing Suit (for the hot springs)

Equipment:

- Sunglasses
- Camera and batteries
- Charger(s)
- Field Notebook & Hand lens
- Pencils/Pens/Sharpie
- Nalgene/Water Bottle
- Travel lock for bag

I will likely bring a couple of rock hammers for us to share, so don't worry about that.

***<u>Note:</u>* The airline limits you to a checked bag (not to exceed 51 lbs), a carry bag, and a personal item. Anything else is at your expense, but let's stick with that.**

Money: Most everything will be covered except the following:

Tips – our driver and guide will deserve a trip at the end of the trip.

Your money - souvenirs, occasional meals, and drinks.

Food - A reasonable estimate for meals is $5-10 each. We have some group money, but not a whole lot. Below is a listing of meals not covered by our tour (~12 meals, ~$90).

Meals we'll have to cover ourselves:

Day 1 – Travel Day - All Meals
Day 2 – Dinner
Day 3 – Lunch and Dinner
Day 4 – None
Day 5 – Dinner
Day 6 – Dinner
Day 7 – None
Day 8 – Dinner
Day 9 – Travel Day - All Meals

BRIEF ITINERARY

Day 1: Saturday, March 9th, 2019 – Board flight

4:00AM: Leave Krebs Parking Lot
7:30AM: Arrive at Dulles Airport
9:08AM: Depart Washington Dulles (Copa Airlines Flight 357) to Panama City, Panama
2:10PM: Arrive in Panama City for layover
3:33PM: Depart Panama (Copa Airlines Flight 159) to Quito, Ecuador
5:31PM: Arrive in Quito, Ecuador – Jonathan will pick us up at the airport and bring us to the hotel. We are staying in the Mariscal Sucre part of town, it is a young, fun part of town with a lot going on.

Hostal El Arupo
Juan Rodriguez E7 22 Y Reina Victoria
170150 Quito, Ecuador
+593 2 222 5716
https://www.booking.com/hotel/ec/hostal-el-arupo.html

7:00PM: Go out for a meal.

Day 2: Sunday, March 10th, 2019 – Quito City Tour, the Equator, and Pululahua Crater

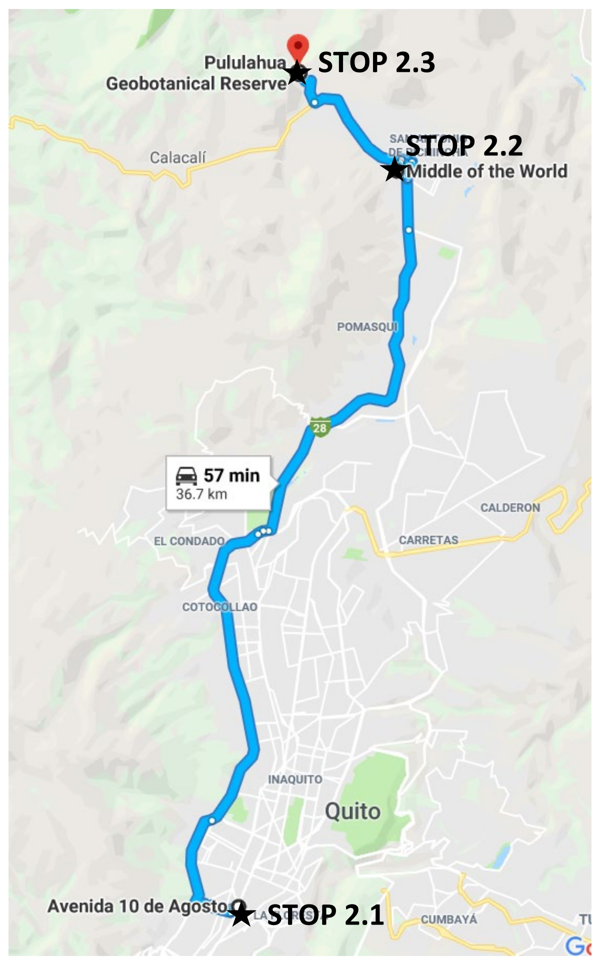
Breakfast – I think all the breakfast meals will be provided. They will likely be light breads, fruit, and coffee/tea.

Morning – City Tour of Quito and up the Cable cars for views of the city. Maybe a tour of the Institute Geofisco Escuela Politecnica National (IGEPN), this is the main volcano observatory for the Ecuadorian Andes.

Lunch – Cuy!

Afternoon – Mitad Del Mundo (Equatorial Monument and Pululahua Crater viewpoint.

Evening – We are on our own for dinner.



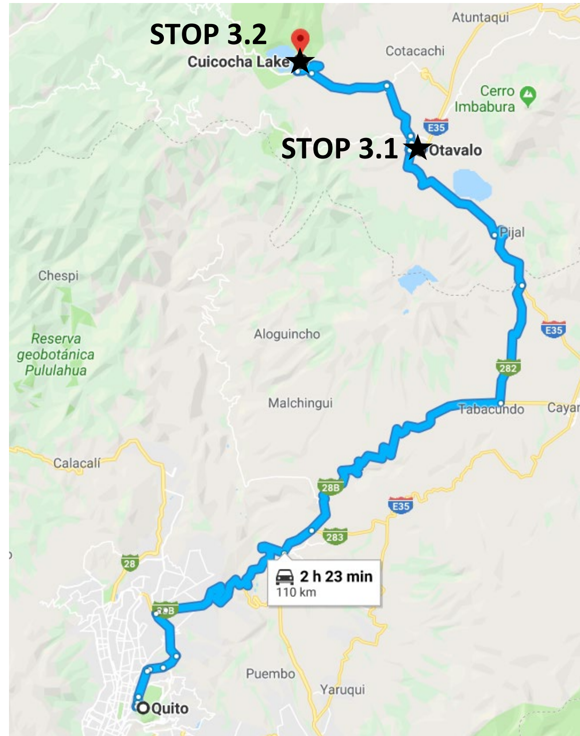
Day 3: Monday, March 11th, 2019 – Otavalo and Cuicocha Crater

Morning – The markets at Otavalo, it will be a good opportunity to pick up some junk.

Lunch – I think we are on our own, the markets should have a lot of options.

Afternoon – Cuicocha Crater Lake likely hike around the crater rim. Jon's notes also say surrounding areas, so there might be other stops.

Evening – We are on our own for dinner.



Day 4: Tuesday, March 12th, 2019 – Hiking and Biking at Volcan Pichincha

Morning – This will be an early morning (at least 6AM). We are packing up our stuff, we are leaving Quito and heading south. We will be taking 4x4 jeeps most of the way up Volcan Pichincha and the mountain biking down.

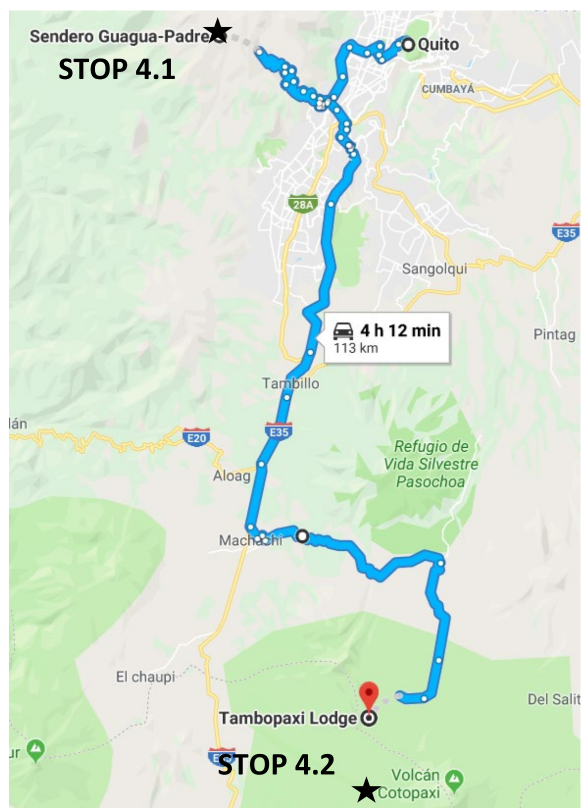
Lunch – Box lunch at the volcano.

Afternoon – After Pichincha we will head to Cotopaxi, where we will spend the night in the park.

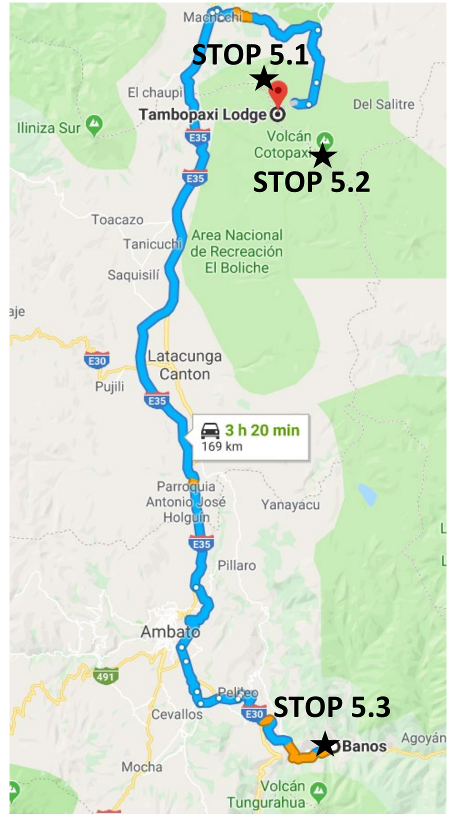
Evening – Dinner at the Lodge.

Here are the accommodations:

Hosteria Tambopaxi Lodge
http://www.tambopaxi.com/en/
Telefonos: +(593 2) 6000365/ 6000366 / 0999448223
Email: tambopaxi@tambopaxi.com / reservas@tambopaxi.com



Day 5: Wednesday, March 13th, 2019 – Rumiñahui, Cotopaxi, and Baños



Morning – We will spend most of the day in the park. In the morning we will hike around Rumiñahui.

Lunch – Box lunch at the volcano.

Afternoon – Hike around Cotopaxi, go up to the glaciers. When we finish up here, we will head to Baños.

Evening – We are on our own for dinner in Baños.

Here are the accommodations in Baños:

Napolitano Apart Hotel
Av. Oriente 470
+593 992936175

Day 6: Thursday, March 14th, 2019 – Biking to Rio Verde and Hiking around Tungurahua

Morning – Mountain Biking to Rio Verde, visiting several waterfalls along the way.

Lunch – Fish for trout and have lunch.

Afternoon – Hiking on Tungurahua and viewpoints of the deposits. And likely the hot springs of Baños.

Evening – We are on our own for dinner in Baños.

Day 7: Friday, March 15th, 2019 – Tungurahua, Chimborazo, and Quilotoa

Morning – Loop drive around Chimborazo including the old road which circles around Tungurahua, where you'll see the deposits from the past 20 years.

Lunch – Box lunch

Afternoon – Drive up to the Quilotoa, where we will stay the night.

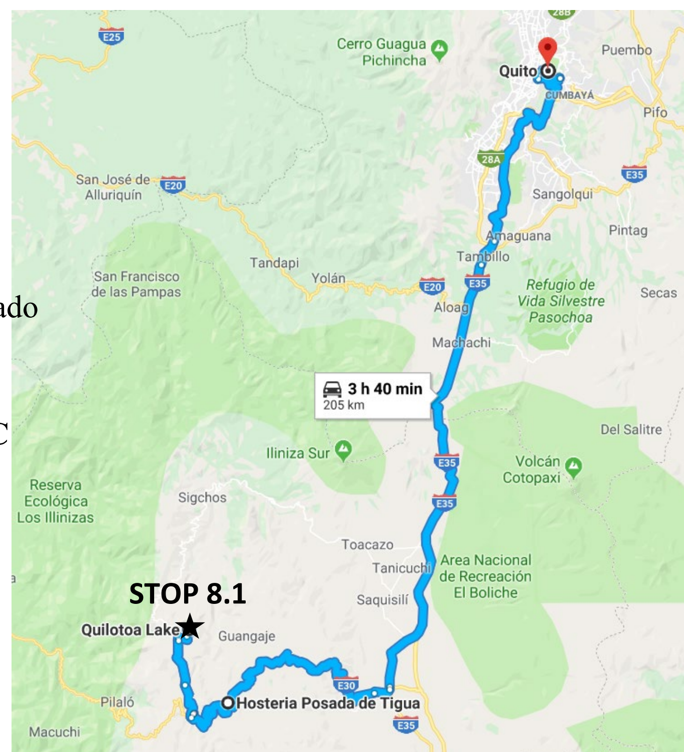
Evening – Dinner at the hostel.

Here are the accommodations:

Hosteria Posada De Tigua
Quito y Julio Hidalgo El Remanso C1
Tigua 050103, Ecuador

https://www.tripadvisor.com/Hotel_Review-g1202656-d1239028-Reviews-Posada_De_Tigua-Tigua_Cotopaxi_Province.html

Day 8: Saturday, March 16th, 2019 – Quilotoa and Quito



Morning – Quilotoa crater and hike down to lake.
Lunch – Box lunch
Afternoon – Return to Quito
Evening – We are on our own
Here are the accommodations:

Rancho San Carlos
Justo Coella y Pedro Vicente Maldonado
+593 359 9057

Day 9: Sunday, March 17th, 2019 – Fly back to DC

3:00 AM: Leave hostel for the airport

6:12 AM: Depart from Quito (Copa Airlines, Flight 210) to Panama City, Panama

8:14 AM: Arrive in Panama

9:15 AM: Depart for Washington Dulles (Copa Airlines, Flight 304)

3:05 PM: Arrive in Washington, DC-Dulles

BASIC ECUADORIAN BACKGROUND INFORMATION

Random Factoids

Independence	24 May 1822 (from Spain)
Capital City	Quito
Largest City	Guayaquil
Total area	283,561 sq km
Population	16,290,913 (as of 07/2017)
Suffrage	18-65 years of age, universal and compulsory; 16-18, over 65, and other eligible voters, voluntary
Literacy rate	94.4%
Official	Spanish
Demonym	Ecuadorian
Borders	Brazil, Ecuador, Panama, Peru, and Venezuela.
Currency	United States dollar (USD)
Religion	Roman Catholic 74%, Evangelical 10.4%, Jehovah's Witness 1.2%, other 6.4%
Life expectancy	77 years (2017) Life expectancy at birth indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life.
Climate	tropical along coast, becoming cooler inland at higher elevations; tropical in Amazonian jungle lowlands
Terrain	coastal plain (costa), inter-Andean central highlands (sierra), and flat to rolling eastern jungle (oriente)
Natural resources	petroleum, fish, timber, hydropower
Agricultural land	29.7%
Government type	presidential republic
President	Lenín Moreno
Vice President	María Alejandra Vicuña
Birth rate	17.9 births/1,000 population (2017 est.)
Death rate	0.99 male(s)/female (2017 est.)
Sex ratio	0.99 male(s)/female (2016 est.)
National symbol	Andean condor
National colors	yellow, blue, red
National anthem	"Salve, Oh Patria!" (We Salute You, Our Homeland)
Industries	petroleum, food processing, textiles, wood products, chemicals
Exports	$18.34 billion (2017 est.)petroleum, bananas, cut flowers, shrimp, cacao, coffee, wood, fish
Imports	$16.84 billion (2017 est.) industrial materials, fuels and lubricants, non durable consumer goods
GDP - per capita	$11,200 (2017 est.)
Time Zone	ECT / GALT (UTC−5 / −6)
Internet country	.ec
Calling Code	593
Drives on the	Right

Important and Interesting Facts about Ecuador

The following is modified after:
The Fact File, 2018, Ecuador Facts – 44 Important Facts about Ecuador. Last updated on August 14th, 2018, accessed December 2018, http://thefactfile.org/ecuador-facts/

Ecuador is home to a wide variety of scenic and environmental wonders. From the Amazonian rainforest to the tops of the Andes Mountains; and the coastal towns to the Galapagos Islands, there are sights and experiences that are sure to impress. With these 44 facts about Ecuador; let's gather more information about its history, culture, tradition, economy, food, tourism, people, and more…

Ecuador's History

1. Before the Incas created settlements in Ecuador, it was inhabited by its Native American peoples.

2. Ecuador was founded in 1532 by the Spanish, who drove out the Incans to claim it.

3. Ruled for 300 years from Peru and then by Spanish governors from Colombia, these Spaniards brought to Ecuador their religion, language and architecture. In 1822, this era ended with the achievement of independence. They first declared independence on August 10, 1809; they finally achieved it from Spain on May 24, 1822.

4. Simon Bolivar united Ecuador to the territories of what are today Panama, Venezuela, and Colombia to form what was called The Gran Colombia (1819-30). This short-lived country collapsed in 1830 and three separate countries were created from it: Ecuador, Venezuela, and Colombia (which included what later became Panama).

Figure 1. *Simon Bolivar (wikipedia)*

5. Ecuador was named after the equator which runs through the country, the only country in the world named after a geographical feature. Its official name, República del Ecuador, literally means "the Republic of the Equator".

Figure 2. *Equator passing through Ecuador. The Equator–an imaginary line on the surface, equidistant from the North and South Poles, dividing the Earth into Northern and Southern Hemispheres–passing through Ecuador. Image*

Figure 3. *Conflicted Territories between Ecuador and Peru (wikipedia)*

6. Ecuador and Peru battled over control of Ecuador's Amazon territories for well over a century, in what became the Western Hemisphere's longest-running dispute over territory. It ended in May of 1999 with both countries signing an agreement.

7. As the country became a republic, many coup d'état and dictatorships have been part of the country's more recent history. It has had 48 presidents in its first 131 years of independence.

8. The world's very first and second UNESCO World Heritage Sites are in Ecuador. The Galápagos Islands is site number one and the capital city of Quito is site number two. These were named at the inaugural World Heritage conference in 1978. See the full list here.

9. In spite its border conflicts, Ecuador has been peaceful in recent years. Presently it is one of the safest South American countries to visit.

10. Ecuador is one of only two South American countries that do not share a border with Brazil.

Facts about Ecuador's economy, food, and tourism

11. Ecuador is divided into four main and unique geographic regions that have their own diets and contribute to the country's economy in different ways, according to the natural resources found there. These are the coastal lowlands (La Costa), the mountain highlands (La Costa), the mountain highlands (La Sierra); the eastern jungle lowlands (La Amazonia or El Oriente "the east"); and the Galápagos Islands (La Región Insular).

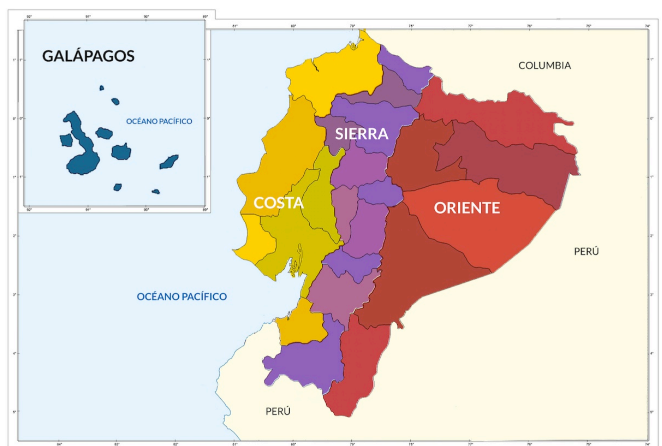


Figure 4. *Geographical Regions of Ecuador (Edy's Ecuadorian Cuisine - WordPress.com)*

12. Ecuador is the world's largest exporter of bananas, exporting 2.7 billion worth of them annually (23.3% of total banana exports, 2016).

13. Oil accounts for 40 percent of all Ecuador's exports and 33 percent of the country's revenues.

14. Ecuador provides the majority of the world's balsa wood. The country also exports coffee and flowers.

15. Ecuador has used the American Dollar as its national currency since 2000.

16. Cuy, or guinea pig, is considered a delicacy in the country. It is roasted whole and its consumption is an ancient tradition. It is said to taste like rabbit.

Figure 5. *Cuy, or cooked Guinea Pig (La pitanza y yo - WordPress.com)*

17. There is no national food as cuisine varies from region to region. Costeños who live in the La Costa region, favor fish, plantains, and beans. Serranos (from La Sierra region) prefer meat, white hominy, and rice.

18. Ecuador is the 9th most biodiverse country in the world and offers much for visitors to see and do.

Facts about Ecuadorian culture and customs

Figure 6. *Typical Native garb. (https://www.insightguides.com/inspire-me/blog/ecuador-clothing)*

19. More than 70 percent of Ecuador's population is made up of Mestizos (an ethnic blend of Spaniards and native people) and the rest includes a significant population of indigenous peoples.

20. Spanish is Ecuador's official language but there are 13 recognized indigenous languages that are also spoken.

21. Several native inland Amazonian tribes managed to avoid both Incan and Spanish conquest. They have preserved their ancient cultural traditions independently of foreign influence.

22. Families may be formed through two different methods. Civil marriage is the legally binding bond between a man and a woman. All married couples are required to undergo the legal ceremony. The other method is Free Union, in which a couple decides to form a family without first undergoing any official service. Both types of unions grant families the same rights and duties.

23. If you need health care, you have no worries. Ecuador's Healthcare System is ranked 20th in the world for quality.

24. Voting is not just a right in Ecuador; it is compulsory for all citizens between the ages of 18 and 65.

25. Children are required to attend school until they have achieved a "basic education". According to the Ministry of Education, this is typically for 6.7 years. Only about 10 percent of all rural students attend high school.

26. Ecuador music is known as Pasillo and is played for dances and festivals, as well as for when men and women in traditional dress perform to the music.

27. Kichwa people of Tigua (in the central Sierra region) are known world-wide for their carefully done traditional paintings on sheepskin canvases. Tigua artists use simple themes with vibrant colors in their work.

Figure 7. *Tigua Art style (found on Pinterest*

28. The three colors of the Ecuadorian flag are yellow for the country's diversity, blue for its sea and sky, and red for the blood of the fighters who won their independence.

Figure 8. *Ecuadorian Flag (wikipedia)*

Ecuador Facts for Kids

29. At the Ciudad Mitad del Mundo (Middle of the World City) is a marked line where you can stand with one foot in the Northern Hemisphere and the other foot in the Southern Hemisphere. Unfortunately, this tourist destination 26 kilometers (16 miles) north of Quito, the national capital, needs some updating. Thanks to new and more precise re-measurements, the exact position of the equator is now said to lie 240 meters (262.5 yards) north of the monument and its marked line!

Figure 9. *Both mainland Ecuador and the Galapagos Islands pass through the equator (GalapagosIslands.com)*

30. Charles Darwin made his famous Voyage of the USS Beagle to the Galápagos Islands in 1835. He based his theory of evolution largely on the discoveries and observations he made in the islands.

31. Ecuador's Cotopaxi is the highest active volcano in the world.

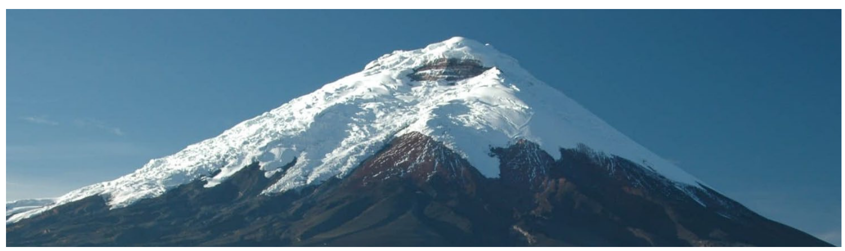


Figure 10. *Looking east at Cotopaxi (www.explore-share.com)*

32. Chimborazo's summit is the point on Earth closest to the sun and the farthest from the core of the earth, due to the earth's slide bulge there. This also means that Ecuador is the closest country on earth to outer space.

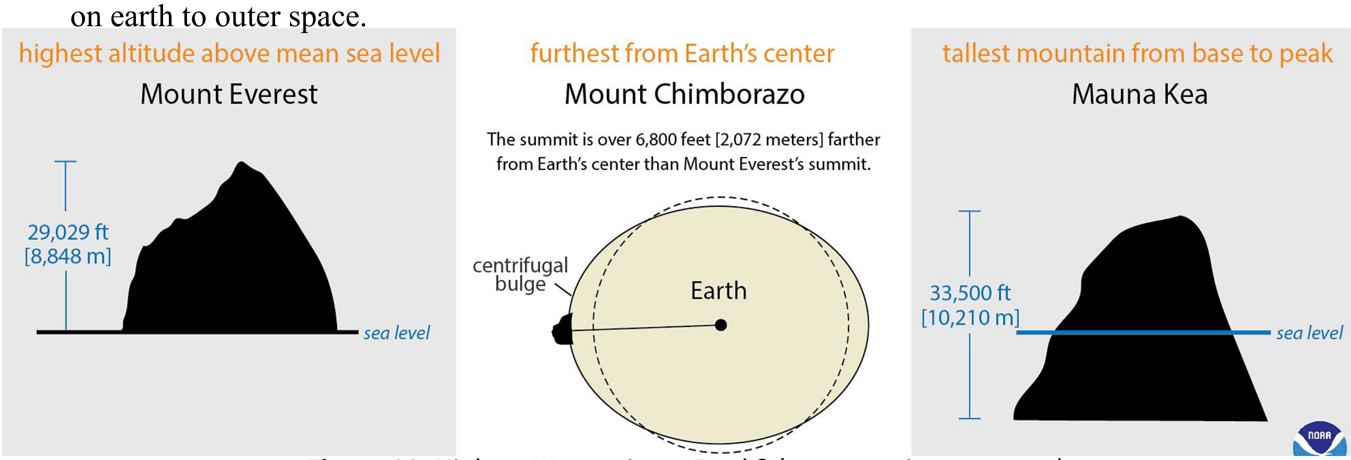


Figure 11. *Highest Mountain on Earth? (oceanservice.noaa.gov)*

33. Ecuador sees very little change in the length of its days from winter to summer due to its location on the equator. Sunrise and sunset happen every day at around 6:00 am and pm, respectively.

Other interesting facts about Ecuador

34. The cinchona tree is Ecuador's national tree. This tree produces Quinine, which was the first drug ever used to treat and prevent malaria.

Figure 12. *Panama Hat (wikipedia.com)*

35. The famous Panama Hat is actually made in Ecuador. Craftsmen on the coast wove straw hats that were taken to Panama to be sold to protect canal workers from the sun. After the canal was complete, they were sold to the affluent Westerners traveling through the Canal.

36. Ecuador was the first nation to ever declare that nature has constitutional rights. In 2008 Ecuador recognized that nature has the "right to exist, persist….and regenerate its vital cycles', and therefore has constitutional rights. Nature should not be treated as property.

37. Ecuador has one of the greatest densities of volcanoes on earth. Ecuador was the first country in the history of the world to eliminate the death penalty. They waived it in 1906.

38. Ecuador maintains a scientific research station in Antarctica. The Antarctica Treaty designated this continent be set aside for research and not for ownership, and Ecuador in a part of that treaty.

39. Forty percent of the adults in Ecuador don't have access to a bank account.

40. There are more mobile phones than people in Ecuador. The government sees this as an opportunity to test the use of digital currency.

41. Ecuador has a military base in Peru on one perpetually leased square kilometer.

42. In Quito water boils at 90°C instead of 100°C. This is a direct effect of altitudes.

43. Members of fifteen percent of the bird species in the world can be found in Ecuador. Which means more than 1600 different bird species live in the country.

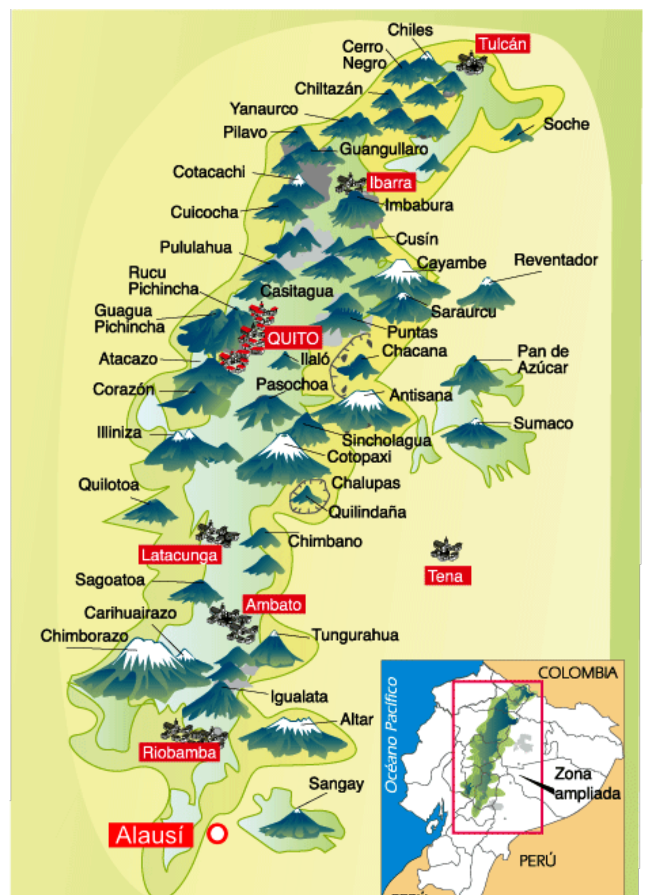


Figure 13. *The Avenue of Volcanoes in Central Ecuador (pinterest.com)*

44. There are more than 25,000 plant species growing in Ecuador and a minimum of 317 documented mammal species native to the country.

Climatic Conditions of Ecuador in March

The following is take from:

Weather Spark, 2018, Average Weather in March in Quito Ecuador. Accessed December 2018, https://weatherspark.com/m/20030/3/Average-Weather-in-March-in-Quito-Ecuador

Note: *This article I found is really just for Quito in March. Quito is at 9,350 ft (2,850 m), we will likely go up to ~15,000 ft (4,572 m) in the mountains and down to ~5,000 ft (1,524 m) outside of Banos. Going higher will be colder, lower will be warmer. Plan for a range of temperatures.*

Temperatures:

Daily high temperatures are around 64°F, rarely falling below 59°F or exceeding 68°F. The lowest daily average high temperature is 64°F on March 3.

Daily low temperatures are around 49°F, rarely falling below 46°F or exceeding 52°F.

For reference, on September 20, the hottest day of the year, temperatures in Quito typically range from 48°F to 66°F, while on July 16, the coldest day of the year, they range from 48°F to 65°F.

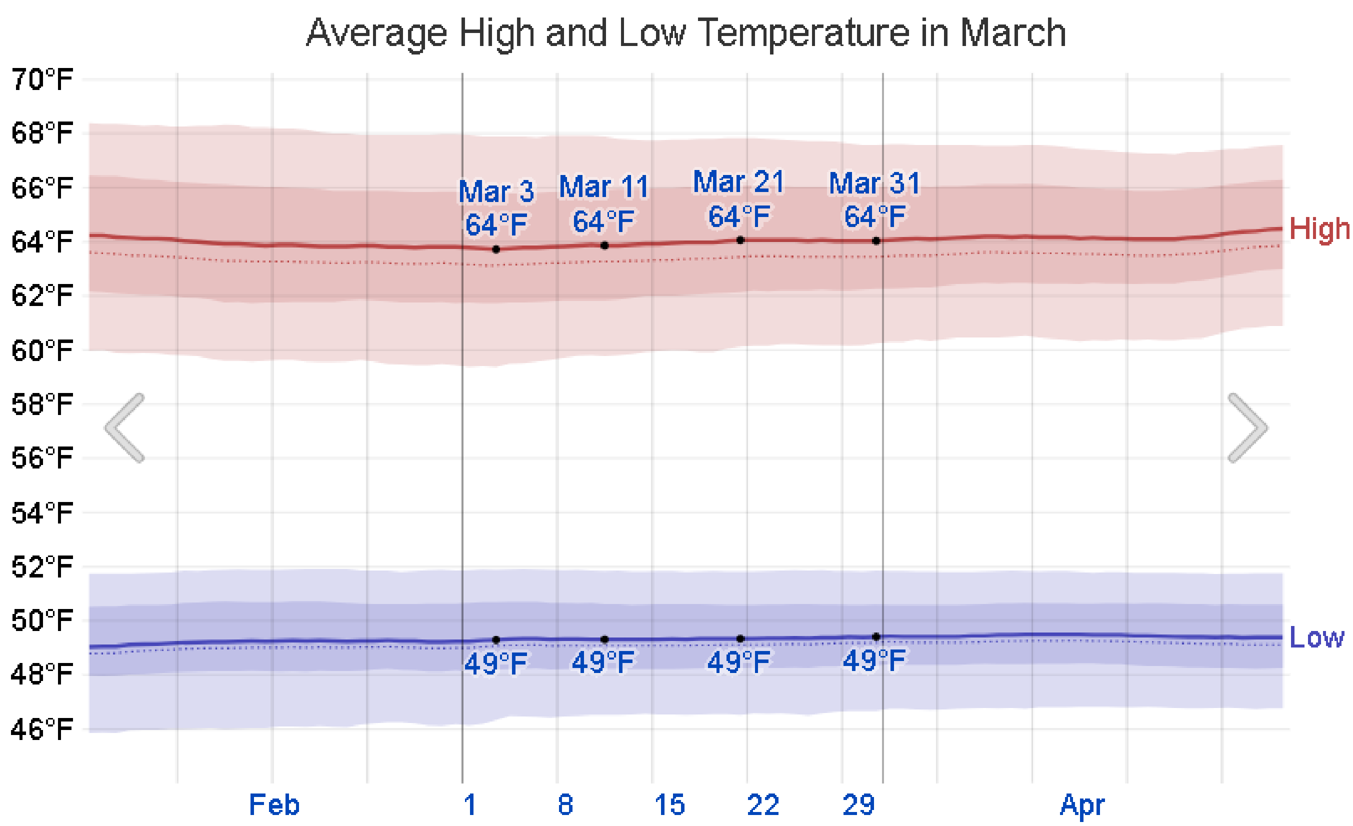


Figure 14. *The daily average high (red line) and low (blue line) temperature, with 25th to 75th and 10th to 90th percentile bands. The thin dotted lines are the corresponding average perceived temperatures.*

The figure below shows you a compact characterization of the hourly average temperatures for the quarter of the year centered on March. The horizontal axis is the day, the vertical axis is the hour of the day, and the color is the average temperature for that hour and day.

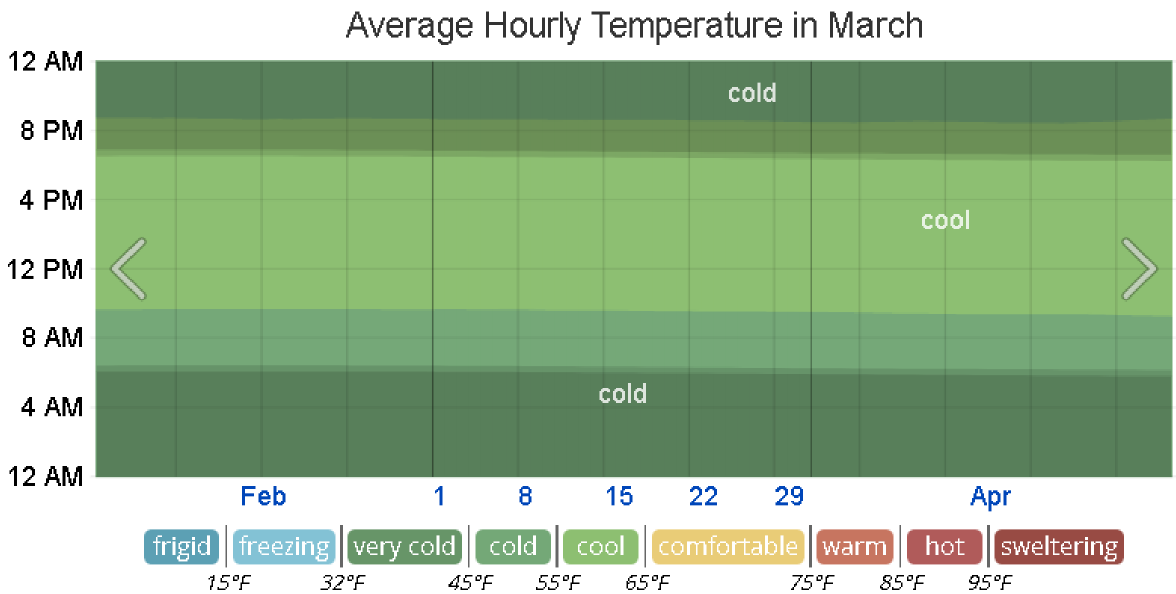


Figure 15. *The average hourly temperature, color coded into bands. The shaded overlays indicate night and civil twilight.*

<u>Clouds:</u>

The month of March in Quito experiences essentially constant cloud cover, with the percentage of time that the sky is overcast or mostly cloudy remaining about 90% throughout the month. The highest chance of overcast or mostly cloudy conditions is 91% on March 14. The clearest day of the month is March 31, with clear, mostly clear, or partly cloudy conditions 10% of the time.

For reference, on March 14, the cloudiest day of the year, the chance of overcast or mostly cloudy conditions is 91%, while on July 31, the clearest day of the year, the chance of clear, mostly clear, or partly cloudy skies is 49%.

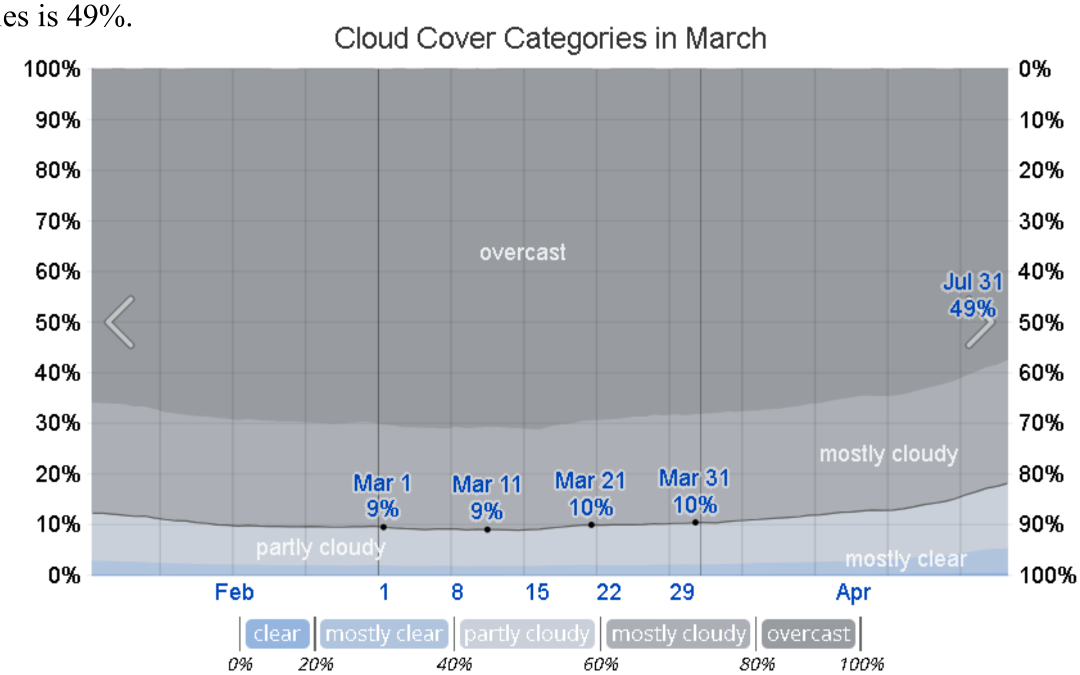


Figure 16. *The percentage of time spent in each cloud cover band, categorized by the percentage of the sky covered by clouds.*

Precipitation

A wet day is one with at least 0.04 inches of liquid or liquid-equivalent precipitation. In Quito, the chance of a wet day over the course of March is gradually increasing, starting the month at 70% and ending it at 73%.

For reference, the year's highest daily chance of a wet day is 76% on April 18, and its lowest chance is 11% on July 31.

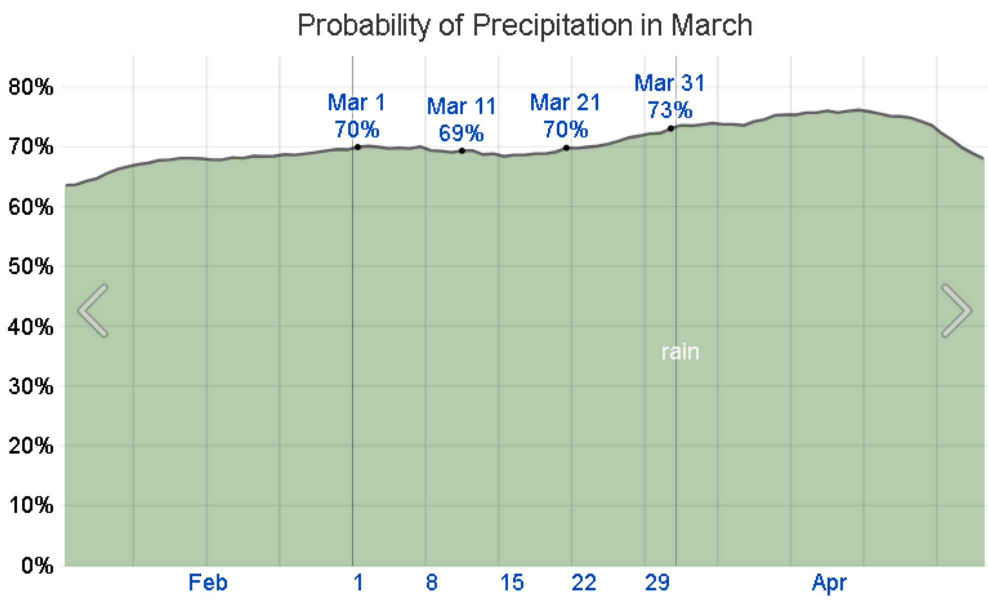


Figure 17. *The percentage of days in which various types of precipitation are observed, excluding trace quantities: rain alone, snow alone, and mixed (both rain and snow fell in the same day).*

Rainfall

To show variation within the month and not just the monthly total, we show the rainfall accumulated over a sliding 31-day period centered around each day.

The average sliding 31-day rainfall during March in Quito is increasing, starting the month at 5.4 inches, when it rarely exceeds 7.9 inches or falls below 2.9 inches, and ending the month at 6.2 inches, when it rarely exceeds 9.4 inches or falls below 2.8 inches.

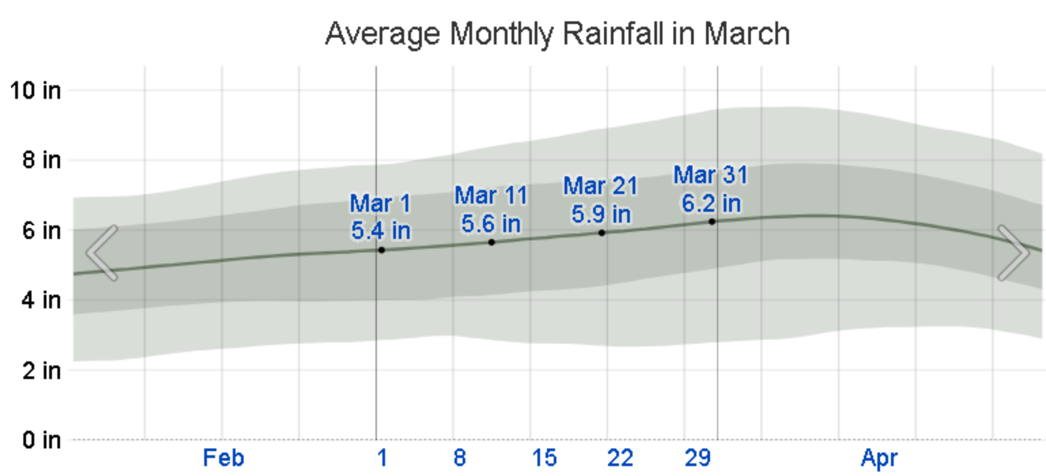


Figure 18. *The average rainfall (solid line) accumulated over the course of a sliding 31-day period centered on the day in question, with 25th to 75th and 10th to 90th percentile bands. The thin dotted line is the corresponding average liquid-equivalent snowfall.*

Sun

Over the course of March in Quito, the length of the day is essentially constant. The shortest day of the month is March 30, with 12 hours, 6 minutes of daylight and the longest day is March 1, with 12 hours, 7 minutes of daylight.

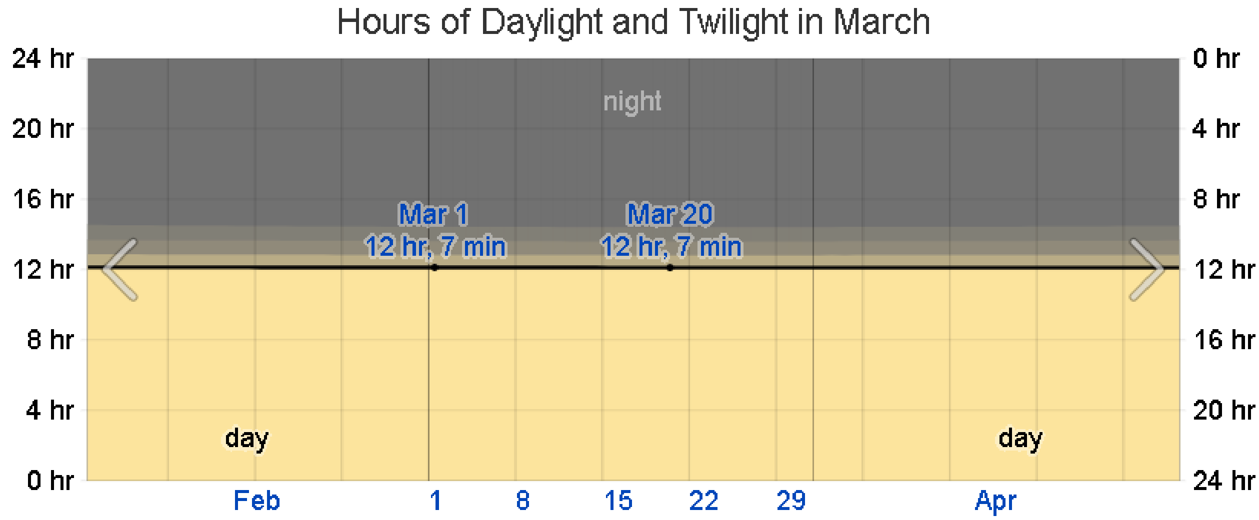


Figure 19. *The number of hours during which the Sun is visible (black line). From bottom (most yellow) to top (most gray), the color bands indicate: full daylight, twilight (civil, nautical, and astronomical), and full night.*

The latest sunrise of the month in Quito is 6:22 AM on March 1 and the earliest sunrise is 8 minutes earlier at 6:15 AM on March 31. The latest sunset is 6:29 PM on March 1 and the earliest sunset is 8 minutes earlier at 6:21 PM on March 31.

Daylight saving time is not observed in Quito during 2018. President Sixto Durán Ballén imposed daylight saving time in 1992 in an energy-saving effort. It was poorly received by the populace and did not last long.

For reference, on December 21, the longest day of the year, the Sun rises at 6:08 AM and sets 12 hours, 8 minutes later, at 6:16 PM, while on June 21, the shortest day of the year, it rises at 6:12 AM and sets 12 hours, 7 minutes later, at 6:19 PM.

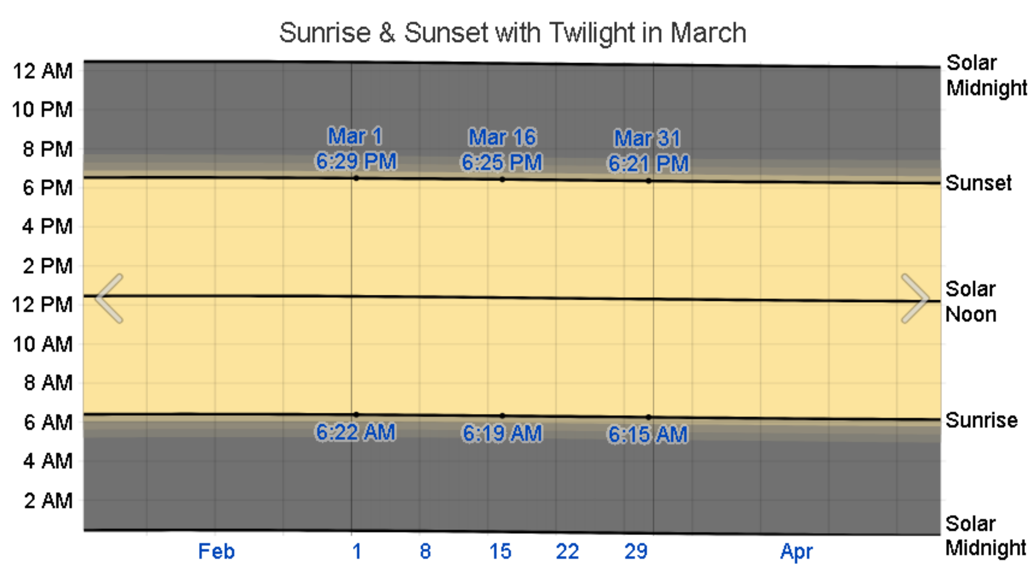


Figure 20.
The solar day over the course of March. From bottom to top, the black lines are the previous solar midnight, sunrise, solar noon, sunset, and the next solar midnight. The day, twilights (civil, nautical, and astronomical), and night are indicated by the color bands from yellow to gray.

Humidity
The chance that a given day will be muggy in Quito is essentially constant during March, remaining around 0% throughout.

Wind
This section discusses the wide-area hourly average wind vector (speed and direction) at 10 meters above the ground. The wind experienced at any given location is highly dependent on local topography and other factors, and instantaneous wind speed and direction vary more widely than hourly averages.

The average hourly wind speed in Quito is essentially constant during March, remaining within 0.1 miles per hour of 3.1 miles per hour throughout.

For reference, on August 1, the windiest day of the year, the daily average wind speed is 5.5 miles per hour, while on April 18, the calmest day of the year, the daily average wind speed is 2.9 miles per hour.

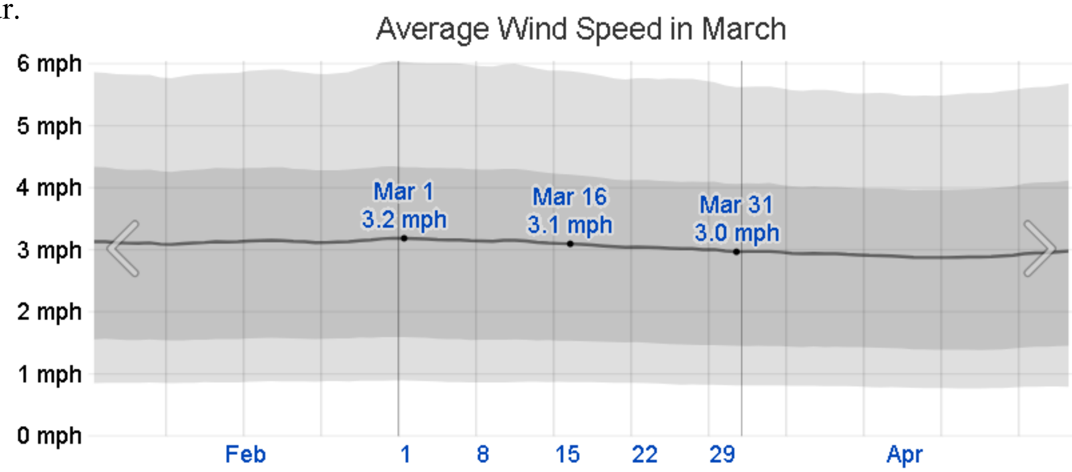


Figure 21. *The average of mean hourly wind speeds (dark gray line), with 25th to 75th and 10th to 90th percentile bands.*

The hourly average wind direction in Quito throughout March is predominantly from the east, with a peak proportion of 44% on March 31.

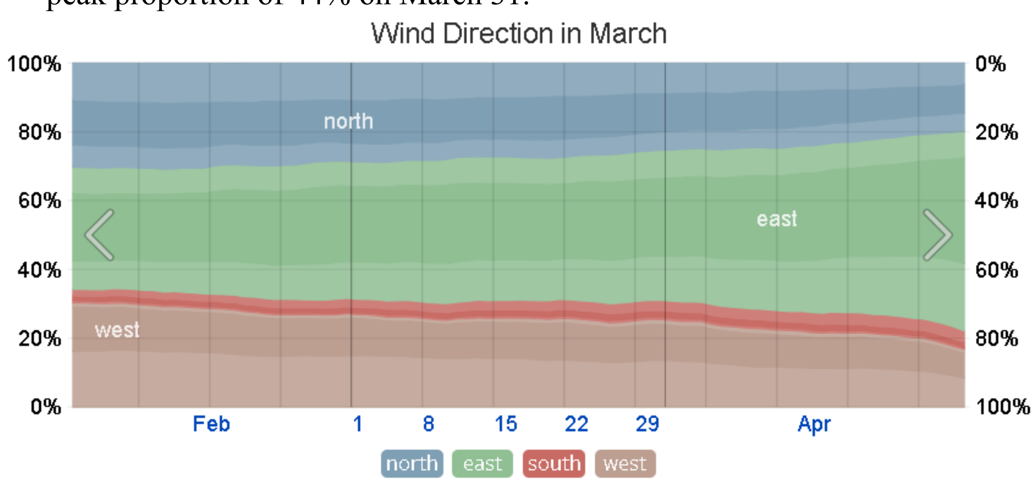


Figure 22. *The percentage of hours in which the mean wind direction is from each of the four cardinal wind directions, excluding hours in which the mean wind speed is less than 1.0 mph. The lightly tinted areas at the boundaries are the percentage of hours spent in the implied intermediate directions (northeast, southeast, southwest, and northwest).*

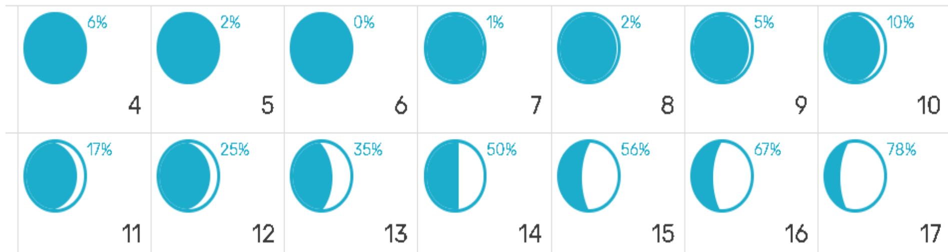
Topography

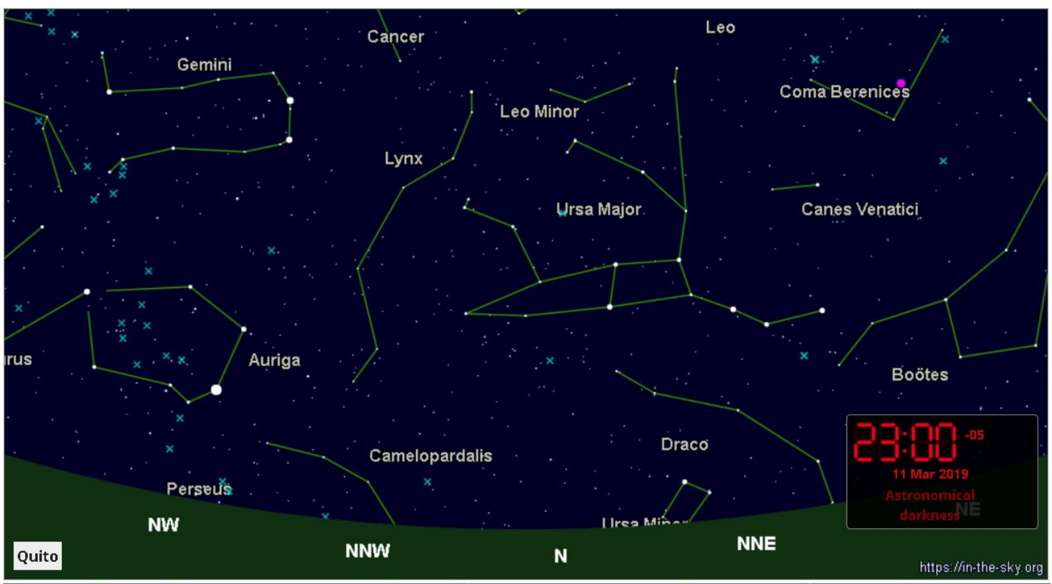
For the purposes of this report, the geographical coordinates of Quito are -0.230 deg latitude, -78.525 deg longitude, and 9,629 ft elevation.

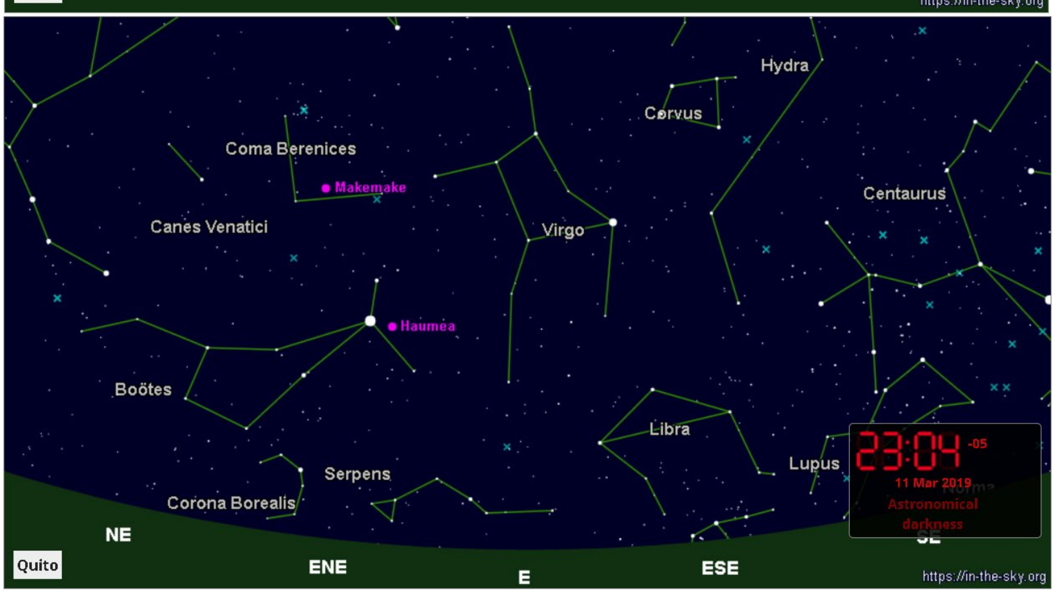
The topography within 2 miles of Quito contains large variations in elevation, with a maximum elevation change of 2,776 feet and an average elevation above sea level of 9,756 feet. Within 10 miles contains large variations in elevation (8,606 feet). Within 50 miles also contains extreme variations in elevation (18,576 feet).

Astronomical Conditions

Figure 23.
Lunar occurrence while we are in Ecuador (https://calendariohispanohablante.com)







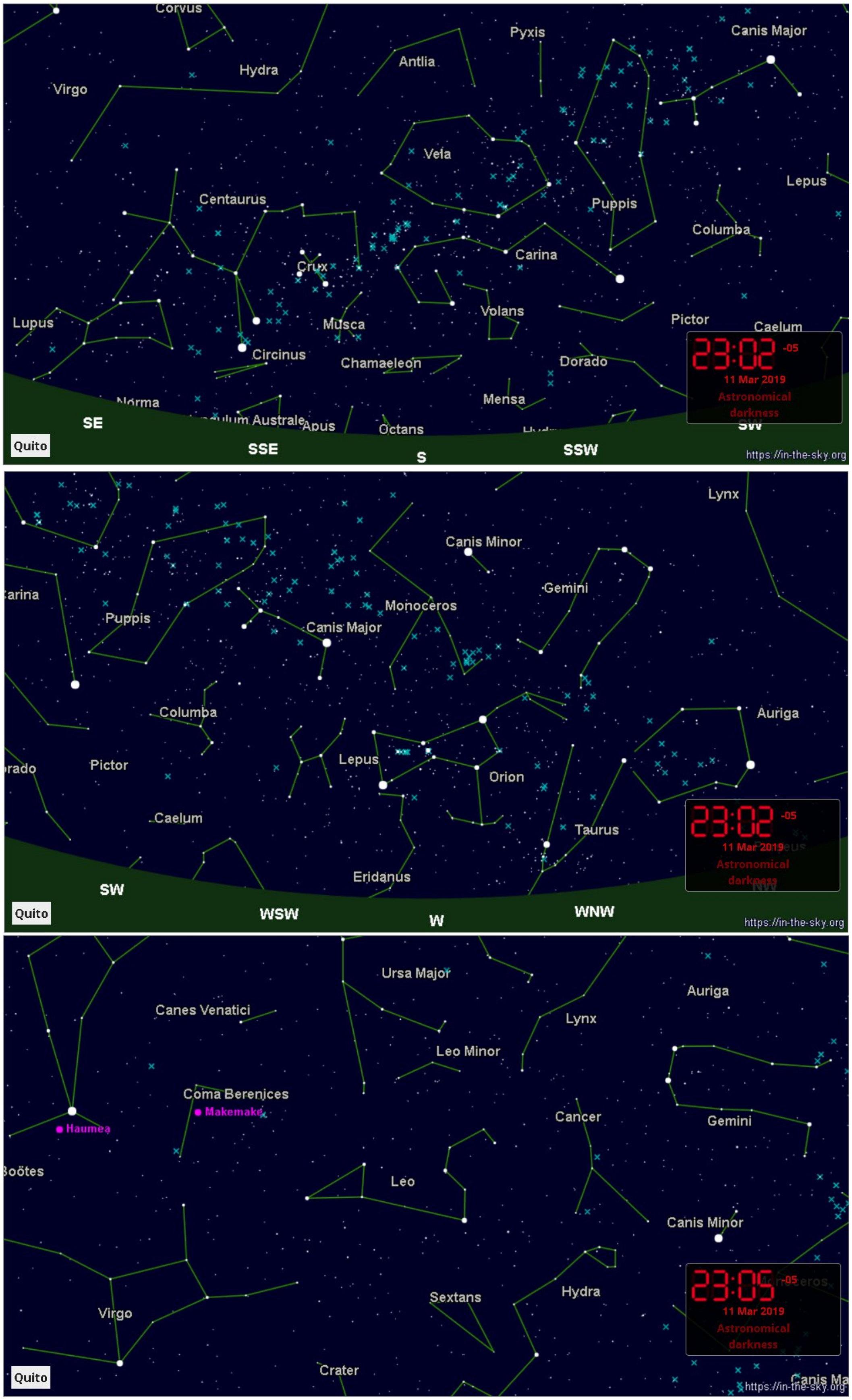


Figure 24. *The astronomical arrangement for March 11, 2019 in Quito (http://in-the-sky.org)*

Ecuadorian Food

All of this comes from Wikipedia:
https://en.wikipedia.org/wiki/Ecuadorian_cuisine
https://en.wikipedia.org/wiki/List_of_Ecuadorian_dishes_and_foods
Among other Wikipedia pages as I went down the Wiki Rabbit Hole.

Ecuadorian cuisine is diverse, varying with altitude, and associated agricultural conditions. Beef, chicken, and seafood are popular in the coastal regions and are typically served with carbohydrate-rich foods, such as rice accompanied with lentils, pasta, or plantain. Whereas in the mountainous regions pork, chicken, beef and cuy (guinea pig) are popular and are often served with rice, corn, or potatoes. A popular street food in mountainous regions is hornado, consisting of potatoes served with roasted pig. Some examples of Ecuadorian cuisine in general include patacones (unripe plantains fried in oil, mashed up, and then refried), llapingachos (a pan-seared potato ball), and seco de chivo (a type of stew made from goat). A wide variety of fresh fruit is available, particularly at lower altitudes, including granadilla, passionfruit, naranjilla, several types of banana, uvilla, taxo, and tree tomato.

The food is somewhat different in the southern mountainous areas, featuring typical Loja food such as repe, a soup prepared with green bananas; cecina, roasted pork; and miel con quesillo, or "cuajada", as dessert. In the rainforest, a dietary staple is the yuca, elsewhere called cassava. The starchy root is peeled and boiled, fried, or used in a variety of other dishes. Across the nation it's also used as a bread, pan de yuca which is analogous to the Brazilian pão de queijo and its often consumed alongside different types of drinkable yogurt. Many fruits are available in this region, including bananas, tree-grapes, and peach-palms.

Typical meal

Most regions in Ecuador follow the traditional 3 course meal of sopa/soup and segundo/second dish which includes rice or pasta and a protein such as meat, poultry, pig or fish. Dessert and a coffee are customary. Dinner is usually lighter and sometimes just coffee or agua de remedio/herbal tea with bread.

For the most part, Ecuador is known not only for its bananas, and all the dishes made from them, but for its starch consumption of products like potato, bread, pasta, rice, and yuca. Traditionally, any of these ingredients can be found in either the soup or the rice platter that may be served.

Ecuador maize varieties

The varieties of Ecuadorian maize are the repository of a rich farming and cooking tradition. Maize is cropped almost everywhere in Ecuador, with the exception of the Altiplano, the cold desert highlands 3000 meters above sea level. Maize production is concentrated in the provinces of Loja, Azuay, and Pichincha, and to a lesser extant Bolívar, Chimborazo, Tungurahua, and Imbabura, provinces located in the mountains. Maize is also found in the coastal provinces, Manabí, Esmeraldas, and Guayas, as well as Pastaza, part of the Ecuadorian Amazon.

Most traditional foods are strictly linked to specific maize kernel types as well as grinding and cooking techniques. Cooked or toasted grains, and puddings of partially ripe grains, are prepared with mostly floury kernel varieties:

Chicha - brewed drink of ground maize kernels
Chullpi - sweet maize
Maíz tierno - soft maize, at the milk ripeness stage
Maíz cao - waxy stage maize
Mote - boiled maize with beans
Pan - bread of maize flour, kneaded and baked
Palomitas de Maíz or Canguil - popcorn
Tamal - maize and meat rolls
Tortillas - flatbread of maize flour, kneaded and cooked on a hot plate
Tostado - toasted maize with or without fat

Random Foods

Bolón de verde – (also known as tacacho) is a roasted banana Amazonian cuisine dish. It is usually served *con cecina,* with bits of pork.

Caldo de bolas de verde – (green plantain dumpling soup) is from coastal Ecuador.

Carrots – a local delicacy of Latacunga, Ecuador, and the surrounding area prepared with deep fried pork and several other ingredients

Cassava – a woody shrub native to South America extensively cultivated for its edible starchy tuberous root. Though it is often called yuca in Spanish and in the United States, it differs from yucca, an unrelated fruit-bearing shrub. Cassava, when dried to a powdery (or pearly) extract, is called tapioca; its fried, granular form is named garri.

Cuy – roasted guinea pig. Guinea pig meat is high in protein and low in fat and cholesterol, and is described as being similar to rabbit and the dark meat of chicken. The animal may be served fried (chactado or frito), broiled (asado), or roasted (al horno), and in urban restaurants may also be served in a casserole or a fricassee. Ecuadorians commonly consume sopa or locro de cuy, a soup dish. Pachamanca or huatia, a process similar to barbecueing, is also popular, and is usually served with corn beer (chicha) in traditional settings

Durian – is the fruit of several tree species belonging to the genus Durio. It is native to Southeast Asia but grown in many tropical regions. Named in some regions as the "king of fruits", the durian is distinctive for its large size, strong odor, and thorn-covered rind. The fruit can grow as large as 30 centimeters (12 in) long and 15 centimeters (6 in) in diameter, and it typically weighs one to three kilograms (2 to 7 lb). Its shape ranges from oblong to round, the color of its husk green to brown, and its flesh pale yellow to red, depending on the species. Some people regard the durian as having a pleasantly sweet fragrance, whereas others find the aroma overpowering with an unpleasant odor. The smell evokes reactions from deep appreciation to intense disgust, and has been described variously as rotten onions, turpentine, and raw sewage. The persistence of its odor, which may linger for several days, has led to the fruit's banishment from certain hotels and public transportation in southeast Asia. By contrast, the nineteenth-century British naturalist Alfred Russel Wallace described its flesh as "a rich custard highly flavored with almonds".

Empanadas de Platano – An empanada is a type of pastry baked or fried in Hispanic cultures. The name comes from the Spanish verb empanar, and literally translates as "enbreaded", that is, wrapped or coated in bread. with plantains…

Encebollado (Spanish: cooked with onions) is a fish stew from Ecuador, where it is regarded as a national dish. The dish is most popular in the country's coastal region. It is served with boiled cassava and pickled red onion rings. A dressing of onion is prepared with fresh tomato and spices such as pepper or coriander leaves. It is commonly prepared with albacore, but tuna, billfish, or bonito may also be used. It may be served with ripe avocado. Encebollado is usually served with banana chips, plantains, or bread as side dishes. It may be garnished with lime juice and chili sauce. People in Ecuador eat it for breakfast, lunch, or dinner.

Fanesca – is a soup traditionally prepared and eaten by households and communities in Ecuador during Holy Week. The components of fanesca and its method of preparation vary regionally, or even from one family to another. It is typically prepared and served only in the week before Easter (Holy Week). It is a rich soup, with the primary ingredients being figleaf gourd (sambo), pumpkin (zapallo), and twelve different kinds of beans and grains including chochos (lupines), habas (fava beans), lentils, peas, corn and others, together with bacalao (salt cod) cooked in milk, due to the Catholic religious prohibition against red meat during Holy Week. It is also generally garnished with hard boiled eggs, fried plantains, herbs, parsley, and sometimes empanadas. The twelve beans represent the twelve apostles of Jesus, and the bacalao is symbolic of Jesus himself. Fanesca is usually consumed at midday, which is generally the principal meal of the day within Ecuadorian culture. The making and eating of fanesca is considered a social or family activity.

Fritada – is a typical dish in Ecuadorian cuisine. Its main ingredient is fried pork. It is a traditional dish, and its origins date back to the colonial era, to the beginning of the 19th century. The pork is cooked in boiling water with various spices and then is fried with pork fat in a brass pan over flames. It is generally served with Llapingacho or whole boiled potatoes, mote or cooked corn, pickled onions and tomato, and fried ripe plantains. It may also be accompanied by cooked fava beans or mellocos, though mellocos are rather uncommon.

Guatitas – ([little] guts or [little] bellies, from Spanish: Guata; "Gut/Belly"), or guatitas criollas, is a popular dish in Chile and in Ecuador, where it is considered a national dish. Guatitas is essentially a stew whose main ingredient is pieces of tripe (cow stomach), known locally as "guatitas". The tripe is often cleaned several times in a lemon-juice brine, after which it is cooked for a long time until the meat is tender. Then it is allowed to cool and finely chopped. The traditional Ecuadorian recipe is served hot and accompanied by potatoes and a peanut sauce. The dish is often considered an acquired taste. Because of its strong taste, it is sometimes served in small quantities. In Ecuador, it is believed that guatita helps relieve hangover symptoms. For this reason, it is often served by restaurants early on Saturday and Sunday mornings.

Hornado – is roast pig, cooked whole, in Ecuadorian cuisine. It is often served in highland markets. Hornado is generally accompanied by llapingacho, mote (hominy), and vegetables.

Humita – (from Quechua humint'a) is a Native American dish from pre-Hispanic times, and a traditional food in Bolivia, Chile, although their origin is unclear. It consists of masa harina and corn, slowly steamed or boiled in a pot of water. Ecuadorian humitas are prepared with fresh ground corn with onions, eggs and spices that vary from region to region, and also by each family's tradition. The dough is wrapped in a corn husk, but is steamed rather than baked or boiled. Ecuadorian humitas may also contain cheese. This dish is so traditional in Ecuador that they have developed special pots just for cooking humitas. Ecuadorian humitas can be salty or sweet.

Lechón – is a pork dish in several regions of the worid. Lechón is a Spanish word referring to a roasted suckling pig. Lechón is a popular food in many Latin America countries. The dish features a whole roasted pig cooked over charcoal. After seasoning, the pig is cooked by skewering the entire animal, entrails removed, on a large stick and cooking it in a pit filled with charcoal in a rotisserie action. The pig is roasted on all sides for several hours until done. The process of cooking and basting usually results in making the pork skin crisp and is a distinctive feature of the dish.

Llapingachos are fried potato cakes that originated in Ecuador. They are usually served with a peanut sauce. The dish is similar to Colombian arepas. The potato patties or thick pancakes are stuffed with cheese and cooked on a hot griddle until crispy brown. In Ecuador they are sometimes made with mashed, cooked yuca, or cassava, instead of potato. The yuca or cassava root used to make llapingachos is not to be confused with the similarly spelled yucca, the roots of which are generally not edible.

Locro – (from the Quechua ruqru) is a hearty thick stew popular along the Andes mountain range. It's one of the national dishes of Argentina, Bolivia, Peru and Ecuador. The dish is a classic corn, beans, and potato or pumpkin soup well known along the South American Andes. Typically locro is made using a specific kind of potato called "papa chola", which has a unique taste and is difficult to find outside of its home region. The defining ingredients are corn, some form of meat (usually beef, but sometimes beef jerky or chorizo), and vegetables. Other ingredients vary widely, and typically include onion, beans, squash or pumpkin. It is mainly eaten in winter. In Ecuador, a variant known as yahuarlocro is popular. It incorporates lamb entrails and lamb blood to the recipe.

Mangosteen is a tropical evergreen tree, which produces a delicious fruit, known to many to be "the queen of fruits." It grows mainly in Southeast Asia, southwest India and other tropical areas where the tree has been introduced. The fruit of the mangosteen is sweet and tangy, juicy, somewhat fibrous, with fluid-filled vesicles (like the flesh of citrus fruits), with an inedible, deep reddish-purple colored rind (exocarp) when ripe. In each fruit, the fragrant edible flesh that surrounds each seed is botanically endocarp, i.e., the inner layer of the ovary. Seeds are almond-shaped and -sized.

Mote – (from Quechua: mut'i, through Spanish mote) is the generic name for several varieties of corn grains boiled, consumed in many regions of South America. It is usually prepared by boiling the grains in water made alkaline by the addition of ashes or lime, a process known as nixtamalization. In Ecuador, "mote" refers to corn kernels that have been boiled and cooked, which are served peeled. They often accompany popular dishes such as hornado and fritada. They are used in many soups, including caldo de patas. It is also the main ingredient in dishes typical of the city of Cuenca, such as mote pillo, mote sucio and mote pata.

Rambutan – is a medium-sized tropical evergreen tree in the family Sapindaceae. The name also refers to the edible fruit produced by this tree. The rambutan is native to the Indonesian region and other regions of tropical Southeast Asia. The fruit is a round to oval single-seeded berry, 3–6 cm (rarely to 8 cm) long and 3–4 cm broad, borne in a loose pendant cluster of 10–20 together. The leathery skin is reddish (rarely orange or yellow), and covered with fleshy pliable spines, hence the name, which means 'hairs'. The fruit flesh, which is actually the aril, is translucent, whitish or very pale pink, with a sweet, mildly acidic flavor very reminiscent of grapes.

Salak – is a species of palm tree native to Java and Sumatra in Indonesia and is cultivated in other regions. The fruits grow in clusters at the base of the palm, and are also known as snake fruit due to the reddish-brown scaly skin. They are about the size and shape of a ripe fig, with a distinct tip. The pulp is edible. The taste is usually sweet and acidic, with a strong astringent edge, but its apple-like texture can vary from very dry and crumbly to moist and crunchy.

Sancocho – (from the Spanish verb sancochar, "to parboil") is a traditional soup (stew) in several Latin American cuisines. It usually consists of large pieces of meat, tubers and vegetables served in a broth. In the "Sierra" of Ecuador, sancocho, also known as fritada, is a comfort food made with pork. In the coastal region, it is similar to the Colombian sancocho. It has the typical ingredients: yuca, plantain, and corn "choclo". It can be made of fish, hen,[clarification needed] chicken, ox tail, or beef. Due to cultural differences, it can cause confusion when people go from one region to the other.

Salchipapa or salchipapas – is a fast food dish commonly consumed as street food throughout Latin America. The dish's name is a portmanteau of the Spanish words "salchicha" (sausage) and "papa" (potato). Salchipapas typically consist of thinly sliced pan-fried beef sausages and French fries, mixed together with a savory coleslaw on the side. The dish is served with different sauces, such as ketchup and mustard, crema de aceituna (olive sauce), along with aji or chili peppers. Sometimes a fried egg or cheese is added on top; it can also come with tomato and lettuce, and is occasionally garnished with oregano.

Seco – is a popular stewed meat plate served in Peru and Ecuador. One popular variation is seco de cordero (stewed Lamb).

Refrito – referred to as refrito in Ecuador, and it is made of Spanish onions, cubanelle peppers, fresh tomatoes, roasted garlic, cilantro and ground toasted cumin. Preparations may vary, but it typically consists of aromatic ingredients cut into small pieces and sauteed or braised in cooking oil.

T'anta wawa – ("bread baby", from Aymara and Quechua t'anta "bread" and wawa "child, baby"; hispanicized names: guagua de pan, tantaguaguas, tantahuahua, wawas de pan, tantawawas and muñecas de pan) is a type of sweet roll shaped and decorated in the form of a small child or infant. They are generally made of wheat and sometimes contain a sweet filling. They are made and eaten as part of ancestral rites in Andean regions of Bolivia, Ecuador, Peru, the south of Colombia, and the north of Argentina, mainly on All Souls' Day, but also as part of agricultural festivals, carnivals, and Christmas. T'anta wawa are consumed on November 2 all over the Andean region. They are eaten with colada morada. They are made by families and exchanged among groups of family and friends and given to godchildren. In rural cemeteries and indigenous communities, such as Tungurahua Province, they are used as offerings as part of a ceremony of encounter with one's ancestors.

Ecuadorian Drink

Beverages

Aguardiente, a sugar cane-based spirit, is probably the most popular national alcohol. Canelazo is a popular drink made from aguardiente. Drinkable yogurt, available in many fruit flavors, is popular and is often consumed with pan de yuca (a puffy yet gooey bread roll made from cassava flour eaten hot). One traditional non-alcoholic beverage is pinol, made using machica (toasted barley flour), panela (unrefined sugar), and spices. Another traditional non-alcoholic beverage is colada morada, which is made with black corn flour, sweetened with panela, and flavored with fresh fruit, herbs and spices.

Non-alcoholic:

Jugos - Fresh Juices – Ecuador lies in a tropical region and many fresh fruit are readily available and some of the most popular regular drinks. Some popular favors are: maracuyá (passion fruit), tomate de árbol (tree tomato/tamarillo – a fruity tomato), naranjilla (sweet and tart fruit), piňa (pineapple), naranja (orange), guanábana (very sweet white fruit), taxo (a kind of passion fruit), and babaco (like papaya).

Alcoholic:

Spirits:

Aguardiente is a generic term for alcoholic beverages that contain between 29% and 60% alcohol by volume. The word is a compound of the Romance languages' words for "water" (agua) and "fiery" (ardiente), similarly to the English term "firewater".

In Ecuador, aguardiente is derived from sugar cane and it is left largely unflavored. It is then taken straight as shots, mulled with cinnamon (canela in Spanish) and fruit juices to make the hot cocktail canelazo, or mixed with the juice of agave masts and Grenadine syrup for the hot cocktail *draquita*. Locally or artisanally made aguardiente is commonly called *punta*, "*puro*" or *trago*, and alcohol content can vary widely, from "mild" puntas of about 10% to "strong" of about 40% or higher. Every Ecuadorian province has a slightly different flavor to the aguardiente produced there, and equally each province has a different recipe for *canelazo*. In Ecuador, aguardiente is the most commonly consumed strong alcohol. Aguardiente Astillero is one of the newest brands, which is becoming very popular due to its symbolic title especially around Guayas. The main brands are Cristal and Zhumir

Wine:

Ecuador isn't known as a wine producing country. According to experts, such a geographical area without distinct seasons isn't suitable for the planting and harvesting vineyards. Therefore, the lovers of this drink in this small South American nation are used to getting their wine from either Chile or Argentina, or of course from countries like France, Spain and other European nations. Perhaps this is why the consumption of this beverage was limited to upper income groups here.

Beer

The economy for local Ecuadorian beer has increased significantly in the last decade. Previously, most taverns, restaurants, and stores only stocked the two national brands – Club and Pilsener (basically Bud and Bud light, respectively). Their main selling points were not their taste, but their cheap price. Each bottle costs about $1.50 a bottle.

looks like there are some small microbreweries making some interesting beers:

- **Bandido Brewing**: They have the most acclaimed brews in Ecuador, they are located in Old Town Quito.
  http://bandidobrewing.com/en/
- **Cherusker**: They have two locations; one in Mariscal Sucre, Quito and one in Baños
  http://cherusker.com/

Ecuador in Popular Culture

Movies about Ecuador:

- **Crude** (2009) – about oil exploration in Ecuador (95% on Rotten Tomatoes), 105 min – Available on YouTube: https://www.youtube.com/watch?v=BvrZRvgwBS8

These are Ecuadorian Movies that are supposed to be good, but I am have a tough time tracking them down.

- ¿Qué tan lejos? (2006)
- Prometeo deportado (2007)
- Mejor No Hablar (de Ciertas Cosas) (2012)
- La Muerte de Jaime Roldós (2013)

Shows about Ecuador:

- *Food*:
  - **Anthony Bourdain's No Reservations** (2010) – Season 6, Episode 6
  - **Bizarre Foods** (2007) – Season 1, Episode 4
- *Travel*:
  - **Departures** (2010, 46 min) – "Ecuador" Season 3, Episode 7 – Available on Netflix
  - **Expedition Unknown** (2016) – "Incan King's Mummy" Season 6, Episode 6
  - **Expedition Unknown** (2018) – "Hunt For The Metal Library" Season 4, Episode 6
  - **Ecuador: a travel documentary** (2016, 23 min) – Available on YouTube:
    https://www.youtube.com/watch?v=YViKo_OidK4
  - **Ecuador Vacation Travel Video Guide** (2014, 52 min) – Available on YouTube:
    https://www.youtube.com/watch?v=YMUtyA7wNXI
  - **Ecuador Travel Guide 2016** (2016, 14 min) – Available on YouTube:
    https://www.youtube.com/watch?v=yN_NxTaGO1k
  - **Ecuador Travel Video: 10 Days in Quito, The Equator, Otavalo, Teña, The Amazon, and Baños** (2011, 15 min) – Available on YouTube:
    https://www.youtube.com/watch?v=YnNPEP_oV4M
  - **ECUADOR Travel Documentary with Travel Host Mike Melendy** (2015, 13 min):
    https://www.youtube.com/watch?v=m4JkeSbuA7A
  - **Ecuador Travel Video: 10 Days in Quito, The Equator, Otavalo, Teña, The Amazon, and Baños** (2011, 15 min) – Available on YouTube:
    https://www.youtube.com/watch?v=YnNPEP_oV4M

GENERAL GEOLOGIC BACKGROUND

The following are notes from a short lecture Dr. Kerrigan gave about the geology of Ecuador

Tectonic Configuration

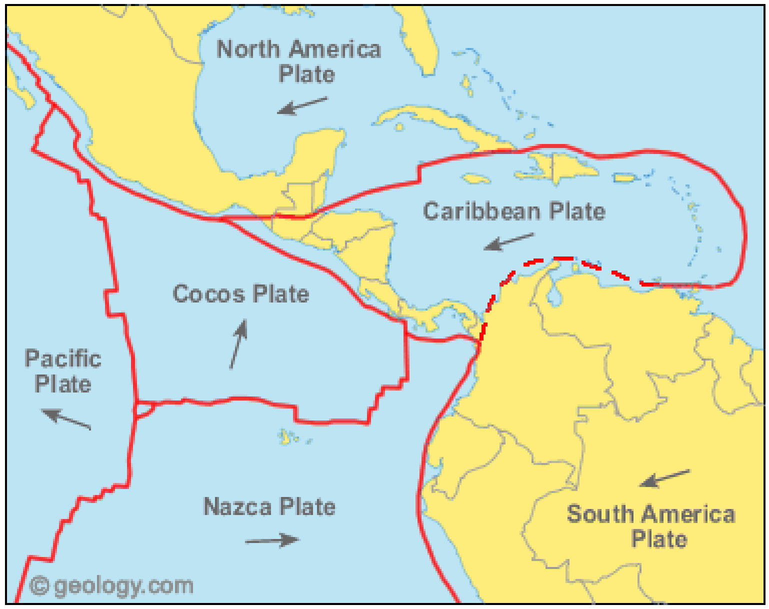


Figure 25: *General Plate Tectonics in the Region*

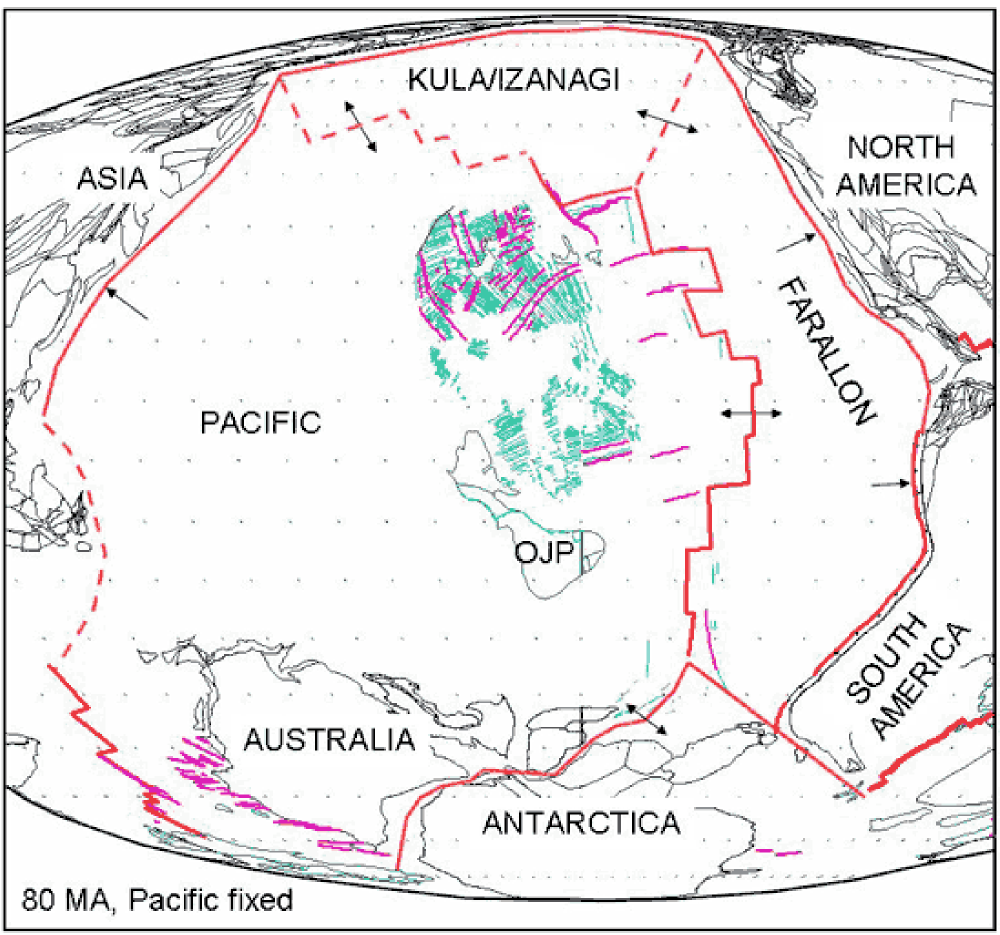
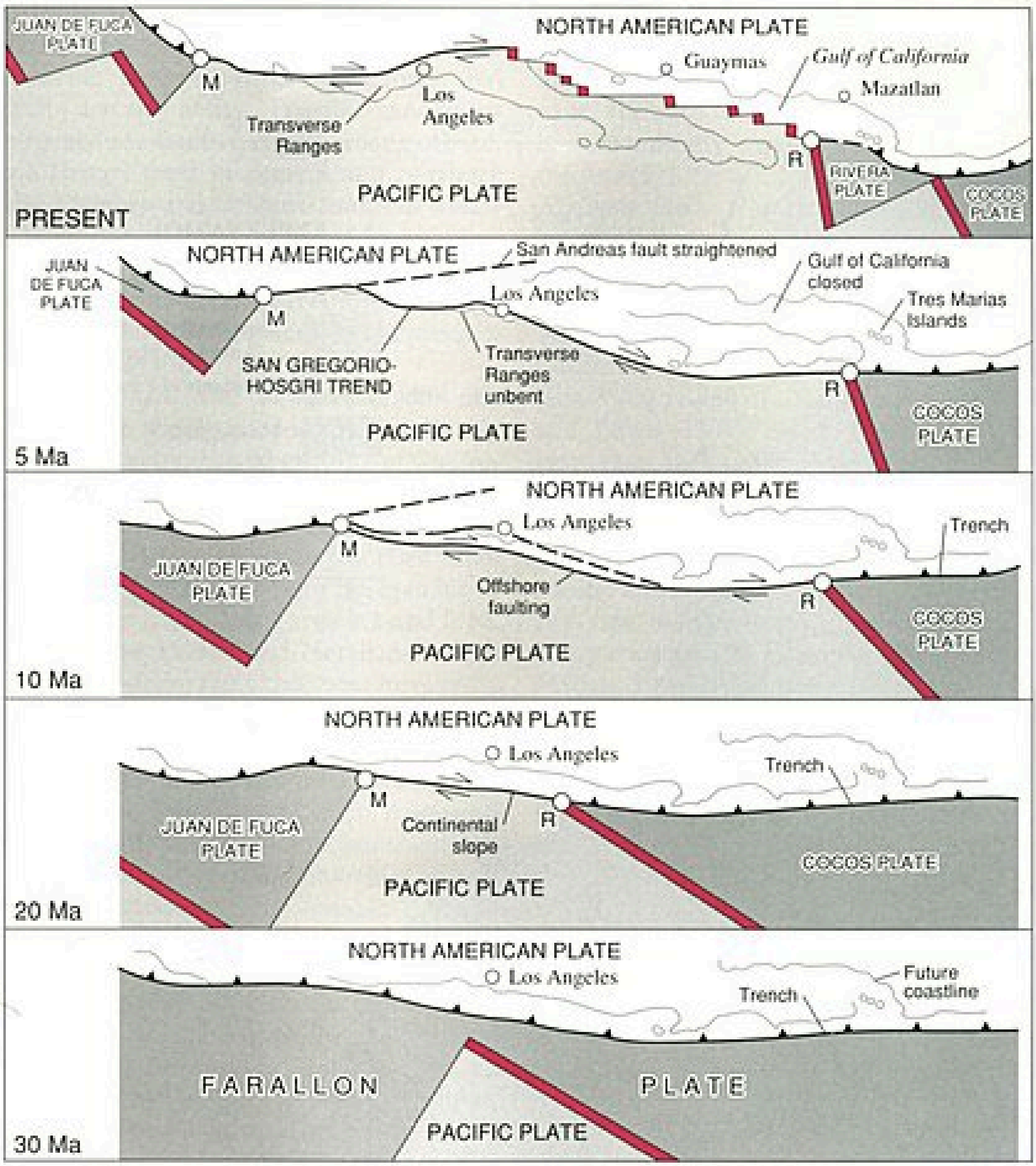


Figure 26: *General Plate Tectonics in the Region c. 80Ma - showing the orientation of the Farallon Plate. (https://alchetron.com/Farallon-Plate#-)*



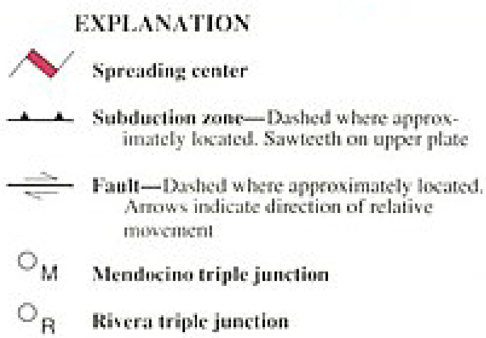


Figure 27: *Formerly subducted Farallon Plate, break of the Farallon 23-28 Ma created the Cocos and Nazca plate in the southeast Pacific (wikipedia.com)*

Nazca Plate:

- It is thought that the Nazca plate has reached 300-500 km beneath the continent (Yepes et al, 2016)
- Moving at ~58 mm cm/yr (most plate range between 20-100 mm/yr)

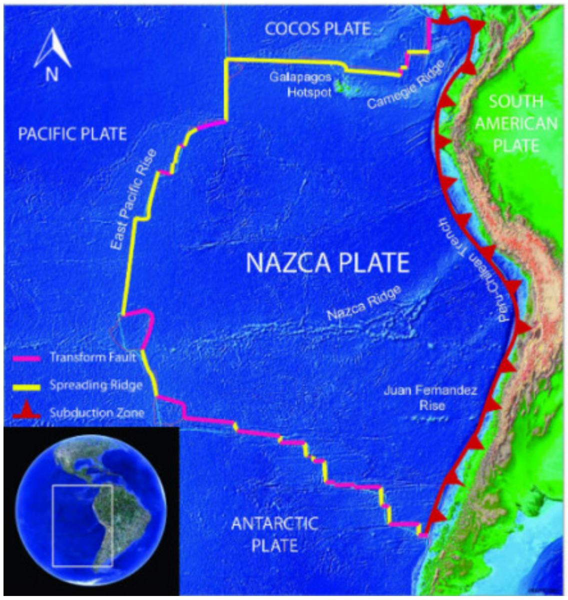
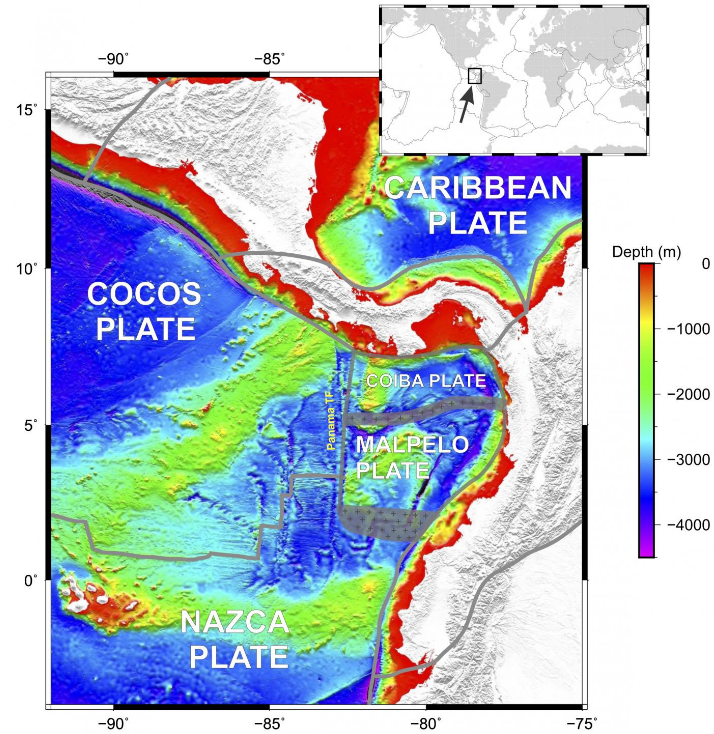


Figure 28: *Nazca Plate (https://caribbeantectonics.weebly.com/)*



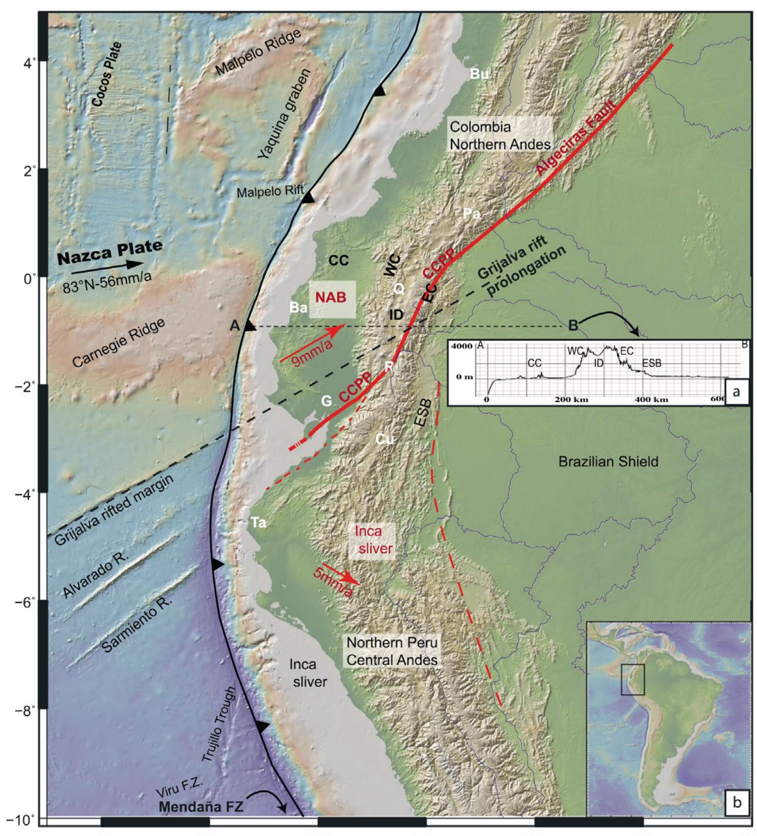


Figure 29: *Grijalva rift separates old Farallon crust and Nazca crust.*

South America fixed;

Nazca - 083°, 56 mm/yr;

Northern Andean Block - 050°, 56 mm/yr;

Inca Sliver - 130°, 56 mm/yr.

(Yepes et al., 2016)

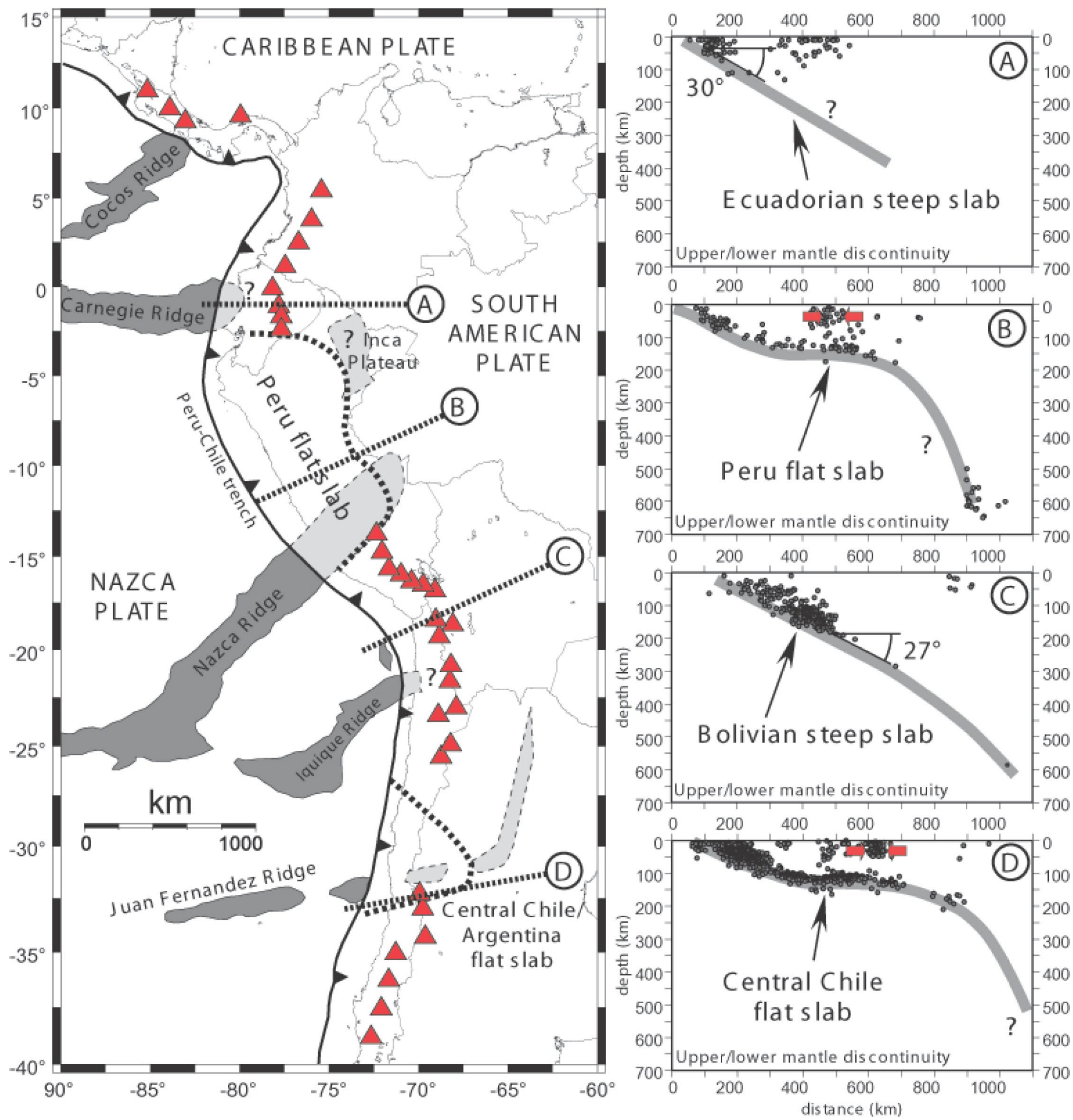
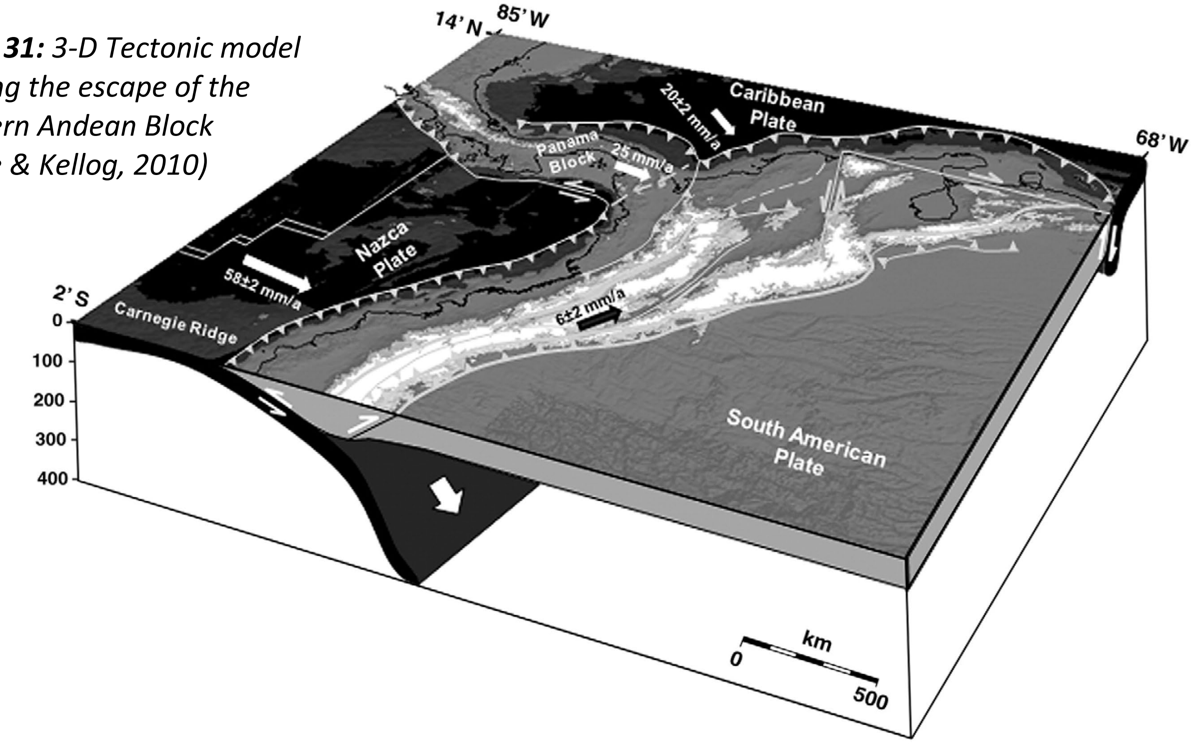


Figure 30: *Present day Cordillera showing the Northern, Central, and Southern Andean Volcanic Zones with cross sections based on earthquake hypocenters (Martinod et al., 2010)*

Figure 31: *3-D Tectonic model showing the escape of the Northern Andean Block (Egbue & Kellog, 2010)*



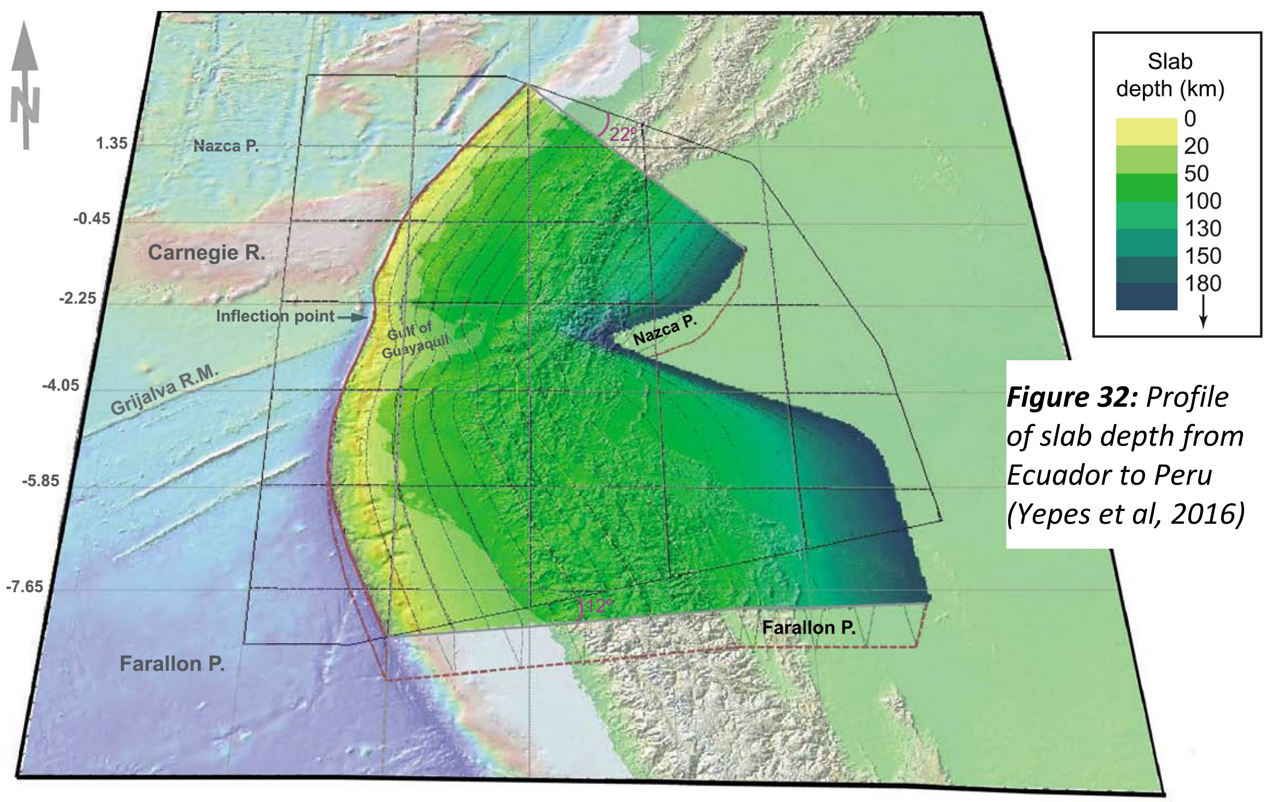


Figure 32: *Profile of slab depth from Ecuador to Peru (Yepes et al, 2016)*

– 7°N to 1°N the 10 to 26 Ma old subducting slab plunges at 35° under Columbia on an azimuth of N120°, making the Columbia volcanic chain
– South of 2°S the Nazca dips at 14° and active volcanism ceases until southern Peru
  · the "flat-slab" subduction areas divide up the Northern, Central, and Southern Volcanic zones
  · Another flat-slab are is in north/central Chile

- 1°N to 2°S a small mountain range (300 km wide, 3 km high), the Carnegie Ridge, sits on the Nazca plate, it is the hotspot track of the Galapagos
    - Sits on 16 Ma oceanic crust
    - dip of the slab is 25° at an azimuth of 085°
    - the slab is at 100km below the Occidental and 140km below the Real
    - Crustal thickness under the Ecuadorian arc is thought to be 50 km
    - Collision with the Carnegie ridge has created the Dolores-Guayaquil Megashear (DGM), moving the Northern Andean block
    - The DGM is pushing the Northern Andean Block NE in a dextral transpressive shear zone.

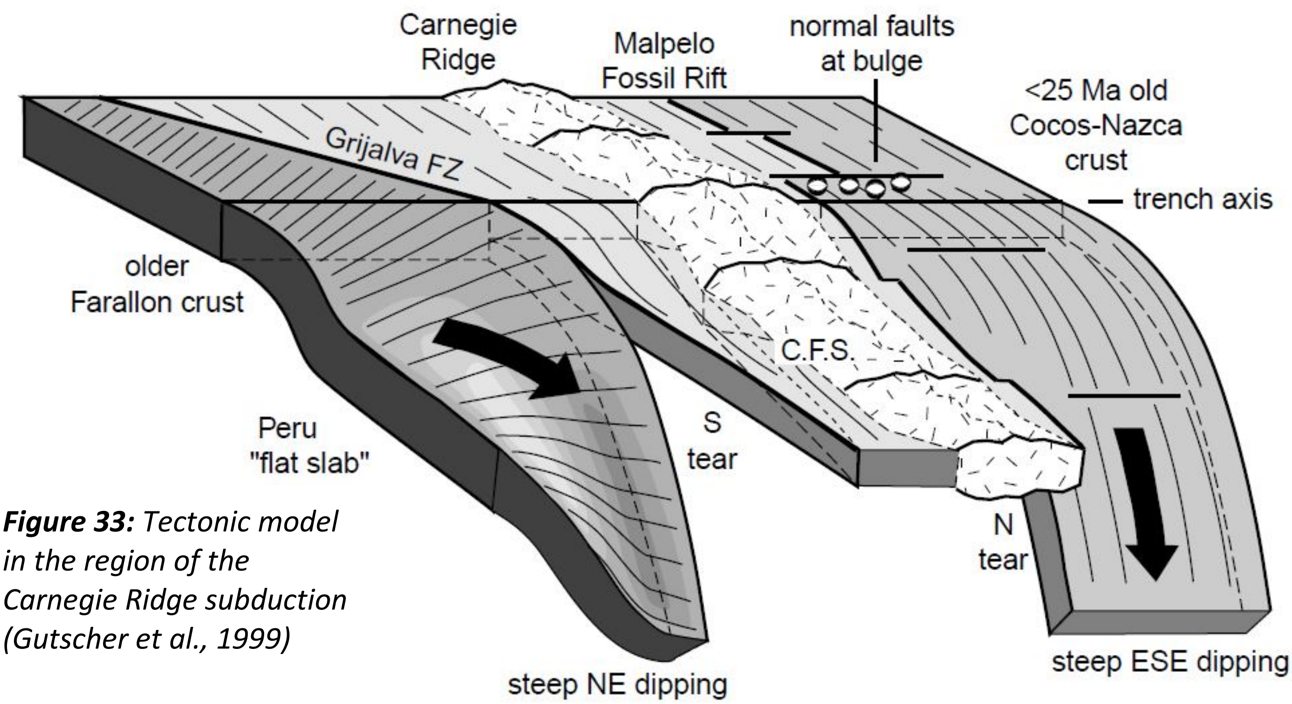


Figure 33: *Tectonic model in the region of the Carnegie Ridge subduction (Gutscher et al., 1999)*

South American Plate:

- There are two major subdivisions of the SA plate in Ecuador: the Guyana-Brazilian Cratons (Amazonia) and the North Andean Block (mostly accreted terranes)
- They are separated by the dextral Dolores-Guayaquil Megashear

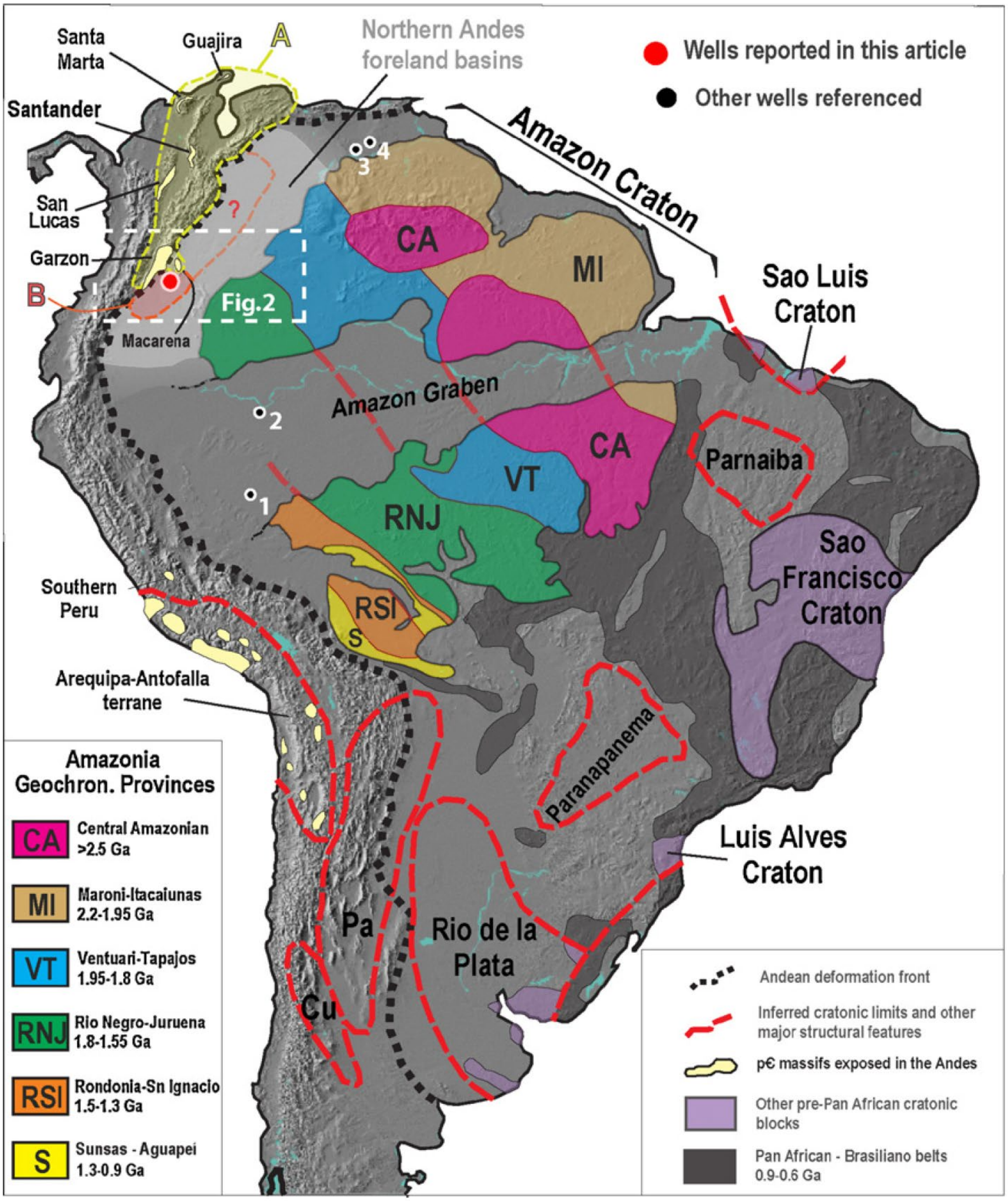


Figure 34: *Tectonic Map of South America (Ibanez-Mejia et al., 2011)*

Geologic Events and History

Andean Orogeny

The following is taken directly from Wikipedia:

Introduction

The Andean orogeny is an ongoing process of orogeny that began in the Early Jurassic and is responsible for the rise of the Andes mountains. The orogeny is driven by a reactivation of a long-lived subduction system along the western margin of South America. On a continental scale the Cretaceous (90 Ma) and Oligocene (30 Ma) were periods of re-arrangements in the orogeny. Locally the details of the nature of the orogeny varies depending on the segment and the geological period considered.

Overview

Subduction orogeny has been occurring in what is now western South America since the break-up of the supercontinent Rodinia in the Neoproterozoic. The Paleozoic Pampean, Famatinian and Gondwanan orogenies are the immediate precursors to the later Andean orogeny. The first phases of Andean orogeny in the Jurassic and Early Cretaceous were characterized by extensional tectonics, rifting, the development of back-arc basins and the emplacement of large batholiths. This development is presumed to have been linked to the subduction of cold oceanic lithosphere. During the mid to Late Cretaceous (ca. 90 million years ago) the Andean orogeny changed significantly in character. Warmer and younger oceanic lithosphere is believed to have started to be subducted beneath South America around this time. Such kind of subduction is held responsible for not only the intense contractional deformation that different lithologies were subject to, but also the uplift and erosion known to have occurred from the Late Cretaceous onward. Plate tectonic reorganization since the mid-Cretaceous might also have been linked to the opening of the South Atlantic Ocean. Another change related to mid-Cretaceous plate tectonic changes was the change of subduction direction of the oceanic lithosphere that went from having southeast motion to having a northeast motion at about 90 million years ago. While subduction direction changed it remained oblique (and not perpendicular) to the coast of South America, and the direction change affected several subduction zone-parallel faults including Atacama, Domeyko and Liquiñe-Ofqui.

Low angle subduction or flat-slab subduction has been common during the Andean orogeny leading to crustal shortening and deformation and the suppression of arc volcanism. Flat-slab subduction has occurred at different times in various part of the Andes, with northern Colombia (6–10° N), Ecuador (0–2° S), northern Peru (3–13° S) and north-central Chile and Argentina (24–30° S) experiencing these conditions at present.

The tectonic growth of the Andes and the regional climate have evolved simultaneously and have influenced each other. The topographic barrier formed by the Andes stopped the income of humid air into the present Atacama desert. This aridity, in turn, changed the normal superficial redistribution of mass via erosion and river transport, modifying the later tectonic deformation.

In the Oligocene the Farallon Plate broke up, forming the modern Cocos and Nazca plates ushering a series of changes in the Andean orogeny. The new Nazca Plate was then directed into an orthogonal subduction with South America causing ever-since uplift in the Andes, but causing most impact in the Miocene. While the various segments of the Andes have their own uplift histories, as a whole the Andes have risen significantly in last 30 millions years (Oligocene–present).

Colombia, Ecuador and Venezuela (12° N–3° S)

Tectonic blocks of continental crust that had separated from northwestern South America in the Jurassic re-joined the continent in the Late Cretaceous by colliding obliquely with it. This episode of accretion occurred in a complex sequence. The accretion of the island arcs against northwestern South America in the Early Cretaceous led to the development of a magmatic arc caused by subduction. The Romeral Fault in Colombia forms the suture between the accreted terranes the rest of South America. Around the Cretaceous–Paleogene boundary (ca. 65 million years ago) the oceanic plateau of the Caribbean large igneous province collided with South America. The subduction of the lithosphere as the oceanic plateau approached South America led to the formation of a magmatic arc now preserved in the Cordillera Real of Ecuador and the Cordillera Central of Colombia. In the Miocene an island arc and terrane (Chocó terrane) collided against northwestern South America. This terrane forms parts of what is now Chocó Department and Western Panamá.

The Caribbean Plate collided with South America in the Early Cenozoic but shifted then its movement eastward. Dextral fault movement between the South American and Caribbean plate started 17–15 million years ago. This movement was canalized along a series of strike-slip faults, but these faults alone do not account for all deformation. The northern part of the Dolores-Guayaquil Megashear forms part of the dextral fault systems while in the south the megashear runs along the suture between the accreted tectonic blocks and the rest of South America.

Geologic Events

Precambrian

- Forms the basement igneous and metamorphic crystalline basement rocks. High-grade, polymetamorphic rocks
- Piedras Group (El Oro Province: western Andean slope in the SW) greenschist-amphibolite schists/quartzite, age = 743 Ma

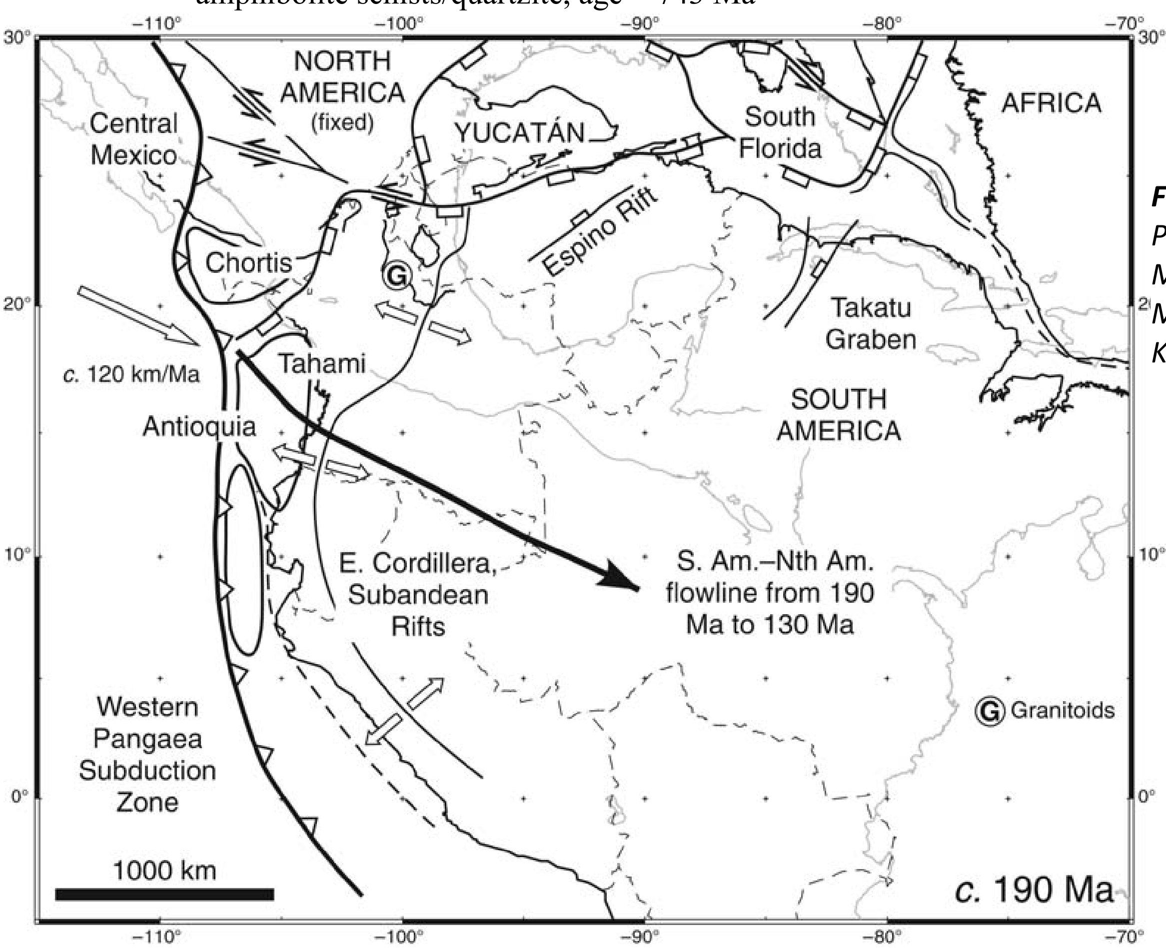


Figure 35: *Paleographic Map from 190 Ma (Pindell & Kennan, 2009)*

Jurassic (200-145 Ma)

- Onset of Farallon subduction with back-arc extension (Baby et al., 2013)
- Intrusion of calc-alkaline (subduction zone magmatism) batholiths (Salado?) in the Jurassic

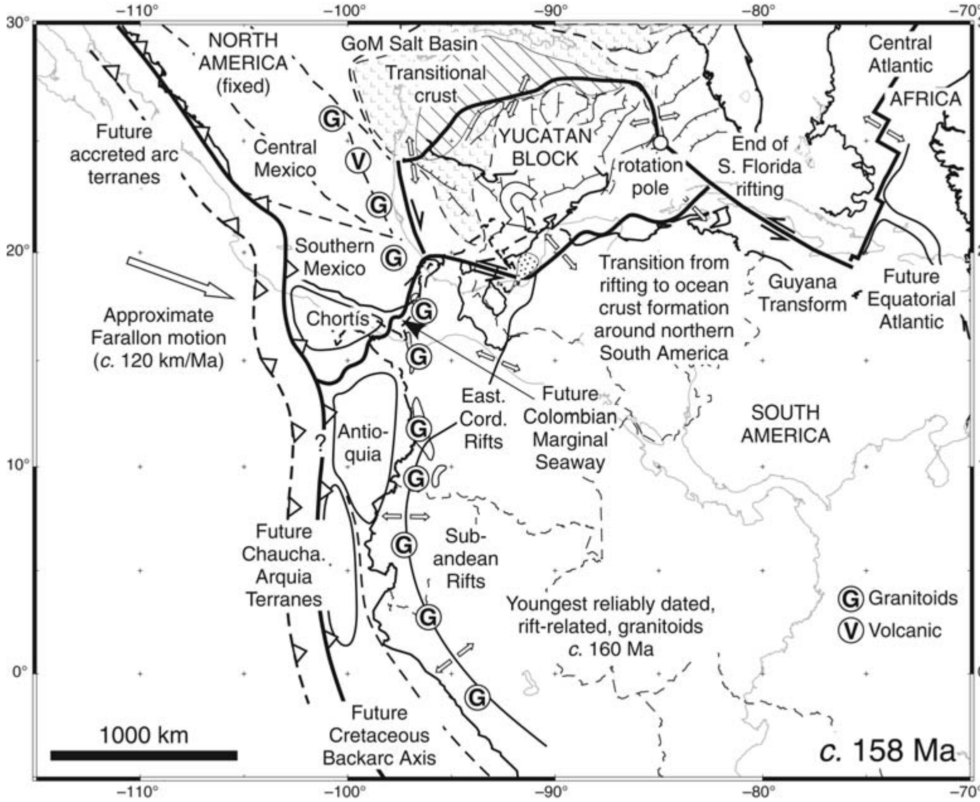


Figure 36: Paleographic Map from 158 Ma (Pindell & Kennan, 2009)

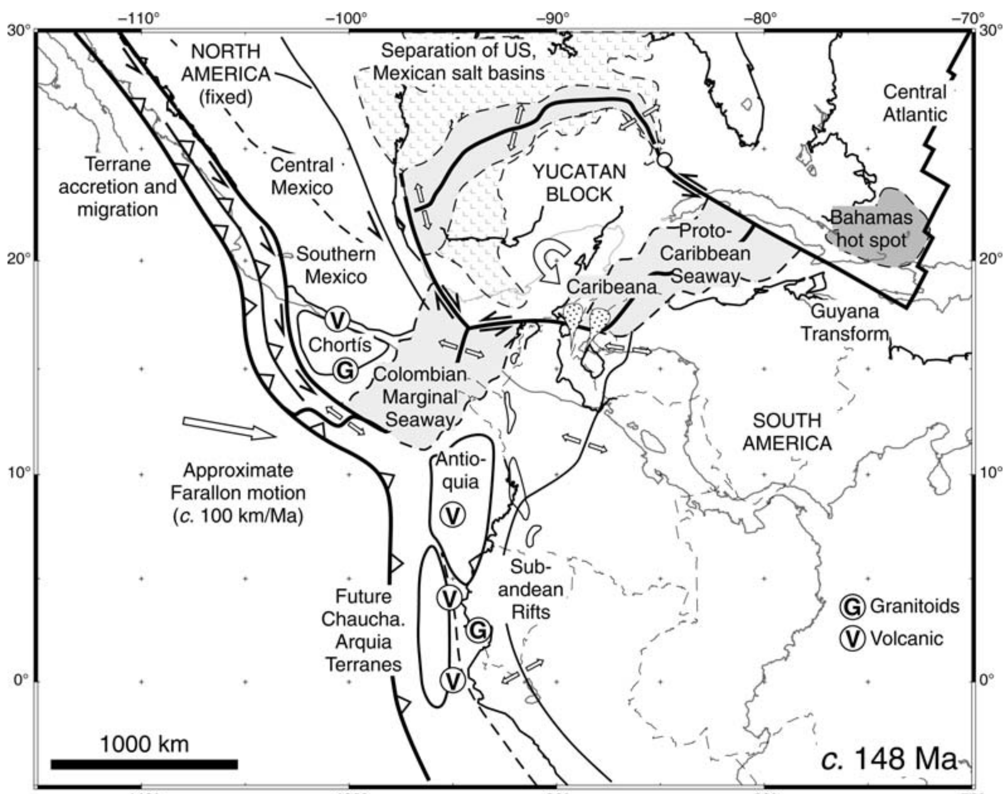


Figure 37: Paleographic Map from 148 Ma (Pindell & Kennan, 2009)

Cretaceous (145-65 Ma)

- Oceanic basalts (Pinon/Pallatanga?) formed in the Jurassic and Cretaceous were accreted to the edge of the continent as a separate terrane around 130 million years ago, forming a belt of basalt and diabase, together with tuff, metasedimentary and sedimentary rocks running north-south into Ecuador.
- Volcanism stopped (130-120 Ma) with the accretion of allochthonous terranes on the western edge of Ecuador (Baby et, 2013)
- 119-105 Ma South America as a whole begins a westward shift with the opening of Equatorial Atlantic Ocean

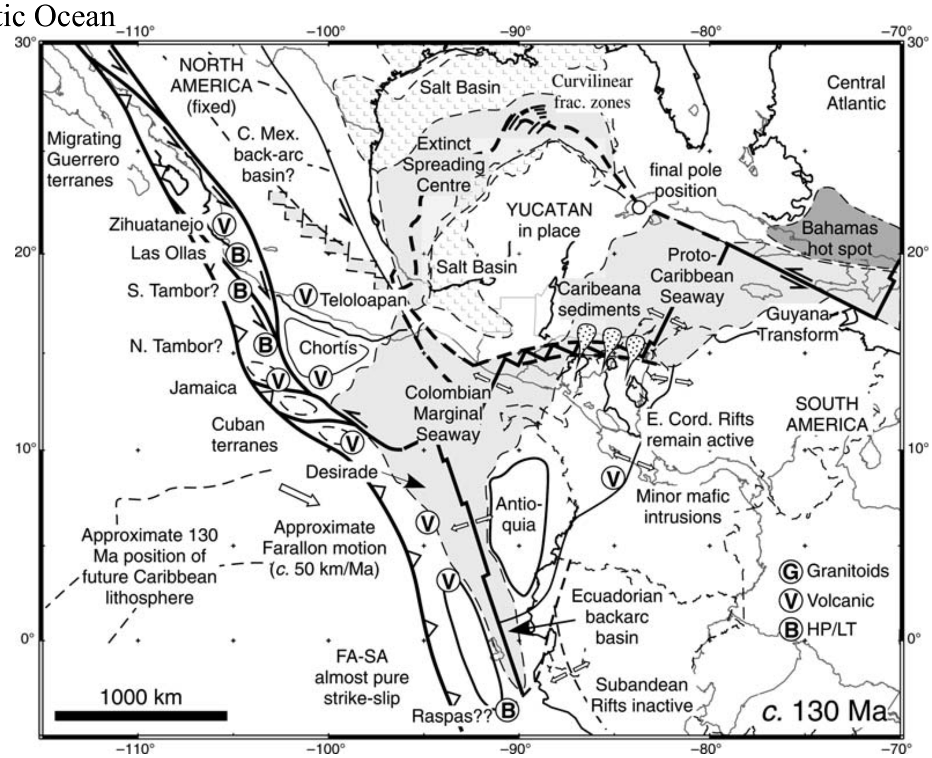


Figure 38: Paleographic Map from 130 Ma (Pindell & Kennan, 2009)

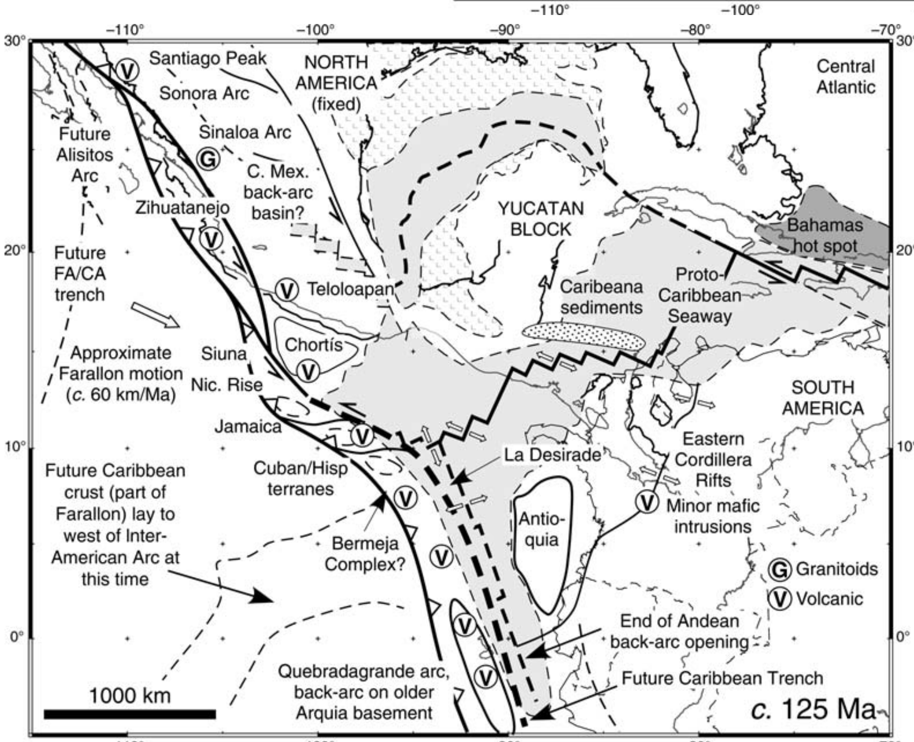


Figure 39: Paleographic Map from 125 Ma (Pindell & Kennan, 2009)

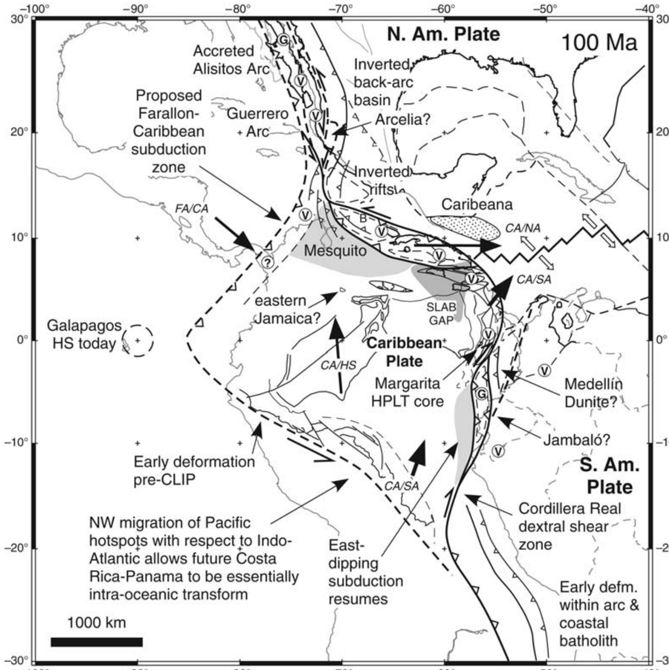


***Figure 40:** Paleographic Map from 100 Ma (Pindell & Kennan, 2009)*

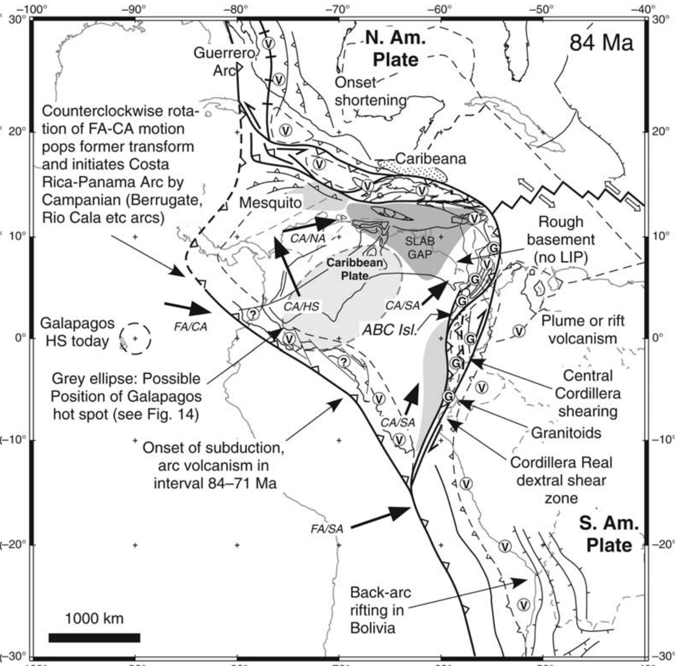


***Figure 41:** Paleographic Map from 84 Ma (Pindell & Kennan, 2009)*

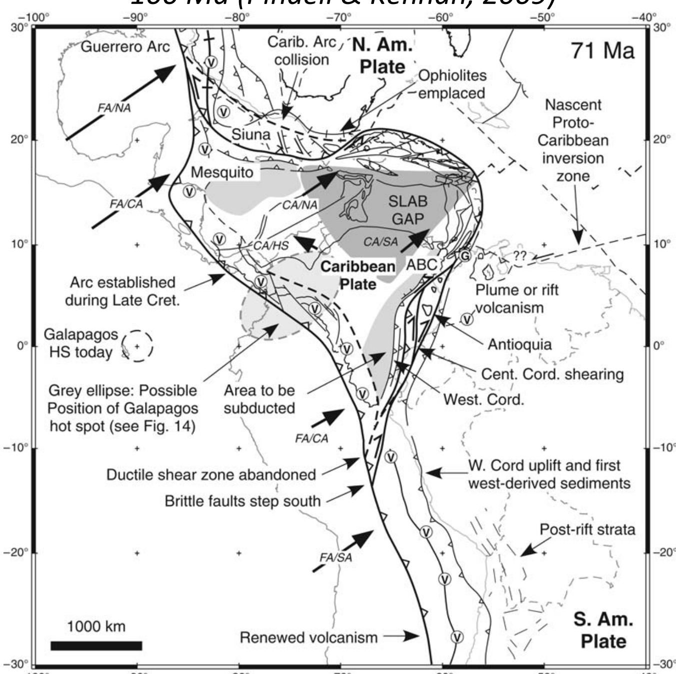


***Figure 42:** Paleographic Map from 71 Ma (Pindell & Kennan, 2009)*

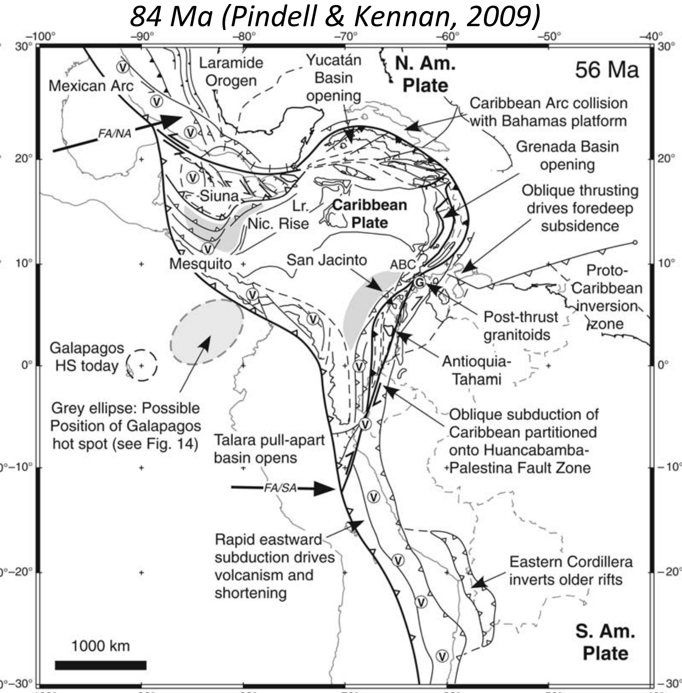


***Figure 43:** Paleographic Map from 56 Ma (Pindell & Kennan, 2009)*

Cenozoic (66 million years ago-present)

- Accretionary tectonics ceased, now mostly uplift and arc magmatism of the Andean orogeny (uplift of the Cordillera Real [65-55 Ma]).
- Volcanic rocks vary geochemically between the Western Cordillera (Occidental) and Eastern Cordillera (Real). These are inferred to be the result of hydrous partial melting of Basic Igneous Complex garnet amphibolite and amphibolite.
  - *Occidental* - plagiodacite
  - *Real* - predominantly rhyolite, andesite and andesite-dacite

Oligocene (28 Ma)

- Major plate reorganization of the old Farallon Plate gave birth to the Cocos and Nazca plates

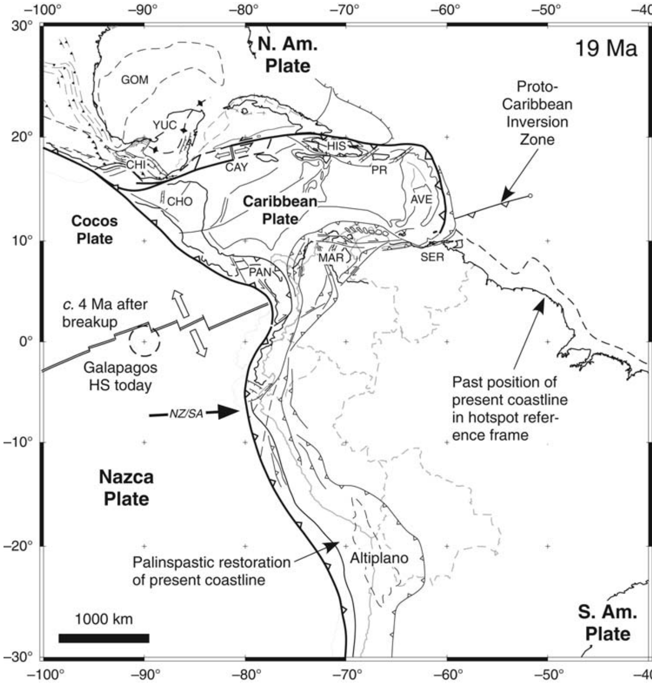


Figure 44: *Paleographic Map from 19 Ma (Pindell & Kennan, 2009)*

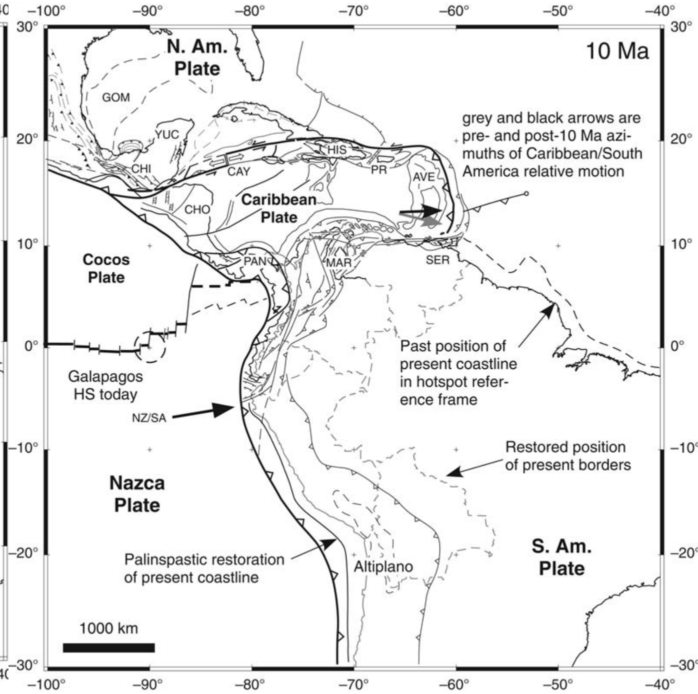


Figure 45: *Paleographic Map from 10 Ma (Pindell & Kennan, 2009)*

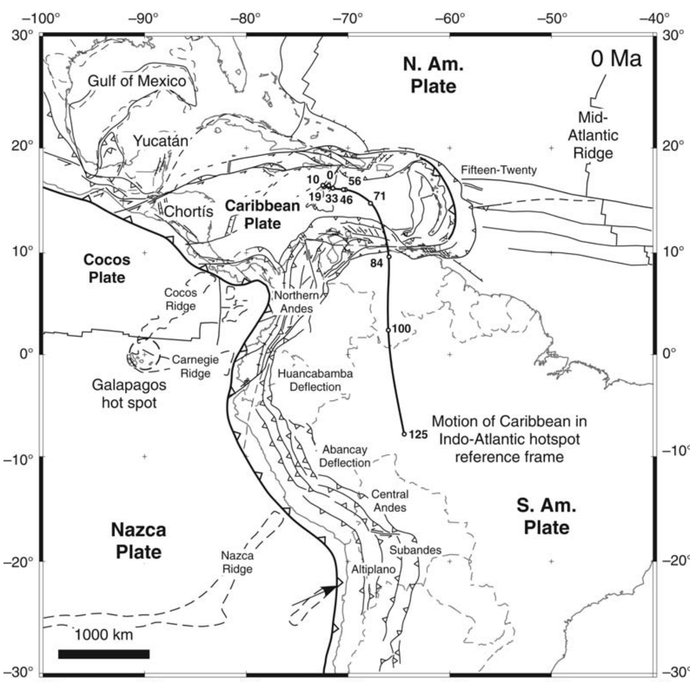


Figure 46: *Paleographic Map from Present Day (Pindell & Kennan, 2009)*

Pleistocene (2-9 Ma)

- onset of the subduction of the Nazca plate

  Volcanism:

  - eruptive centers are spaced 30-35 km apart.
  - Late Pliocene to Present

Geologic and Physiographic Provinces

The following are notes from a short lecture Dr Kerrigan gave about the geology of Ecuador.

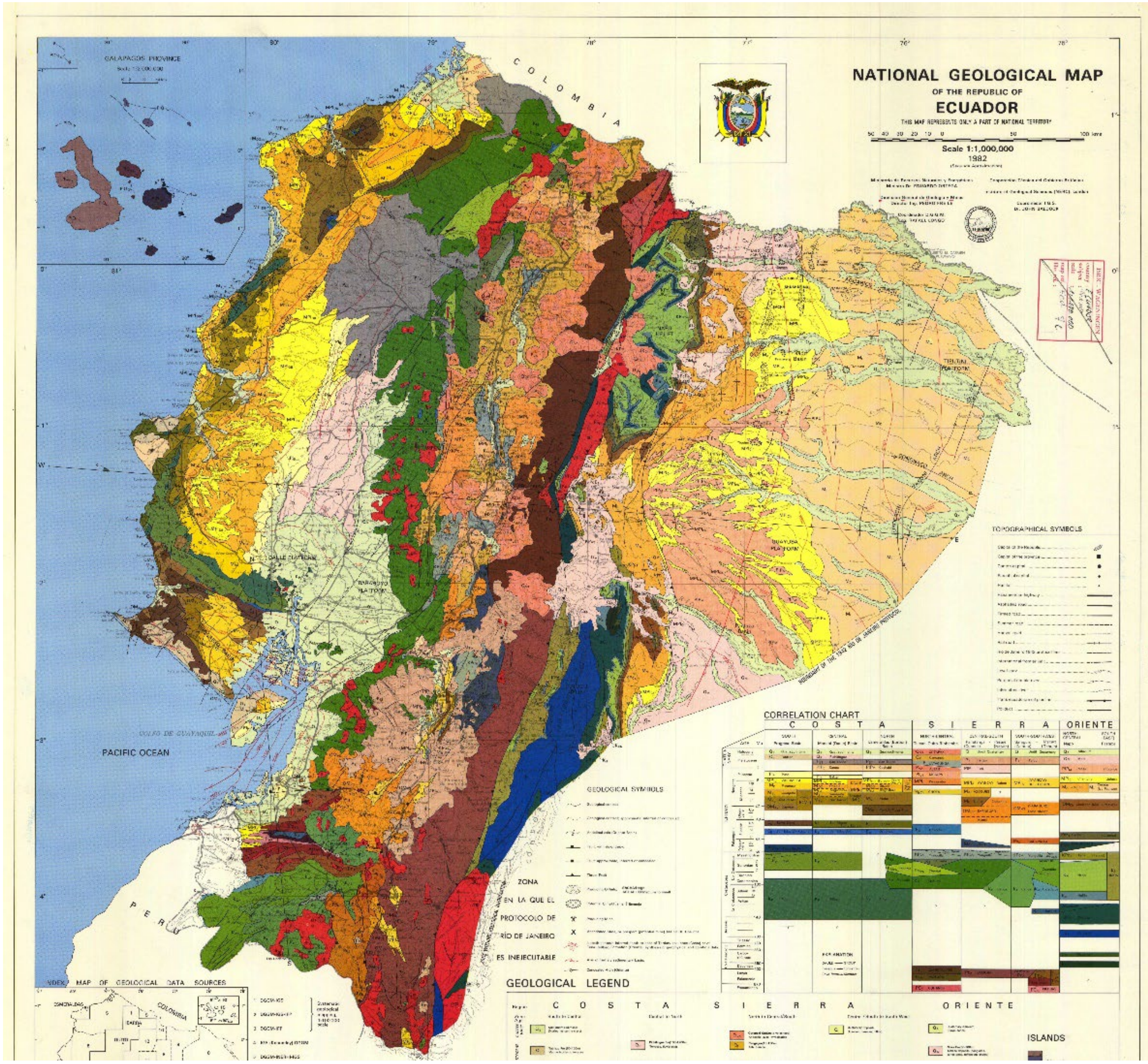
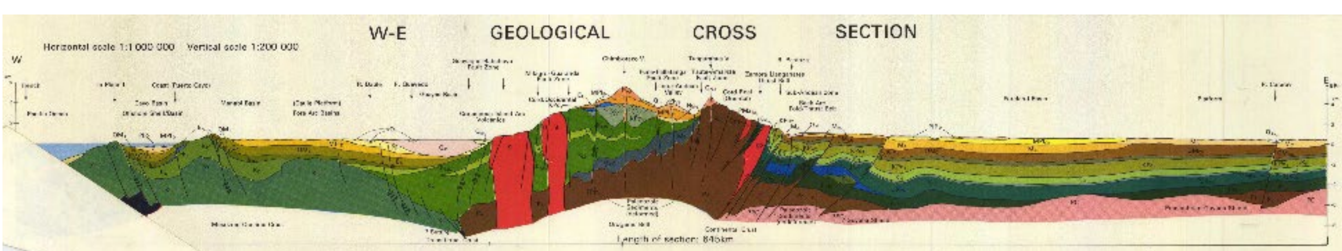


Figure 47: *Geologic map and cross-section of Ecuador*



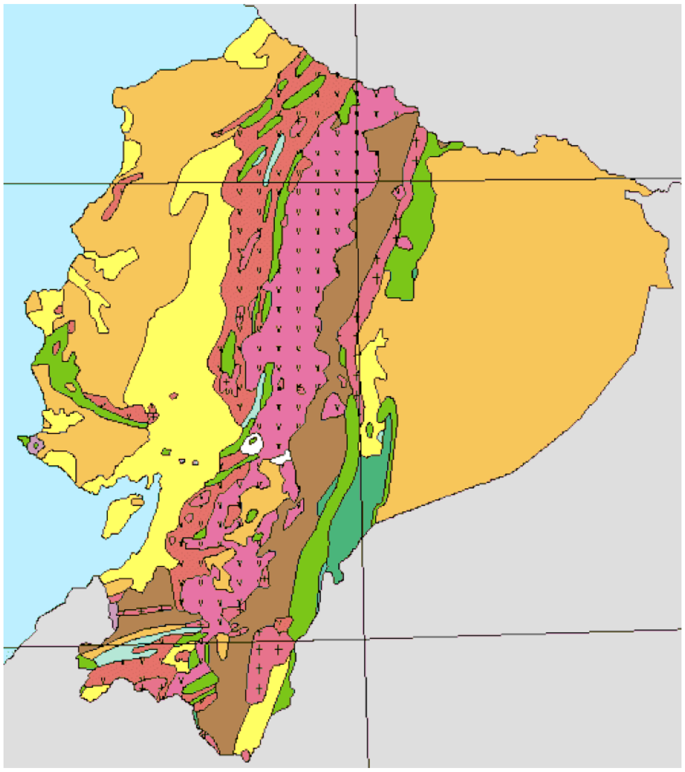


Figure 48: *Major rock types throughout Ecuador (Vera, 2016)*

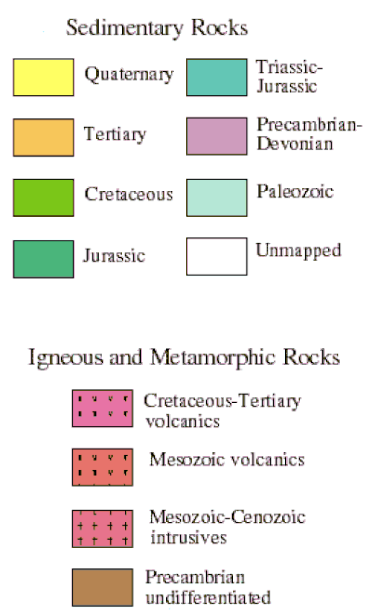
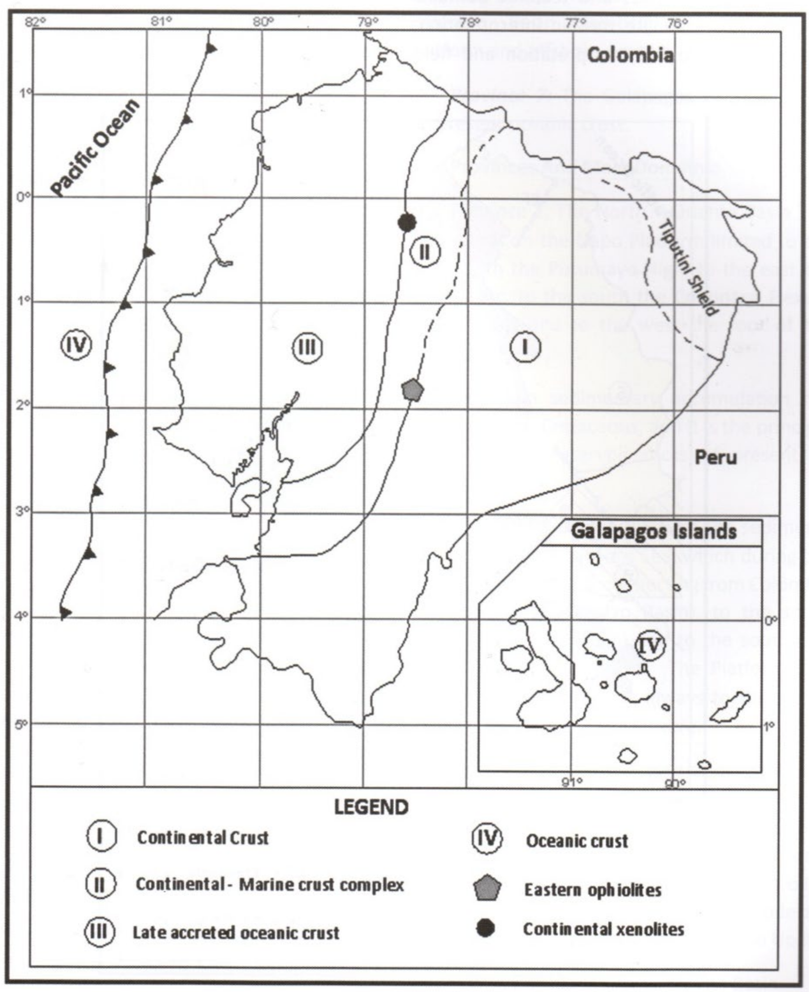


Figure 49: *Divisions of crustal components (Vera, 2016)*



Physiographic Provinces:
Mainland Ecuador is mainly composed of six geo-structural domains

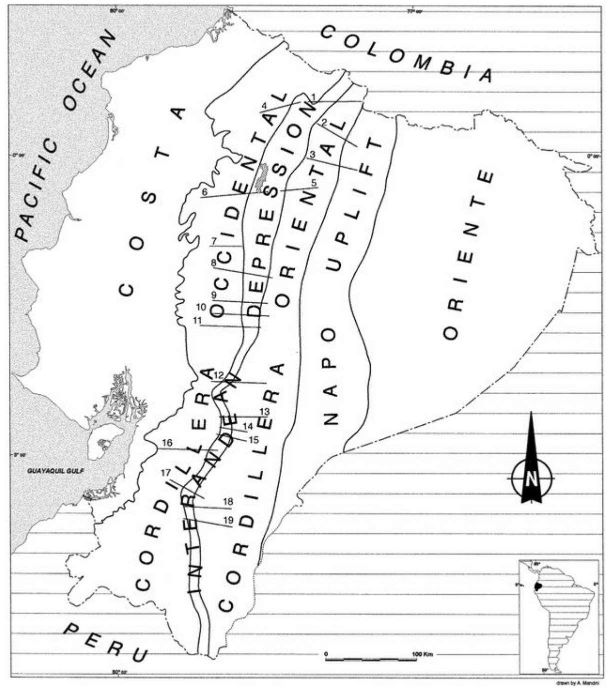


Figure 50: *Physiographic Provinces in Ecuador (Coltori & Ollier, 2000)*

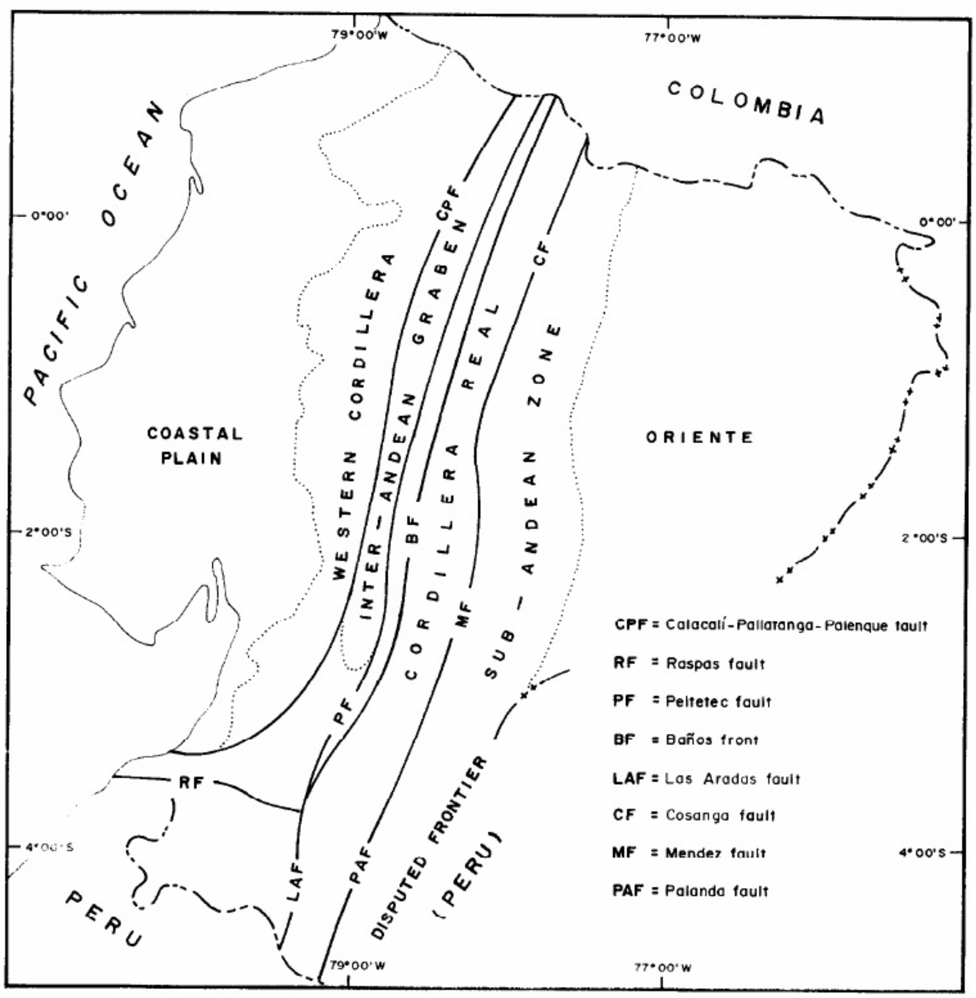
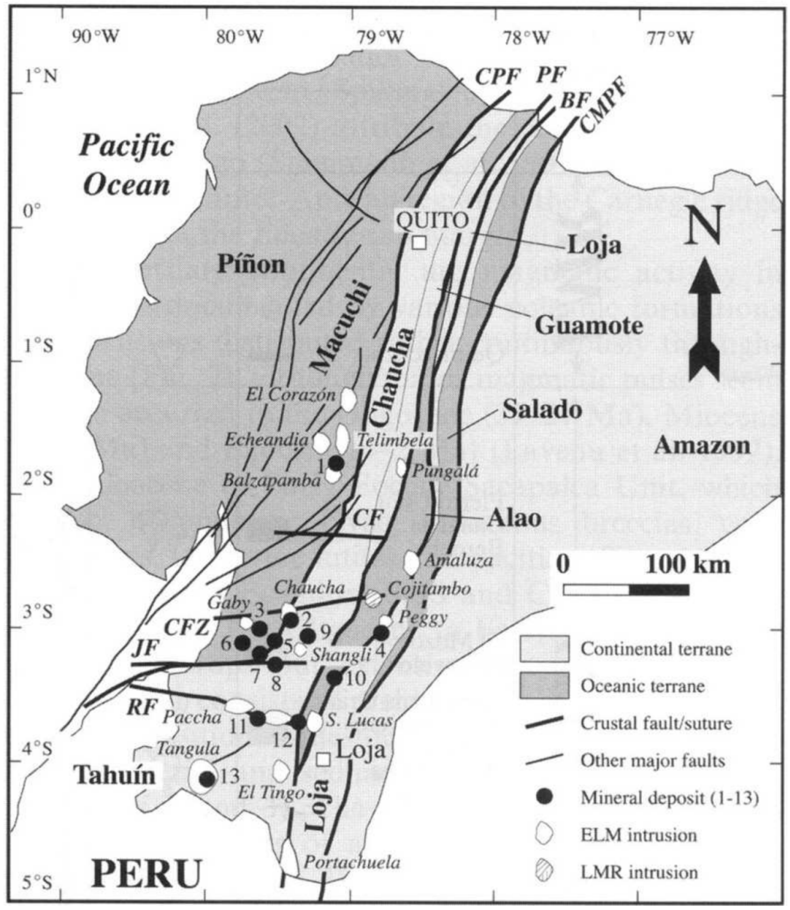


Fig. 1. Principal faults and geomorphological features of Ecuador.

Figure 51: *Physiographic Provinces in Ecuador (Aspen & Litherland, 1992)*

Figure 52: *Major fault systems in Ecuador separating major provinces (Leonard et al., 2005)*



Geotectonic map of Ecuador (from Chiaradia et al., 2004). Lines represent major faults and fault zones (*CPF* Calacali-Pallatanga-Palenque fault, *PF* Peltetec suture, *BF* Baños fault, *CMPF* Cosanga-Mendez-Palanga fault, *CF* Canar fault zone, *CFZ* Chaucha fault zone, *JF* Jubones fault zone, *RF* Raspas fault zone).

- **Galapagos Rise**
  - Cordillera de Carnegie hotspot track
  - Submarine spreading ridge between the Cocos and Nazca oceanic plates
  - Active zone of rifting and extensional tectonics with basaltic volcanism
- **Carnegie Ridge**
  - Named after the research vessel that discovered it in 1929
  - 13-19 km thick
  - Hotspot track of the Galapagos that began 20 Ma
  - The Malpelo Ridge has a similar origin

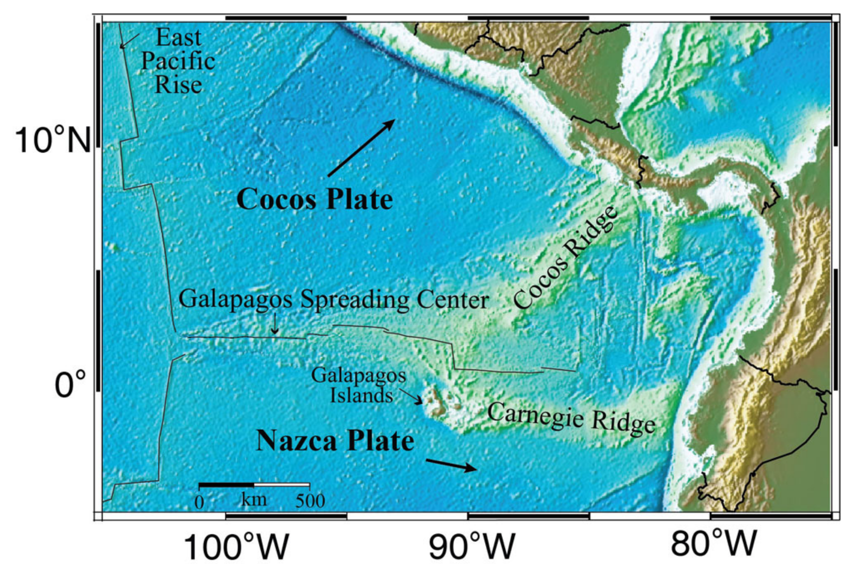
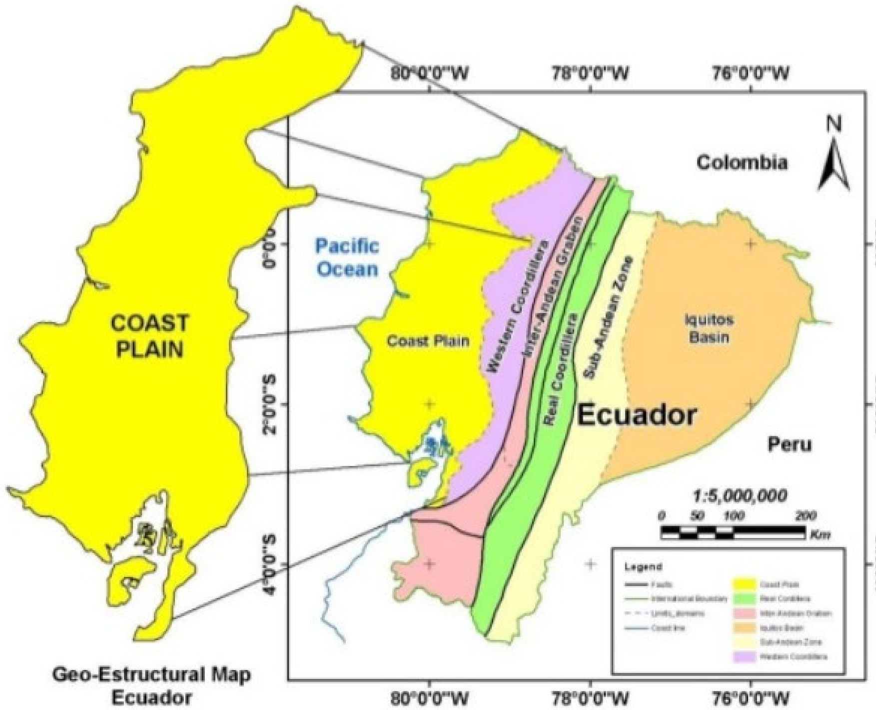


Figure 53: Coastal Plain Physiographic Province (Litherland & Zamora, 1991)



Coastal Plain – forearc Basin of the coast

- Low and Flat
- Cretaceous to Cenozoic basin underlain by allochthonous basaltic ocean crust - ophiolite (Ocean Pinon Terrane)
- Two terranes:
  - *Pinon* – Lower Cretaceous – Allochthonous oceanic crust
    - Forearc Basin and fault-delimited sub-basins with turbidites and flysch covered by quaternary littoral marine sediments
  - *San Lorenzo* – Upper to Mid Cretaceous
    - Allochthonous terrane comprising a primitive island arc with high Mg mafic lavas

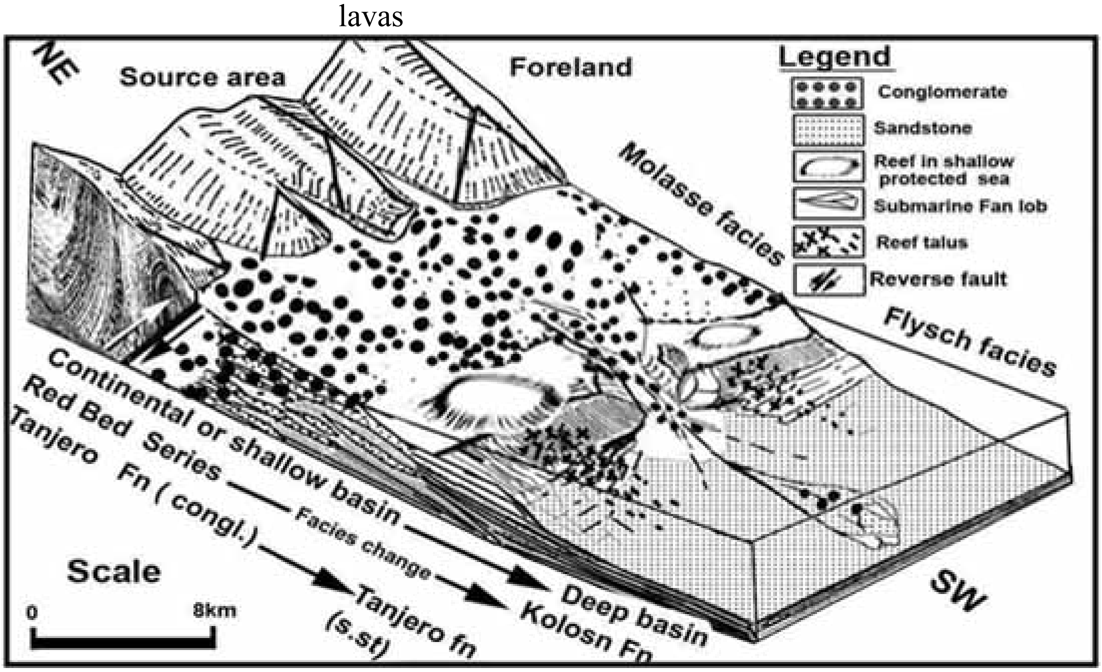
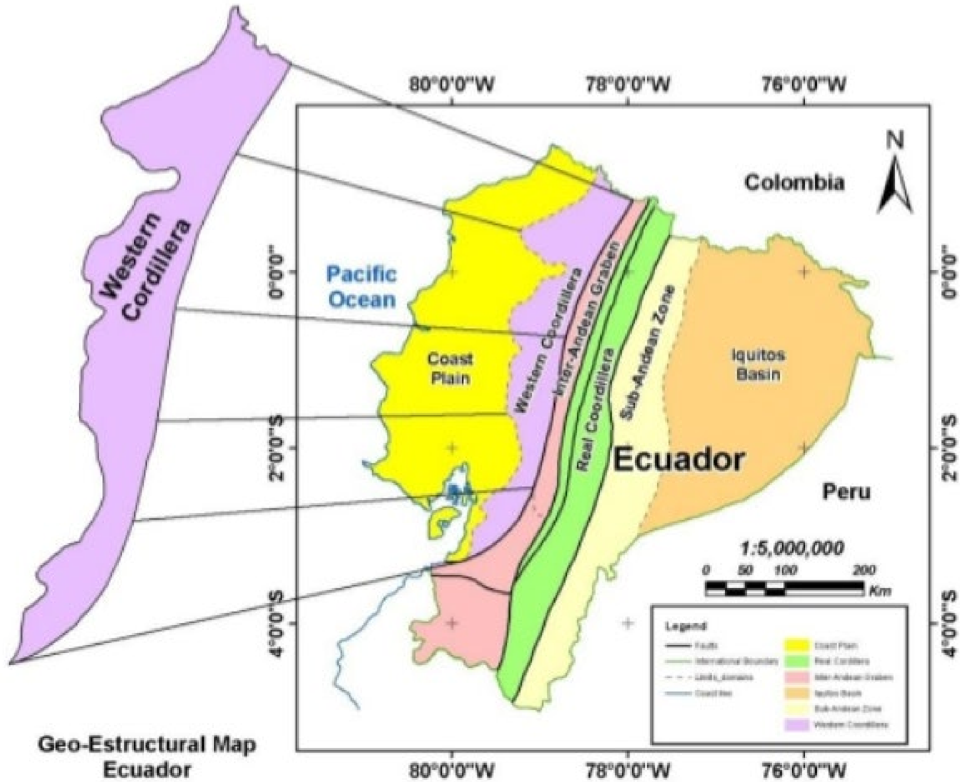


Figure 54: Graphic showing the general relationship of tectonically derived sediments and sedimentary facies.

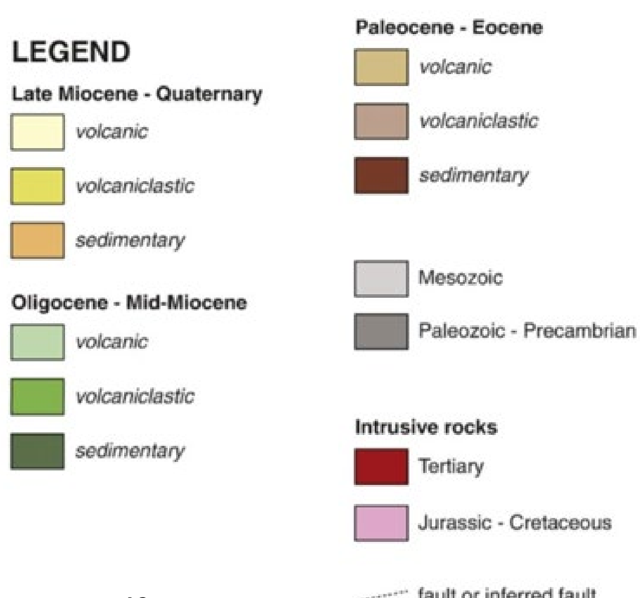
Figure 55: *Cordillera Occidental Physiographic Province (Litherland & Zamora, 1991)*

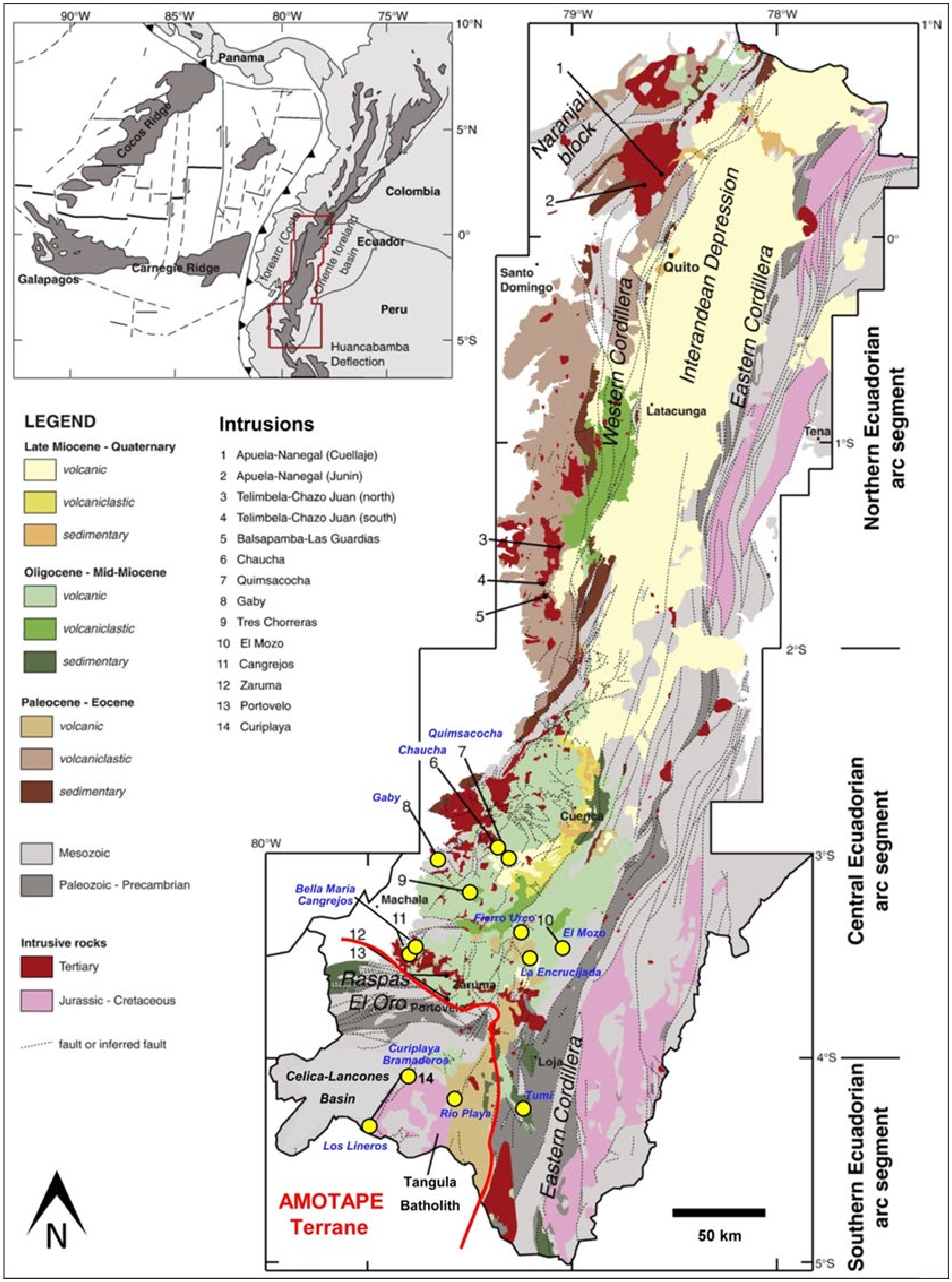


Cordillera Occidental (Western Cordillera)

- Formed by an accretionary prism mainly of oceanic crust composition, continental crust, an accrete Late Mesozoic to Cenozoic ocean terranes (Pinon, Pallatanga, Macuchi)
- Overlain by calc-alkaline Post-Eocene continental margin volcanic sequences:
- Two terranes
  - *Pallatanga* – Mid-Cretaceous to mid-Paleocene
    - Allochthonous terrane of oceanic crust with a forearc or trench-fill turbiditic sequence overlain by Cenozoic continental sediments
  - *Macuchi* – Paleocene to mid-Eocene
    - Allochthonous ensimatic island arc and back are marginal basin terrane tectonically overlain on Pinon/Pallatanga – Flysch/volcanic sequences

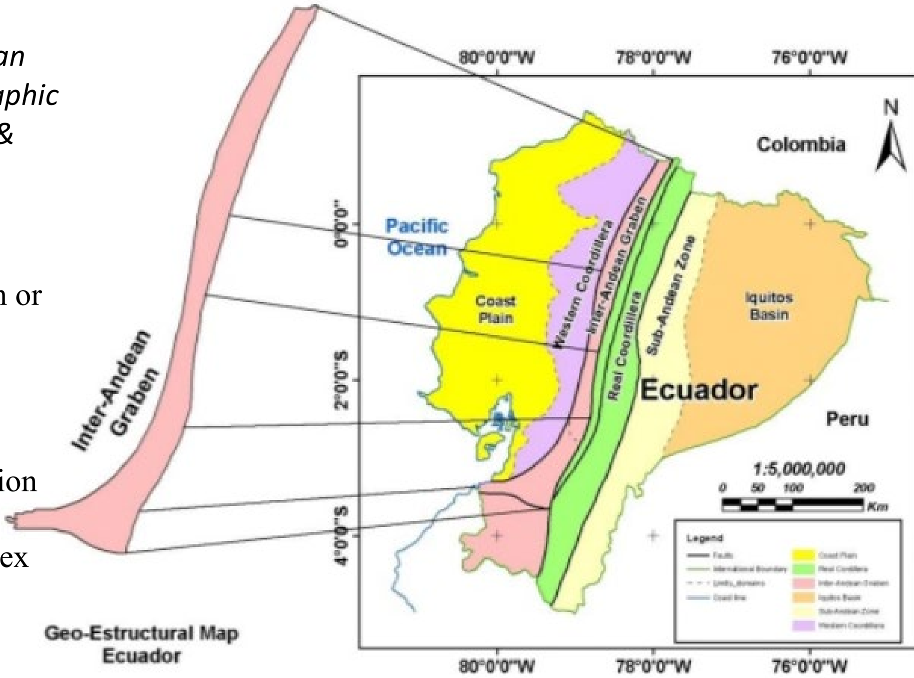
Figure 56: *Geologic Map of the Cordillera, Interandean Depression, and Cordillera Real. (Map next page; Legend adjacent)*





Panama
Cocos Ridge
Colombia
Ecuador
Galapagos
Carnegie Ridge
Peru
Huancabamba Deflection
forearc (Costa)
Oriente foreland basin
90°W
85°W
80°W
75°W
10°N
5°N
0°
5°S
LEGEND
Late Miocene - Quaternary
volcanic
volcaniclastic
sedimentary
Oligocene - Mid-Miocene
volcanic
volcaniclastic
sedimentary
Paleocene - Eocene
volcanic
volcaniclastic
sedimentary
Mesozoic
Paleozoic - Precambrian
Intrusive rocks
Tertiary
Jurassic - Cretaceous
fault or inferred fault
Intrusions
1 Apuela-Nanegal (Cuellaje)
2 Apuela-Nanegal (Junin)
3 Telimbela-Chazo Juan (north)
4 Telimbela-Chazo Juan (south)
5 Balsapamba-Las Guardias
6 Chaucha
7 Quimsacocha
8 Gaby
9 Tres Chorreras
10 El Mozo
11 Cangrejos
12 Zaruma
13 Portovelo
14 Curiplaya
79°W
78°W
1°N
Naranjal block
Interandean Depression
Western Cordillera
Eastern Cordillera
Santo Domingo
Quito
Latacunga
Tena
1°S
2°S
3°S
4°S
5°S
Northern Ecuadorian arc segment
Central Ecuadorian arc segment
Southern Ecuadorian arc segment
Quimsacocha
Chaucha
Gaby
Cuenca
Bella Maria
Cangrejos
Machala
Fierro Urco
El Mozo
La Encrucijada
Raspas
El Oro
Zaruma
Portovelo
Curiplaya
Bramaderos
Celica-Lancones Basin
Loja
Tumi
Rio Playa
Los Lineros
Tangula Batholith
Eastern Cordillera
AMOTAPE Terrane
50 km
N

Figure 57: *Interandean Depression Physiographic Province (Litherland & Zamora, 1991)*



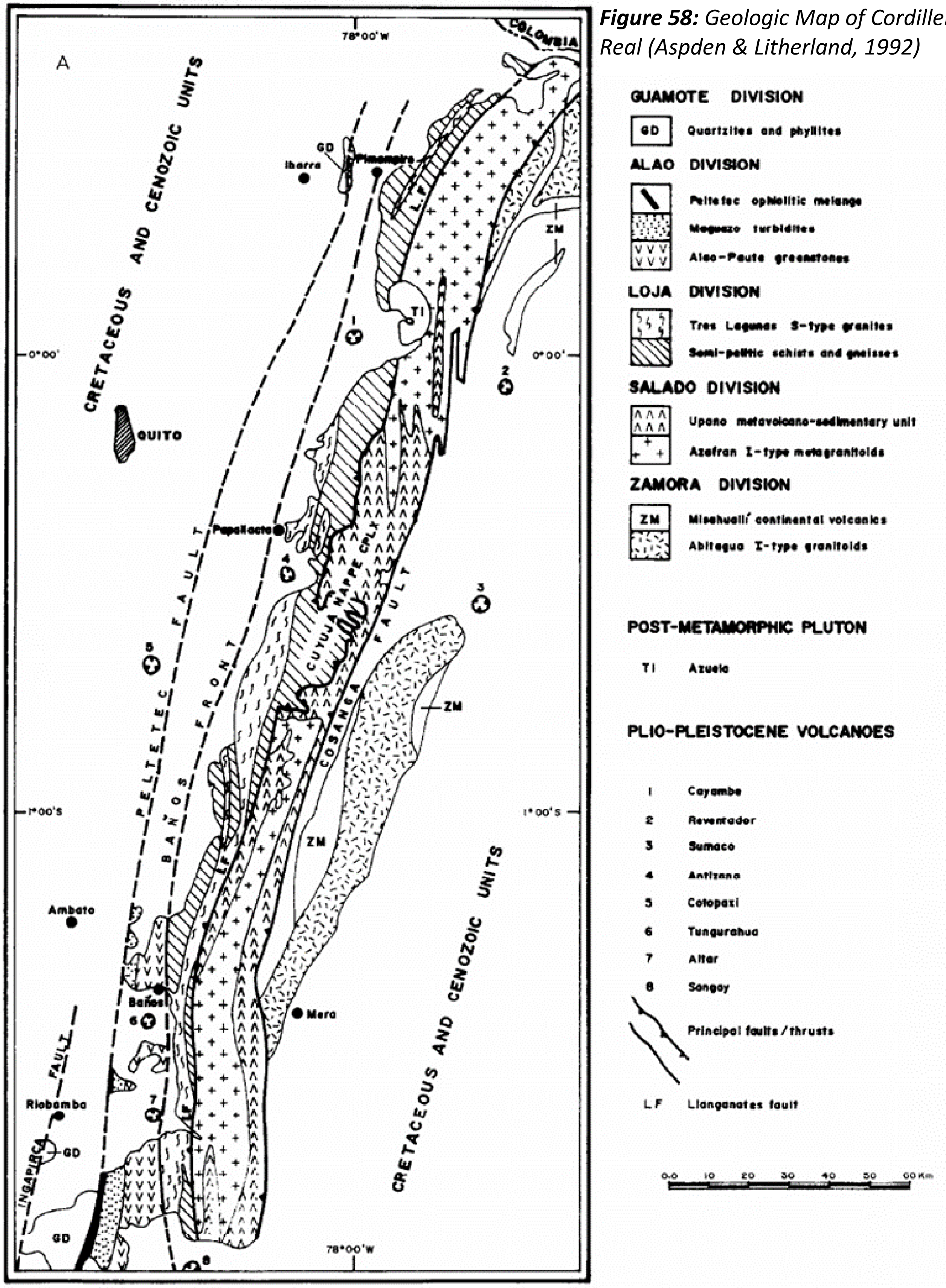
InterAndean Valley (Intervolcanic Depression or Graben)

- 20-30 km wide structural depression
- Formed by complex faulting in the quaternary
    - Likely thrust and strike slip related to cordillera uplift with some normal faulting as a response to tectonic relaxation.
- The valley disappears in southern Ecuador as the two mountain chains merge to make one broad belt with no Holocent to recent volcanism
- Graben Valley formed by thick and large Oligocene to Miocene volcano-sedimentary sequences that cover the Chaucha, Amotape, and Guamote Terranes
    - *Chaucha* – Paleozoic to Quaternary
        - Allochthonous accretionary prism complex with fragments of continental crust (Peltetec-Palenque mélange) and a Cenozoic volcanosedimentary cover
    - *Amotape* – Paleozoic to Oligocene
        - Allochthonous accretionary complex of El Oro and the pull-apart Lancones basin of Lower Cretaceous to Paleogene age, flysch and mafic volcanics
    - *Guamote* – Lower Jurassic to Quaternary
        - Siliciclastic metasedimentary passive margin sequence overthrust onto the Chaucha terrane and with Cenozoic cover
- Lots of mining potential

Real Cordillera (Central Cordillera)

- Formed by several litho-tectonic divisions of Andean –bearing and separated by regional faults. All covered by Cenozoic volcanics
    - *Guamote* – flysch sediments bounded eastwards by ophiolitic Peltetec fault
    - *Alao* – Lower Jurrasic to Quaternary
        - Island arc with a subduction complex (forearc-island arc-retroarc) over continental basement and with Cenozoic volcano-sedimentary cover
        - a mid-jurassic oceanic island arc terrane bounded eastwards by the Banos fault

Figure 58: *Geologic Map of Cordillera Real (Aspden & Litherland, 1992)*



g. 2. Simplified geological maps of the pre-Cretaceous rocks of the Cordillera Real and sub-Andean zone north of 2°S (A) and south of 2°S (B).

- *Loja* – Paleozoic-Triassic to Quaternary
    - Metamorphic semipelitic sequence of continental origin (rift basin or passive margin) with migmatites and S-type granitoids
    - a Triassic S-type biotite granite batholith with flanking semi-pelitic lithologies
- *Salado* – Jurassic
    - Plutonic and Island arc lithologies
    - Marginal basin over continental basement. Metavolcanosedimentary rocks with material sourced from the Loja terrane
- *Zamora division* – continental plutonic and volcanic rocks

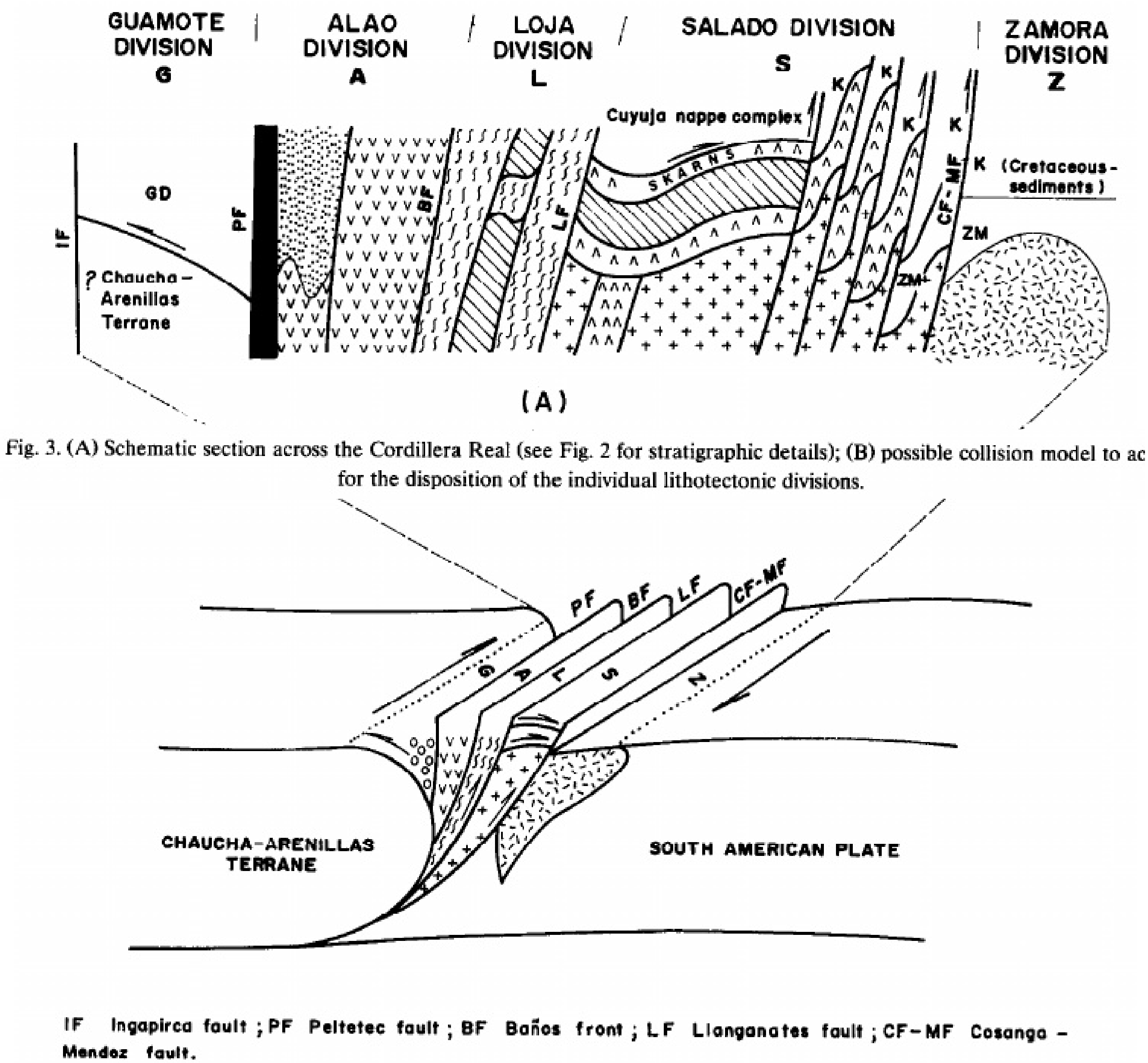
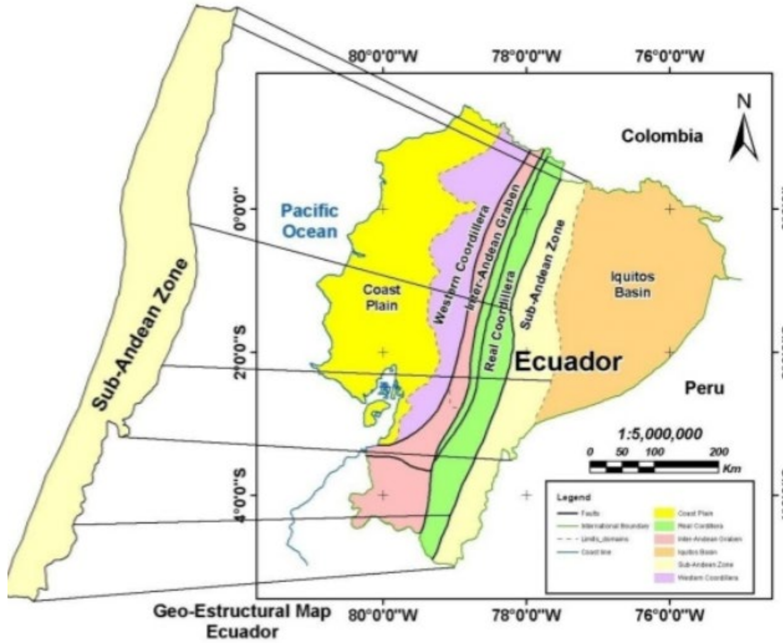


Figure 59: *A schematic cross-section across Cordillera Real and a possible collision model*

Figure 60: *Sub-Andean Zone Physiographic Province (Litherland & Zamora, 1991)*

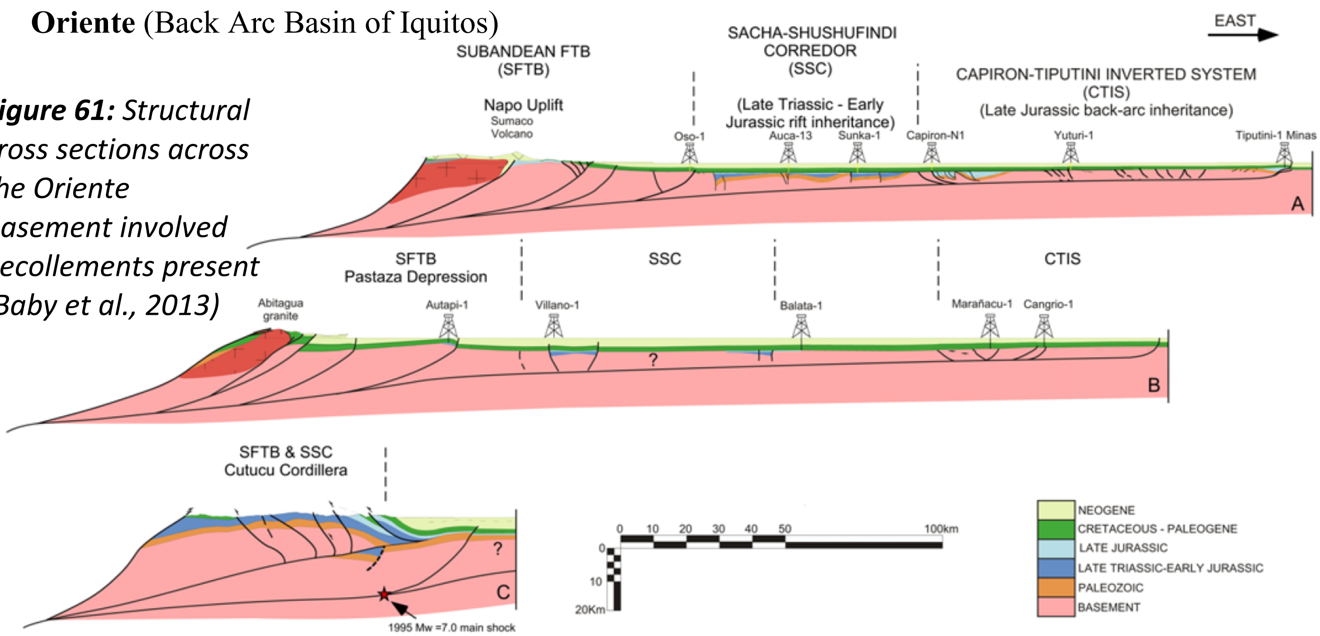


Eastern Subandean Zone
(Napo Uplift)

- Two main terranes
  - *Napo-Cutucu* – Paleozoic to Quaternary
    - Autochthonous continental basement (craton) with sedimentary and volcanosedimentary sequences of continental and marine facies arranged in foreland fold-thrust belts
  - *Zamora* – Paleozoic to Mid-Cretaceous
    - Traissic-Jurassic intracratonic rift basin with a continental magmatic arc of Jurassic age (Zamora Batholith). Continental sedimentation and volcanism in half-grabens
- formed by the forearc belt of the basement covered by volcano-sedimentary sequences
- Intruded by large "I-type" batholiths
- Northern zone the is a large uplift, Southern zone is the Cordillera del Cutucu

Oriente (Back Arc Basin of Iquitos)

Figure 61: Structural cross sections across the Oriente Basement involved decollements present (Baby et al., 2013)



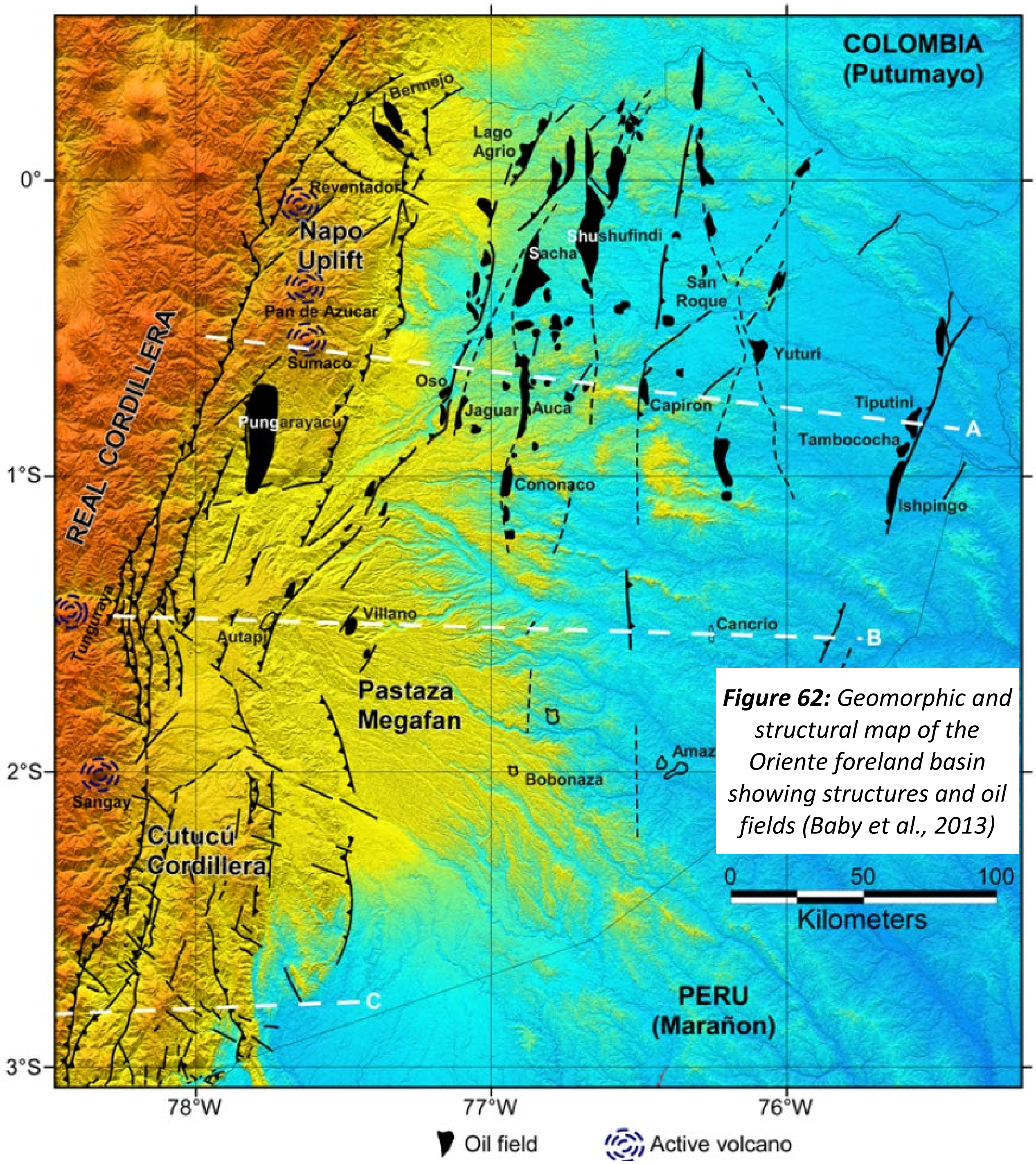


Figure 62: *Geomorphic and structural map of the Oriente foreland basin showing structures and oil fields (Baby et al., 2013)*

- Amazonian basin mainly formed by sedimentary and volcano-sedimentary sequences
- Foreland fold thrust belt
- Most important oil field in Ecuador (300 billion barrels of oil) – largest in the sub-Andean basin (Baby et al, 2013)
- There is evidence for thick-skinned tectonics of deep high angle reverse faults that are thought to control the oil trapping (Baby et al, 2013)
    - *Iquitos* – Pliocene to Quaternary
        - Back-arc basin with fluvio-lacustrine sediments over autochthonous continental basement (craton)

Volcanoes and Volcanology

Basic Igneous Petrology (*the following is from Wikipedia*)

This just has a couple of generalized Maps & Figures

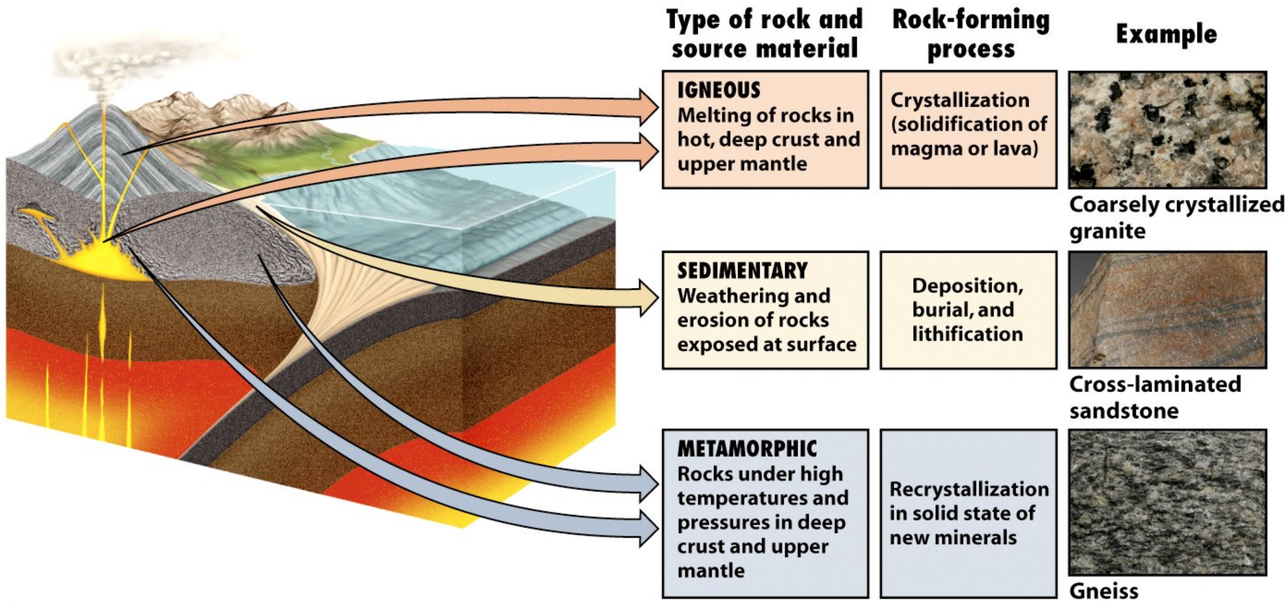


Figure 3-22
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Figure 63: *Rock Types (Jordan & Grotzinger, 2007)*

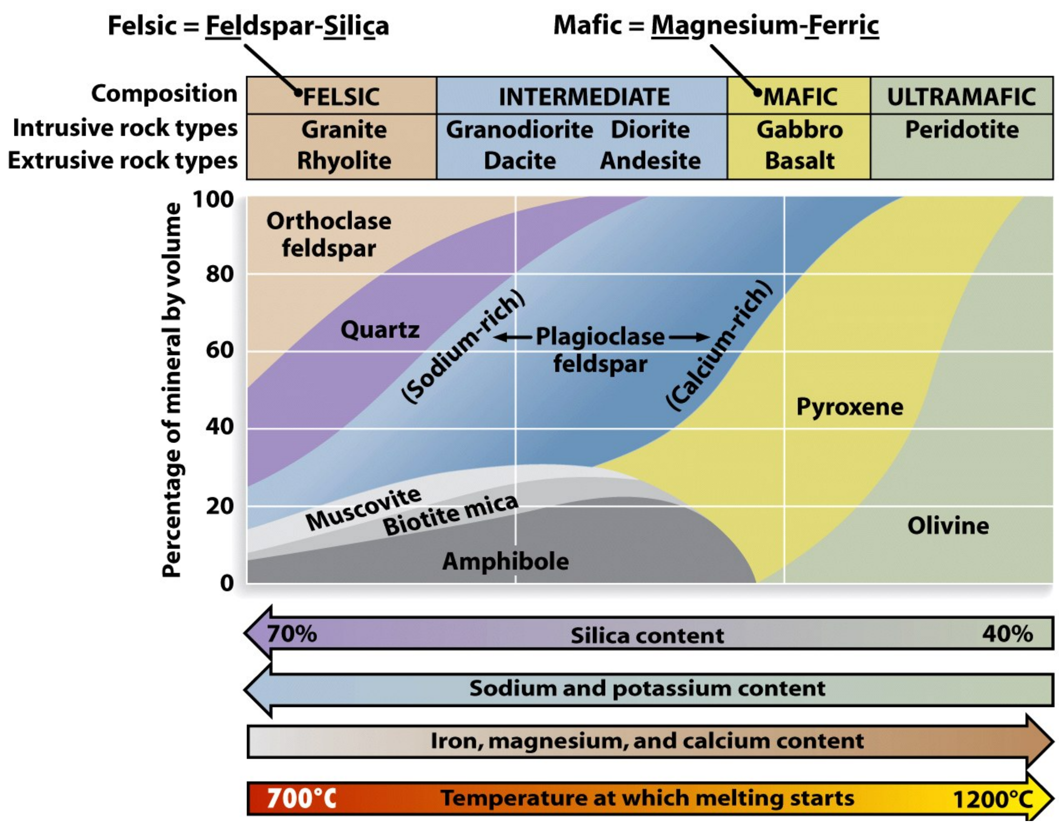

Figure 4-4
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Figure 64: *Igneous Rock Types by composition (Jordan & Grotzinger, 2007)*

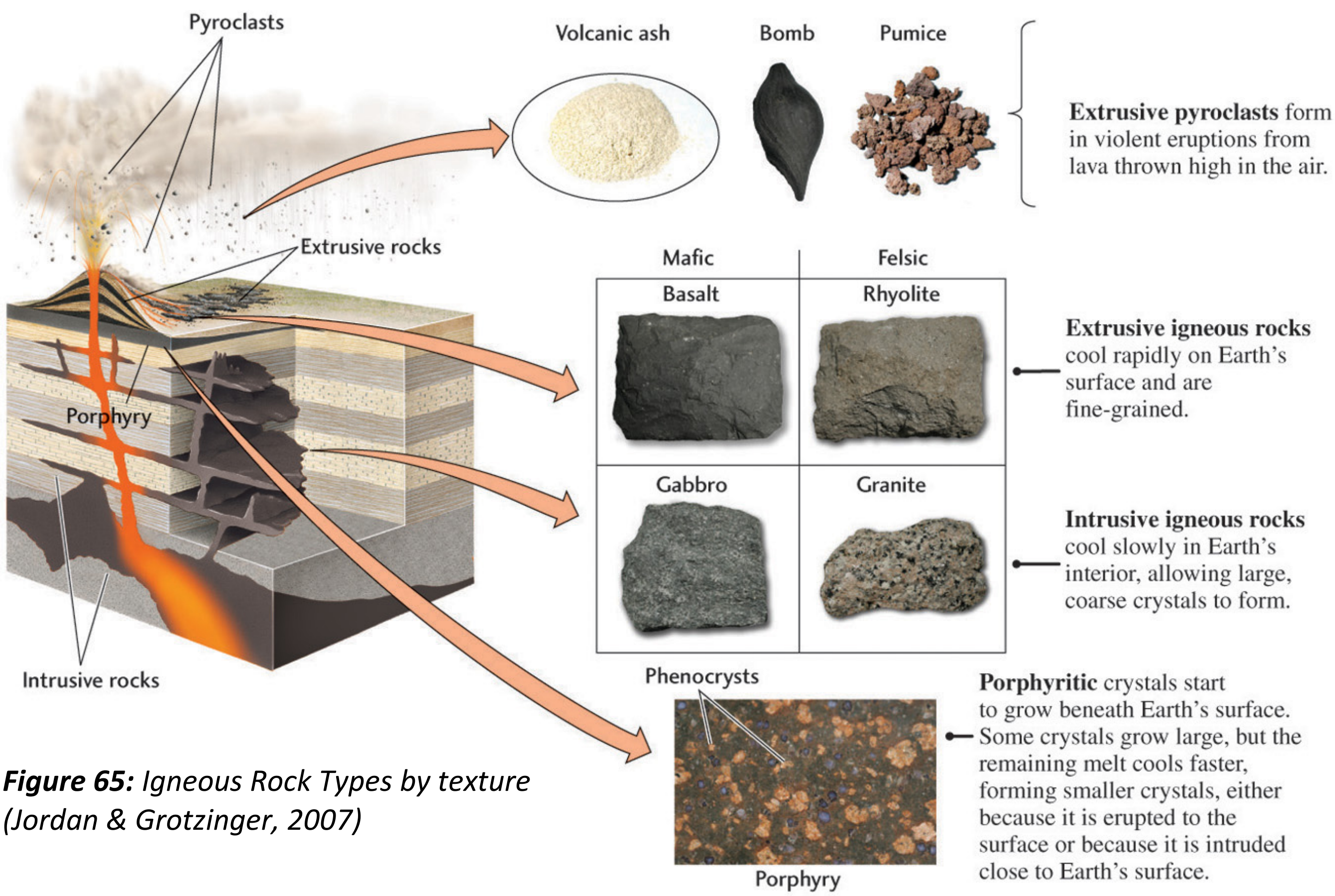
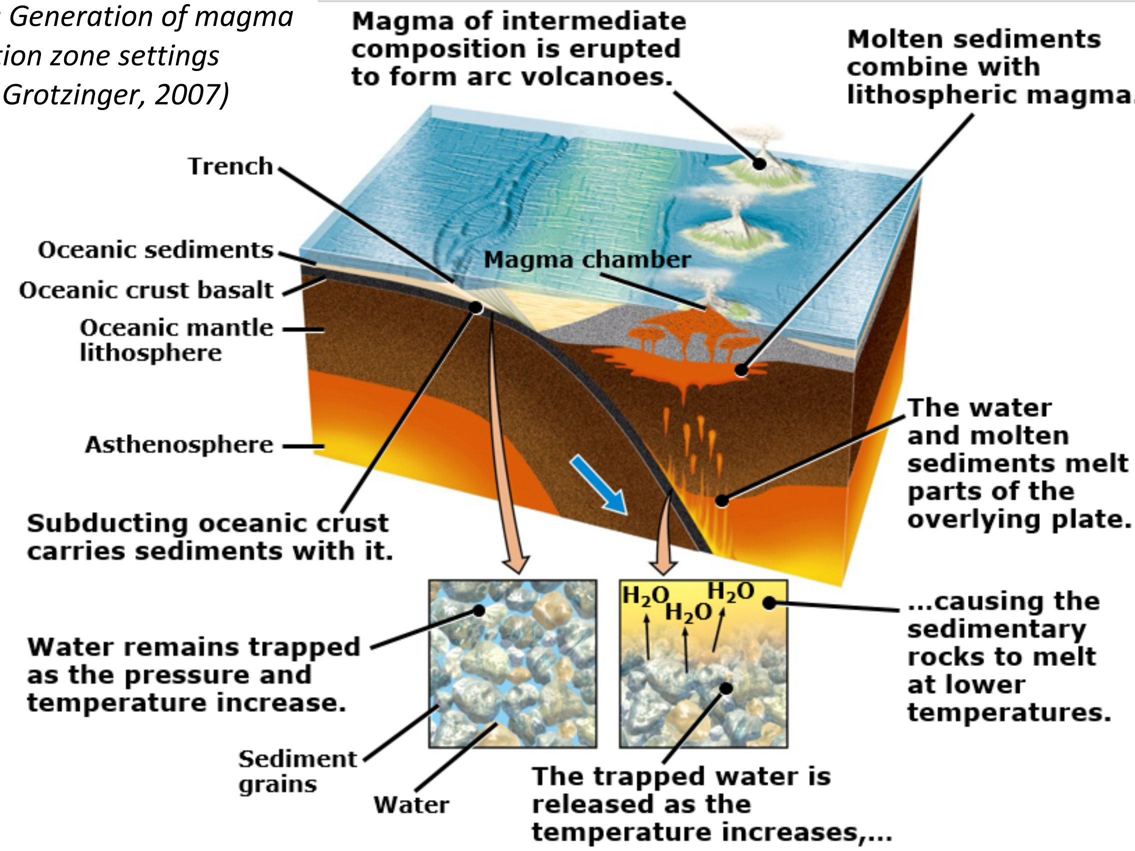


Figure 65: *Igneous Rock Types by texture (Jordan & Grotzinger, 2007)*

Figure 66: *Generation of magma in subduction zone settings (Jordan & Grotzinger, 2007)*



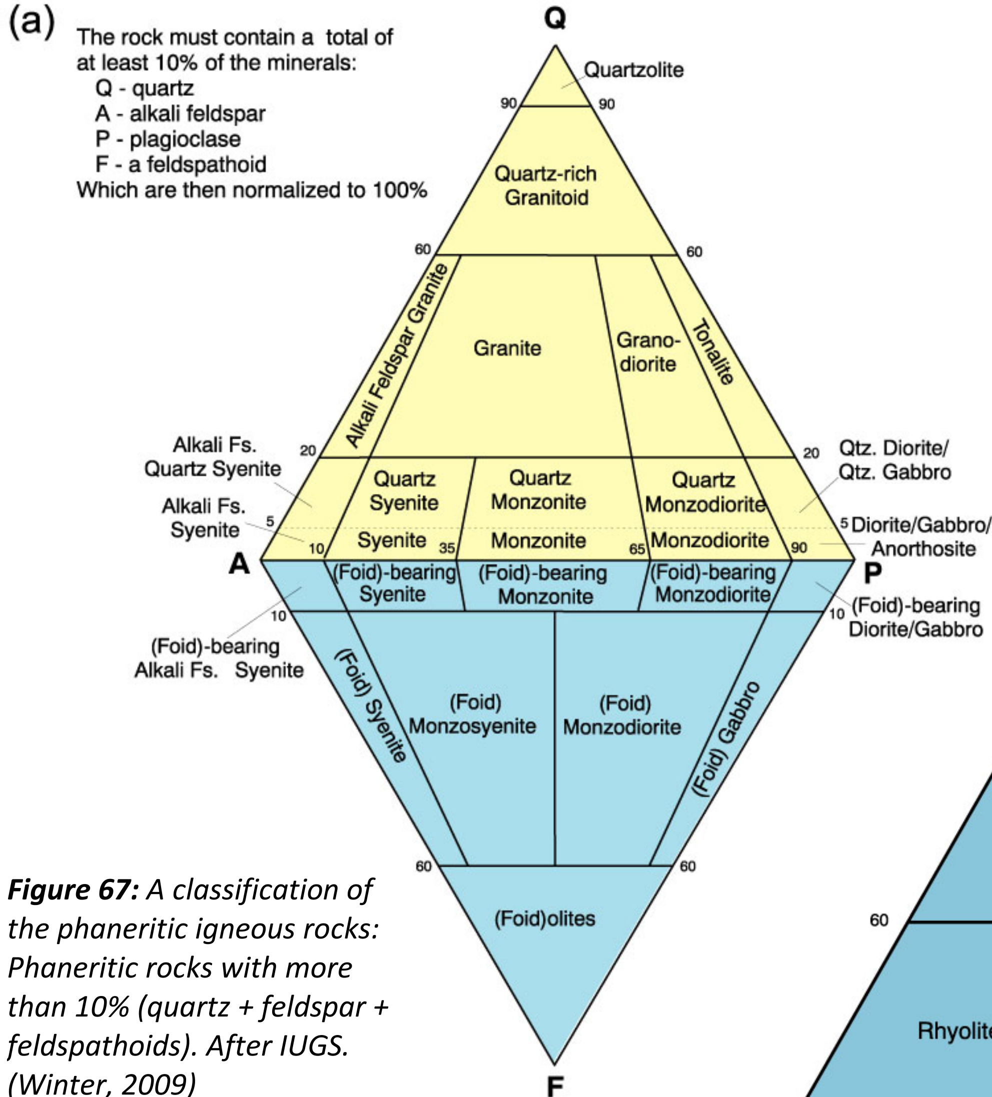


Figure 67: *A classification of the phaneritic igneous rocks: Phaneritic rocks with more than 10% (quartz + feldspar + feldspathoids). After IUGS. (Winter, 2009)*

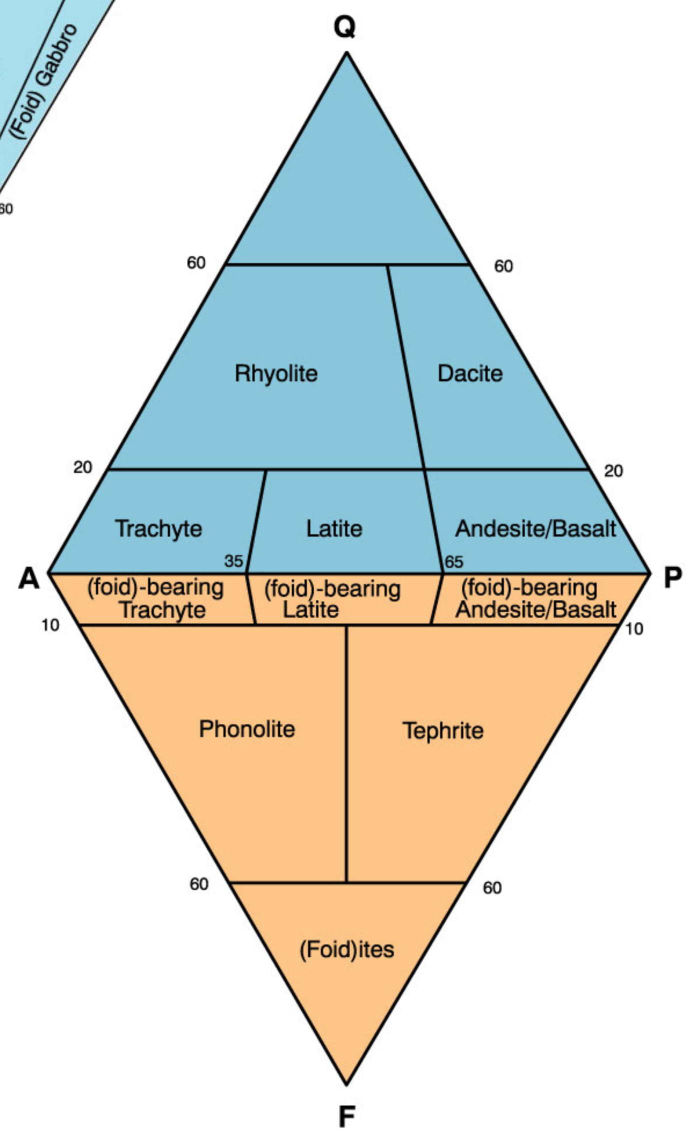
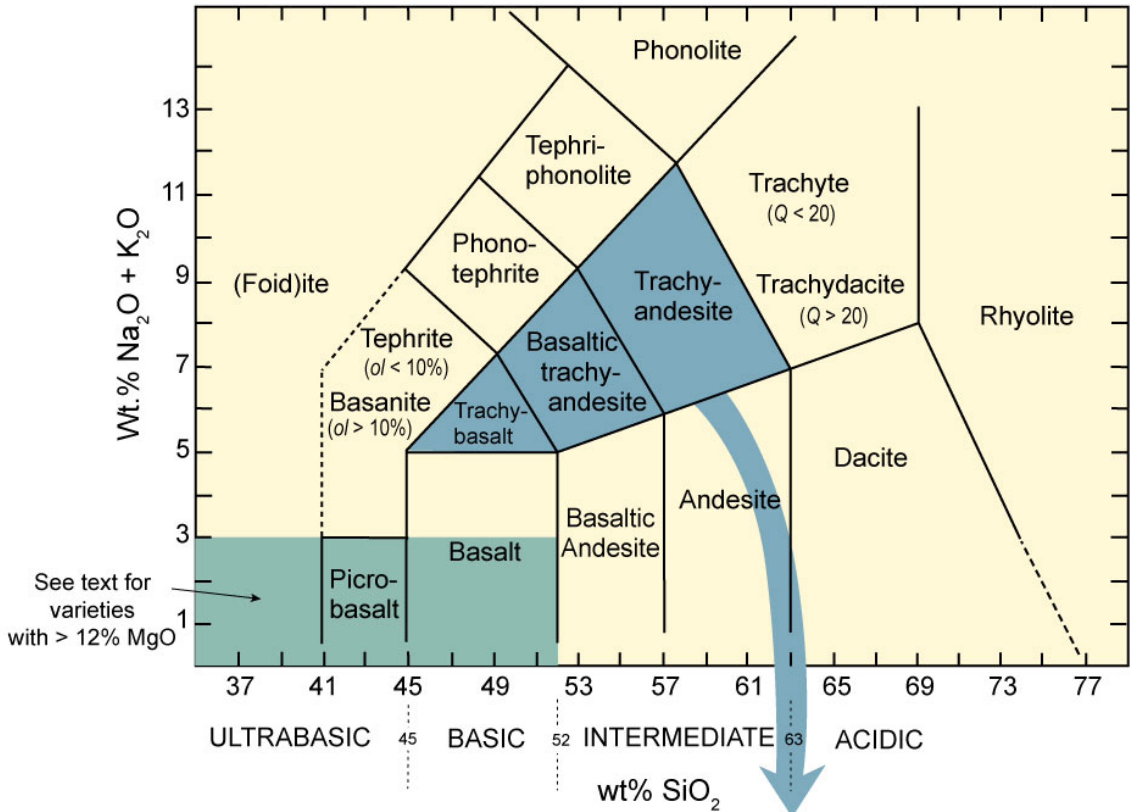


Figure 68: *A classification and nomenclature of volcanic rocks. After IUGS (Winter, 2009)*



Further subdivisions of shaded fields	Trachybasalt	Basaltic Trachyandesite	Trachyandesite
$Na_2O - 2.0 \geq K_2O$	Hawaiite	Mugearite	Benmoreite
$Na_2O - 2.0 < K_2O$	Potassic Trachybasalt	Shoshonite	Latite

***Figure 69:** A chemical classification of volcanics based on total alkalis vs. silica. After Le Maitre (2002) (Winter, 2009)*

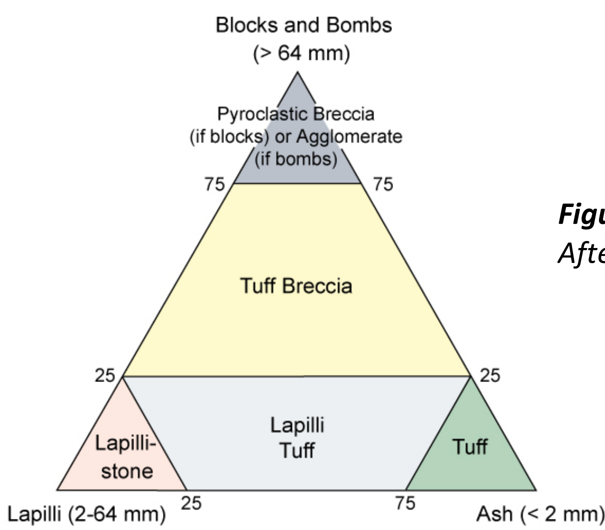


***Figure 70:** Classification of the pyroclastic rocks. After Fisher (1966) (Winter, 2009)*

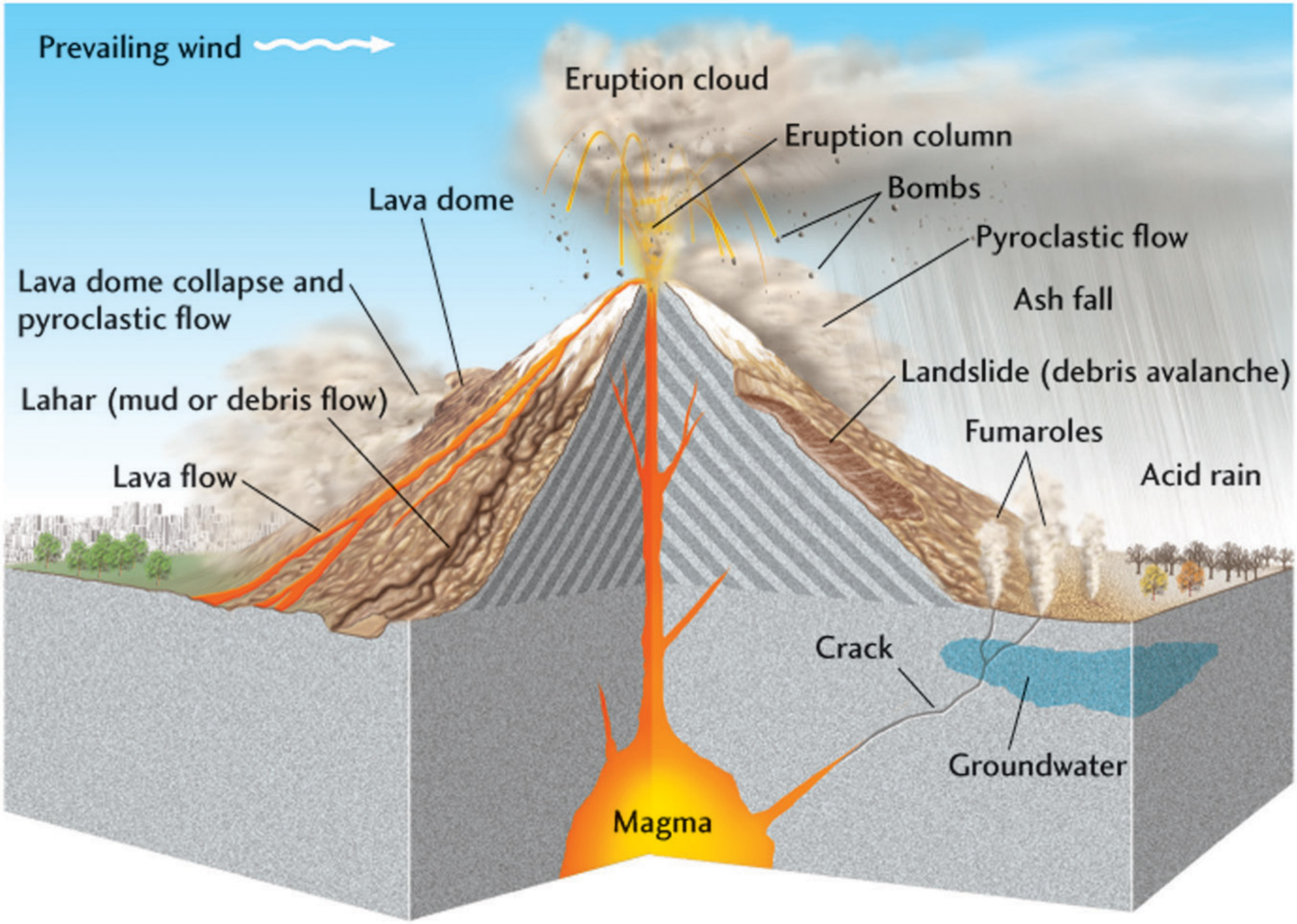


Figure 71: *Some of the volcanic hazards that can kill people and destroy property. [B. Meyers et al./USGS.] (Jordan, 2008)*

Volcanic Explosivity Index (VEI) (*the following is from Wikipedia*)

The Volcanic Explosivity Index (VEI) is a relative measure of the explosiveness of volcanic eruptions. It was devised by Chris Newhall of the United States Geological Survey and Stephen Self at the University of Hawaii in 1982.

Volume of products, eruption cloud height, and qualitative observations (using terms ranging from "gentle" to "mega-colossal") are used to determine the explosivity value. The scale is open-ended with the largest volcanoes in history given magnitude 8. A value of 0 is given for non-explosive eruptions, defined as less than 10,000 m^3 (350,000 cu ft) of tephra ejected; and 8 representing a mega-colossal explosive eruption that can eject 1.0×10^{12} m^3 (240 cubic miles) of tephra and have a cloud column height of over 20 km (66,000 ft). The scale is logarithmic, with each interval on the scale representing a tenfold increase in observed ejecta criteria, with the exception of between VEI-0, VEI-1 and VEI-2.

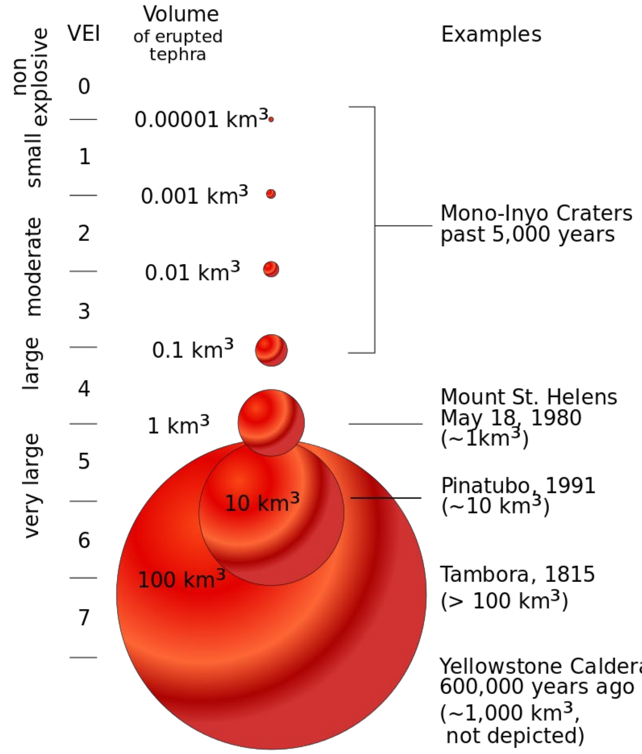


Figure 72: *VEI and ejecta volume correlation*

Classification

With indices running from 0 to 8, the VEI associated with an eruption is dependent on how much volcanic material is thrown out, to what height, and how long the eruption lasts. The scale is logarithmic from VEI-2 and up; an increase of 1 index indicates an eruption that is 10 times as powerful. As such there is a discontinuity in the definition of the VEI between indices 1 and 2. The lower border of the volume of ejecta jumps by a factor of one hundred, from 10,000 to 1,000,000 m^3 (350,000 to 35,310,000 cu ft), while the factor is ten between all higher indices. In the following table, the frequency of each VEI indicates the approximate frequency of new eruptions of that VEI or higher.

About 40 eruptions of VEI-8 magnitude within the last 132 million years (Mya) have been identified, of which 30 occurred in the past 36 million years. Considering the estimated frequency is > 50,000 years, there are likely many such eruptions in the last 132 Mya that are not yet known. Based on incomplete statistics, other authors assume that at least 60 VEI-8 eruptions have been identified. The most recent is Lake Taupo's Oruanui eruption, 25,360 years ago, which means that there have not been any Holocene eruptions with a VEI of 8.

There have been at least 10 eruptions of VEI-7 in the last 10,000 years. There are also 58 plinian eruptions, and 13 caldera-forming eruptions, of large, but unknown magnitudes. By 2010, the Global Volcanism Program of the Smithsonian Institution had catalogued the assignment of a VEI for 7,742 volcanic eruptions that occurred during the Holocene (the last 11,700 years) which account for about 75% of the total known eruptions during the Holocene. Of these 7,742 eruptions, about 49% have a VEI of ≤ 2, and 90% have a VEI ≤ 3.

Figure 73: Table of VEI with historically significant eruptions for context

VEI	Ejecta volume (bulk)	Classification	Description	Plume	Frequency	Tropospheric injection	Stratospheric injection[2]
		Examples					
0	< 10^4 m^3	Hawaiian	Effusive	< 100 m	continuous	negligible	none
		Hoodoo Mountain (c. 7050 BC),[3] Erebus (1963), Kīlauea (1977), Socorro Island (1993), Mawson Peak (2006), Dallol (2011), Piton de la Fournaise (2017)					
1	> 10^4 m^3	Hawaiian / Strombolian	Gentle	100 m – 1 km	daily	minor	none
		Stromboli (since Roman times), Nyiragongo (2002), Raoul Island (2006)					
2	> 10^6 m^3	Strombolian / Vulcanian	Explosive	1–5 km	every two weeks	moderate	none
		Unzen (1792), Cumbre Vieja (1949), Galeras (1993), Sinabung (2010)					
3	> 10^7 m^3	Vulcanian / Peléan/Sub-Plinian	Catastrophic	3–15 km	3 months	substantial	possible
		Lassen Peak (1915), Nevado del Ruiz (1985), Soufrière Hills (1995), Ontake (2014)					
4	> 0.1 km^3	Peléan / Plinian/Sub-Plinian	Cataclysmic	> 10 km (Plinian or sub-Plinian)	18 months	substantial	definite
		Laki (1783), Kīlauea (1790), Mayon (1814), Pelée (1902), Colima (1913), Sakurajima (1914), Katla (1918), Galunggung (1982), Eyjafjallajökull (2010), Nabro (2011), Calbuco (2015)					
5	> 1 km^3	Peléan/Plinian	Paroxysmic	> 10 km (Plinian)	12 years	substantial	significant
		Vesuvius (79), Fuji (1707), Tarawera (1886), Agung (1963), St. Helens (1980), El Chichón (1982), Hudson (1991), Puyehue (2011)					
6	> 10 km^3	Plinian / Ultra-Plinian	Colossal	> 20 km	50–100 yrs	substantial	substantial
		Lake Laach Volcano (c. 10,950 BC), Nevado de Toluca (10,500 BP), Veniaminof (c. 1750 BC), Lake Ilopango (450), Ceboruco (930), Huaynaputina (1600), Krakatoa (1883), Santa Maria (1902), Novarupta (1912), Pinatubo (1991)					
7	> 100 km^3	Ultra-Plinian	Super-colossal	> 20 km	500–1,000 yrs	substantial	substantial
		Aira Caldera (22,000 BC), Kikai Caldera (4,300 BC), Cerro Blanco (c. 2300 BC), Thera (c. 1620 BC), Taupo (180), Baekdu (946), Samalas (1257), Tambora (1815)					
8	> 1000 km^3	Ultra-Plinian	Mega-colossal	> 20 km	> 50,000 yrs[4][5]	vast	vast
		La Garita (26,300,000 BC), Cerro Galán (2,200,000 BC), Huckleberry Ridge Tuff (2,100,000 BC), Yellowstone (630,000 BC), Whakamaru (in TVZ) (254,000 BC),[6] Toba (74,000 BC), Taupo (25,360 BC)					

Plinian Eruptions (*the following is from Wikipedia*)

Plinian eruptions or Vesuvian eruptions are volcanic eruptions marked by their similarity to the eruption of Mount Vesuvius in 79 AD, which destroyed the ancient Roman cities of Herculaneum and Pompeii. The eruption was described in a letter written by Pliny the Younger, after the death of his uncle Pliny the Elder.

Plinian/Vesuvian eruptions are marked by columns of volcanic debris and hot gases ejected high into the stratosphere, the second layer of Earth's atmosphere. The key characteristics are ejection of large amount of pumice and very powerful continuous gas-driven eruptions. According to the Volcanic Explosivity Index, Plinian eruptions have a VEI of 4, 5 or 6, sub-Plinian 3 or 4, and ultra-Plinian 6, 7 or 8.

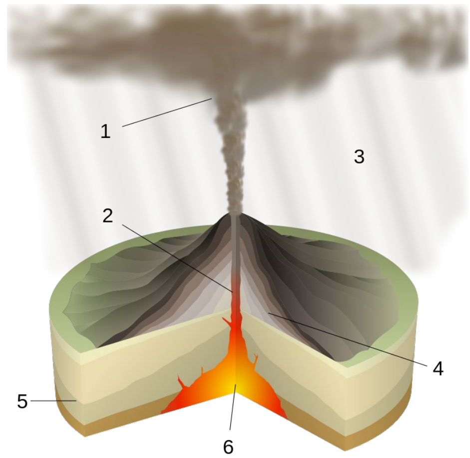


Figure 74: *Plinian eruption: 1: ash plume, 2: magma conduit, 3: volcanic ash fall, 4: layers of lava and ash, 5: stratum, 6: magma chamber.*

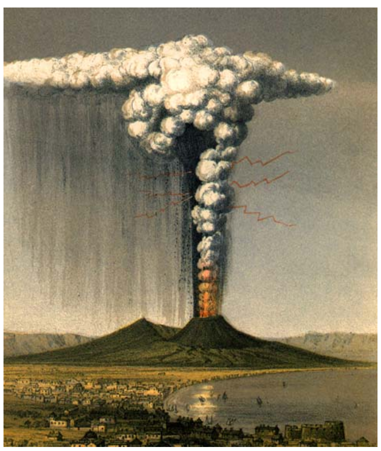


Figure 75: *George Julius Poulett Scrope's depiction of the eruption of 79 AD eruption of Vesuvius (1822)*

Short eruptions can end in less than a day, but longer events can take several days or even months. The longer eruptions begin with production of clouds of volcanic ash, sometimes with pyroclastic surges. The amount of magma erupted can be so large that it depletes the magma chamber below, causing the top of the volcano to collapse, resulting in a caldera. Fine ash and pulverized pumice can deposit over large areas. Plinian eruptions are often accompanied by loud noises, such as those generated by the 1883 eruption of Krakatoa. The sudden discharge of electrical charges accumulated in the air around the ascending column of volcanic ashes also often causes lightning strikes as depicted by the English geologist George Julius Poulett Scrope in his painting of 1822.

The lava is usually rhyolitic and rich in silicates. Basaltic, low-silicate lavas are unusual for Plinian eruptions; the most recent basaltic example is the 1886 eruption of Mount Tarawera on New Zealand's North Island

Pliny described his uncle's involvement from the first observation of the eruption:

> *On August 24th, about one in the afternoon, my mother desired him to observe a cloud which appeared of a very unusual size and shape. He had just taken a turn in the sun and, after bathing himself in cold water, and making a light luncheon, gone back to his books: he immediately arose and went out upon a rising ground from whence he might get a better sight of this very uncommon appearance. A cloud, from which mountain was uncertain, at this distance (but it was found afterwards to come from Mount Vesuvius), was ascending, the appearance of which I cannot give you a more exact description of than by likening it to that of a pine tree, for it shot up to a great height in the form of a very tall trunk, which spread itself out at the top into a sort of branches; occasioned, I imagine, either by a sudden gust of air that impelled it, the force of which decreased as it advanced upwards, or the cloud itself being pressed back again by its own weight, expanded in the manner I have mentioned; it appeared sometimes bright and sometimes dark and spotted, according as it was either more or less impregnated with earth and cinders. This phenomenon seemed to a man of such learning and research as my uncle extraordinary and worth further looking into.* — Sixth Book of Letters, Letter 16, translation by William Melmoth

Andean Volcanic Belt (*the following is from Wikipedia*)

The Andean Volcanic Belt is a major volcanic belt along the Andean cordillera in Argentina, Bolivia, Chile, Colombia, Ecuador and Peru. It formed as a result of subduction of the Nazca Plate and Antarctic Plate underneath the South American Plate. The belt is subdivided into four main volcanic zones that are separated from each other by volcanic gaps. The volcanoes of the belt are diverse in terms of activity style, products and morphology. While some differences can be explained by which volcanic zone a volcano belongs to, there are significant differences within volcanic zones and even between neighboring volcanoes. Despite being a type location for calc-alkalic and subduction volcanism, the Andean Volcanic Belt has a large range of volcano-tectonic settings, such as rift systems and extensional zones, transpressional faults, subduction of mid-ocean ridges and seamount chains apart from a large range on crustal thicknesses and magma ascent paths, and different amount of crustal assimilations.

Romeral in Colombia is the northernmost active member of the Andean Volcanic Belt. South of latitude 49° S within the Austral Volcanic Zone volcanic activity decreases with the southernmost volcano Fueguino in Tierra del Fuego archipelago.

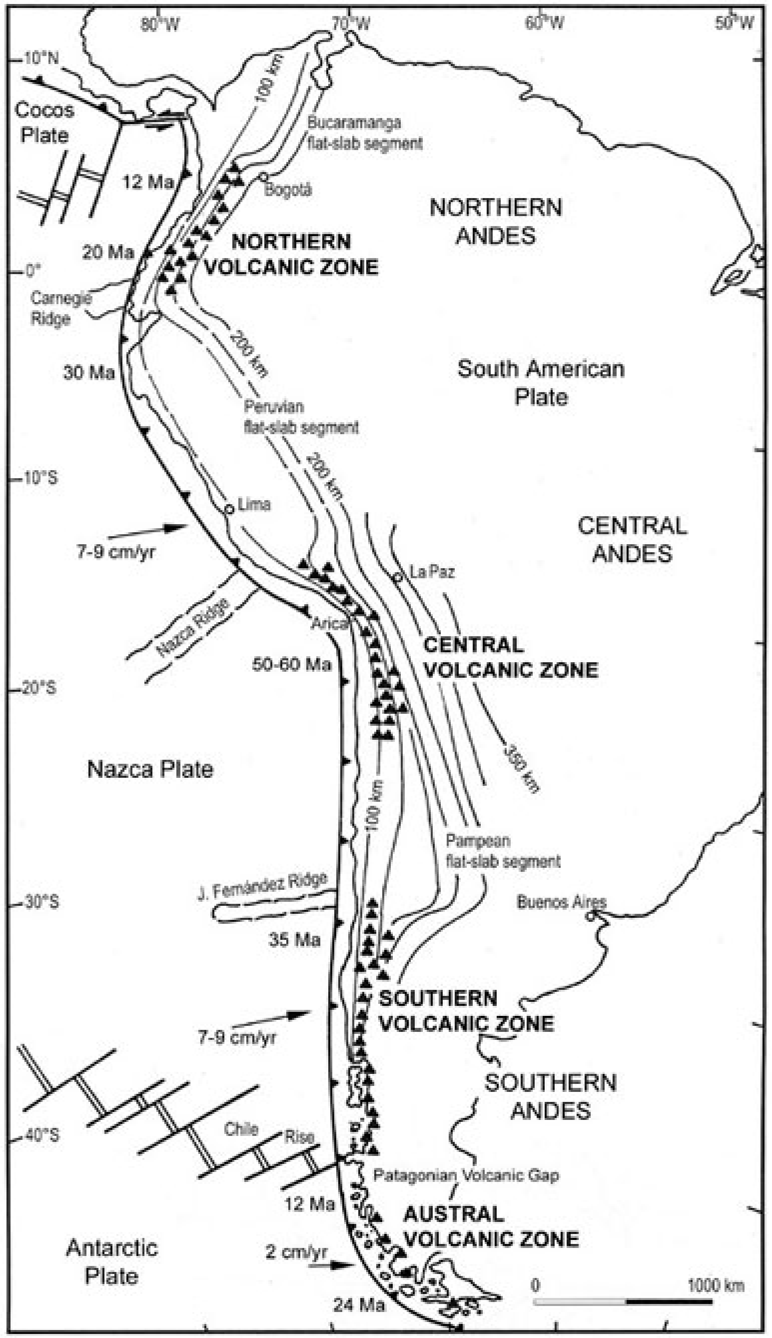


Figure 76: *Schematic map of South America and the Pacific oceanic plates showing the four volcanically active segments in the Andes, subduction geometry as indicated by depth in kilometers to the Benioff zone, oceanic ridges, ages of the oceanic plates close to the Perú-Chile trench, and convergence rates and directions along the length of the Andes. (Stern, 2004)*

Northern Volcanic Zone (*the following is from Wikipedia*)

The Northern Volcanic Zone (NVZ) extends from Colombia to Ecuador and includes all volcanoes on the continental mainland of these countries. Of the volcanoes in this zone, 55 are located in Ecuador, while 19 are in Colombia. In Ecuador, the volcanoes are located in the Cordillera Occidental and Cordillera Real while in Colombia they are located in the Western and Central Ranges. The Pliocene Iza-Paipa volcanic complex in Boyacá, in the Eastern Ranges is the northernmost manifestation of the Northern Andean Volcanic Belt. The volcanic arc has formed due to subduction of the Nazca Plate underneath western South America. Some volcanoes of the Northern Volcanic Zone, such as Galeras and Nevado del Ruiz that lie in densely populated highland areas, are major sources of hazards. It has been estimated that crustal thickness beneath this region varies from around 40 to perhaps more than 55 kilometres (34 mi). Sangay is the southernmost volcano of the Northern Volcanic Zone.

The Geophysics Institute at the National Polytechnic School in Quito, Ecuador houses an international team of seismologists and volcanologists whose responsibility is to monitor Ecuador's numerous active volcanoes in the Andean Volcanic Belt and the Galápagos Islands, all of which is part of the Ring of Fire.

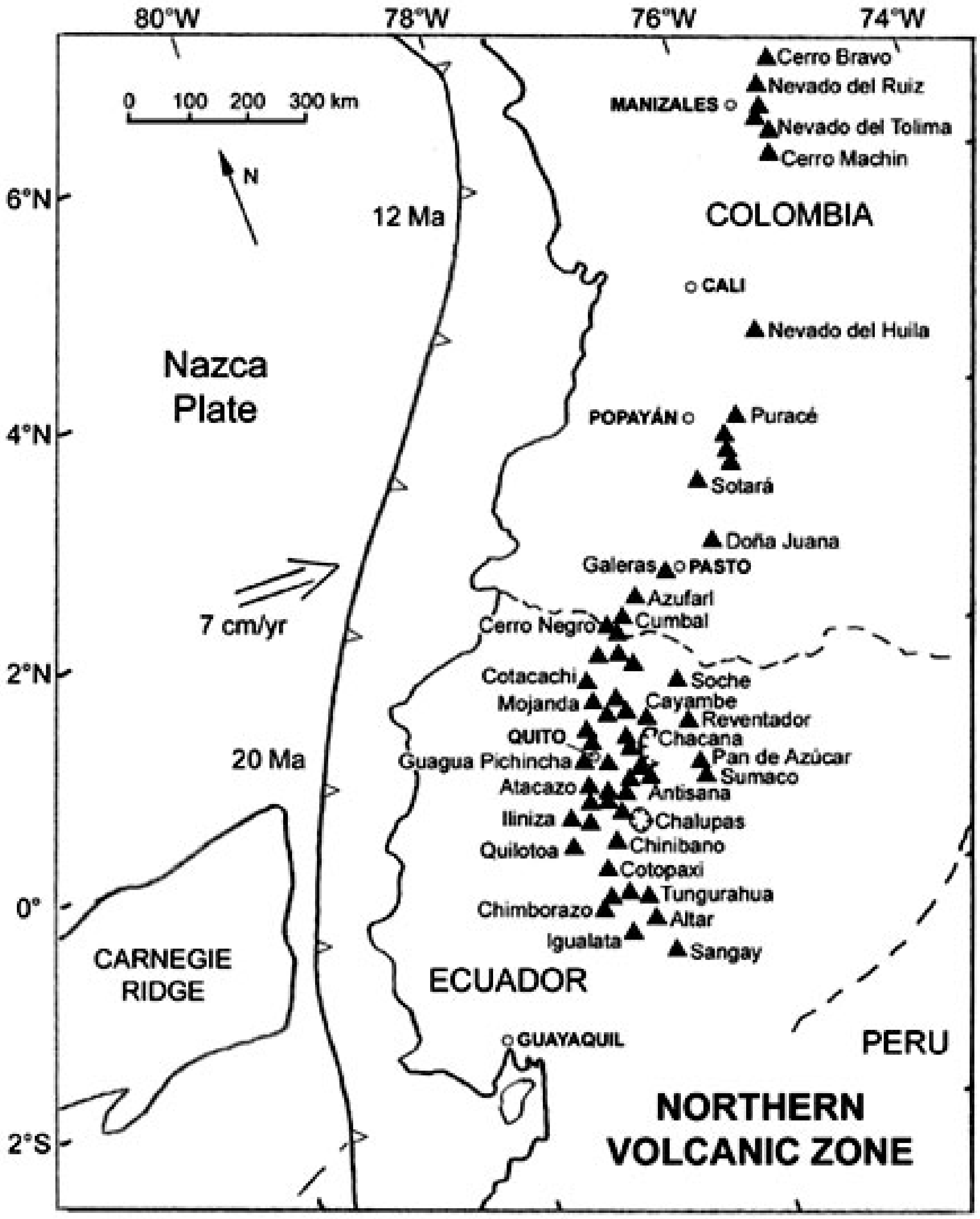


Figure 77: *Schematic map of the Northern Volcanic Zone showing the location of some of the better known volcanoes (Stern, 2004)*

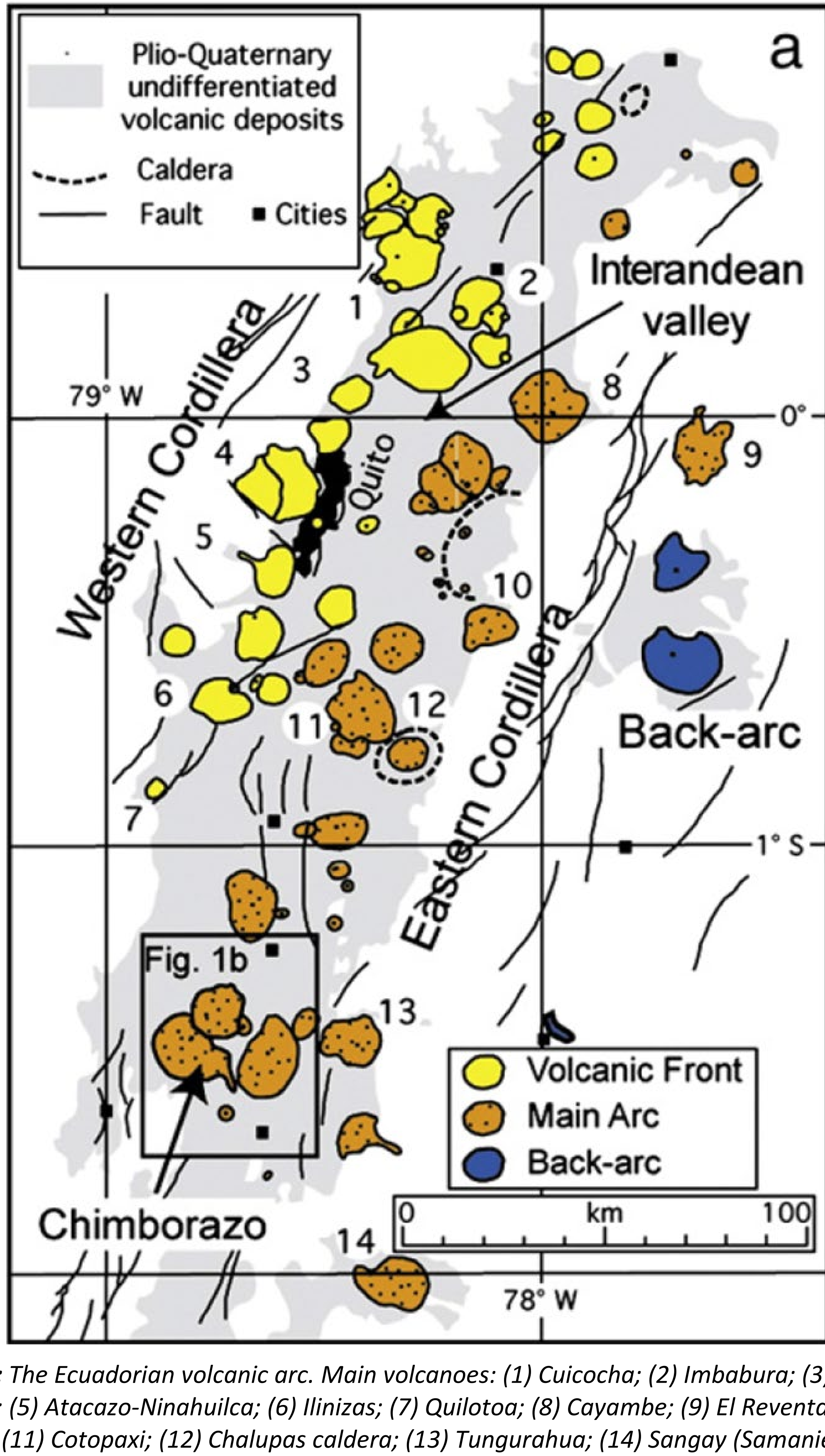


Figure 78: *The Ecuadorian volcanic arc. Main volcanoes: (1) Cuicocha; (2) Imbabura; (3) Pululahua; (4) Pichincha; (5) Atacazo-Ninahuilca; (6) Ilinizas; (7) Quilotoa; (8) Cayambe; (9) El Reventador; (10) Antisana; (11) Cotopaxi; (12) Chalupas caldera; (13) Tungurahua; (14) Sangay (Samaniego et al, 2012)*

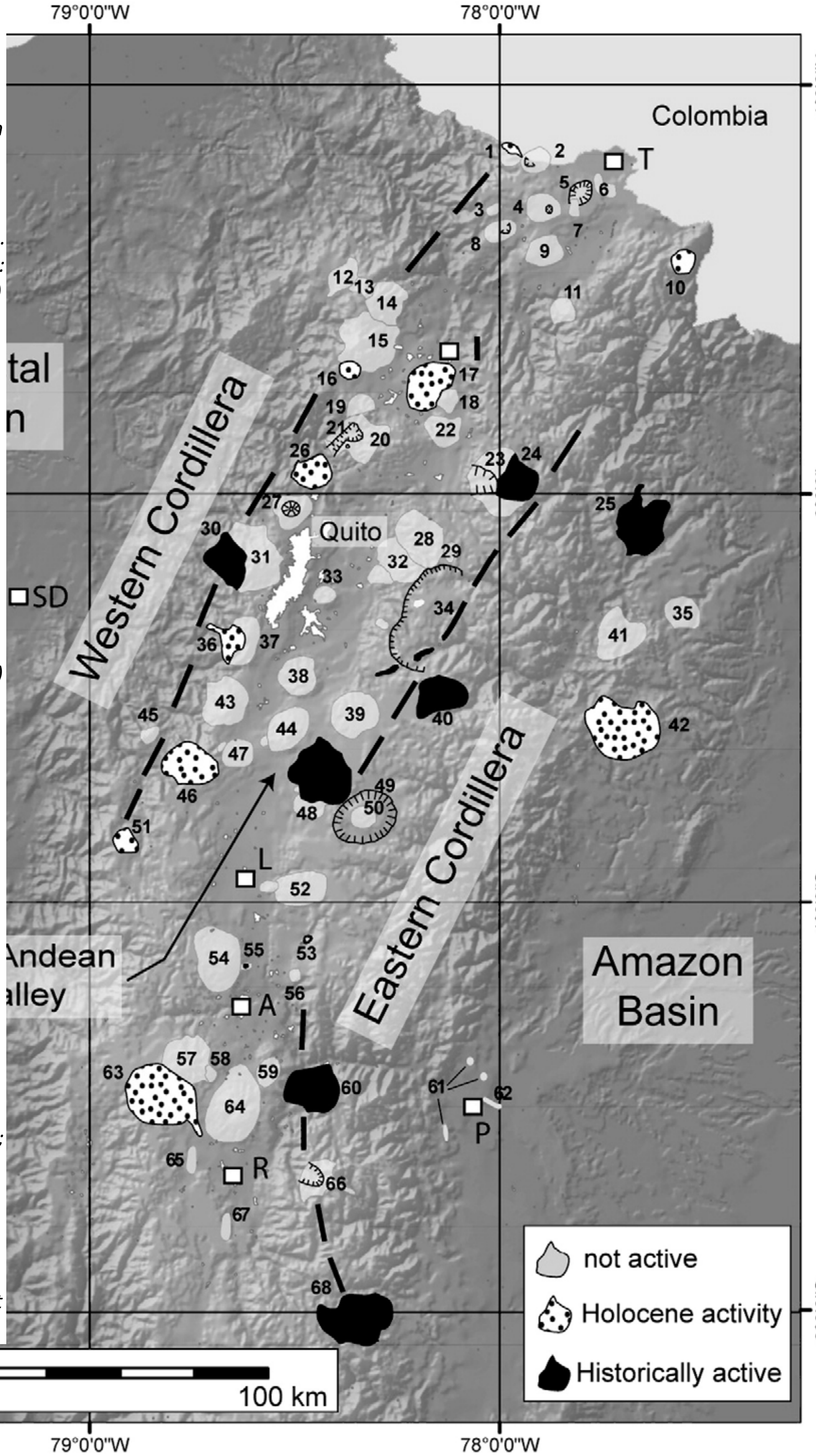


Figure 79: *Distribution of Ecuador's continental volcanoes along two principal axes (dashed lines), plus back-arc group. Digital Elevation Model of the Ecuadorian Andes, provided by M. Souris (IRD), was generated from 1:50,000 topographic maps of the Instituto Geográfico Militar, Quito. Names of the volcanic edifices are: (1) Cerro Negro de Mayasquer; (2) Chiles; (3) Chiltazón; (4) Potrerillos; (5) Chalpatán; (6) Chulamuez; (7) Horqueta; (8) Iguán; (9) Chaquilulo; (10) Soche; (11) Mangus; (12) Pilavo; (13) Yanaurcu de Piñan; (14) Huanguillaro; (15) Cotacachi; (16) Cuicocha; (17) Imbabura; (18) Cubilche; (19) Cushnirumi; (20) Mojanda; (21) Fuya Fuya; (22) Cusín; (23) Viejo Cayambe; (24) Nevado Cayambe; (25) El Reventador; (26) Pululahua; (27) Casitagua; (28) Pambamarca; (29) Izambi; (30) Guagua Pichincha; (31) Rucu Pichincha; (32) Puntas; (33) Ilaló; (34) Chacana; (35) Yanaurcu; (36) Ninahuilca; (37) Atacazo; (38) Pasochoa; (39) Sincholagua; (40) Antisana; (41) Pan de Azucar; (42) Sumaco; (43) Corazón; (44) Rumiñahui; (45) Almas Santas; (46) Ilinizas; (47) Tres Marías; (48) Cotopaxi; (49) Chalupas; (50) Quilindaña; (51) Quilotoa; (52) Chinibano; (53) Angahuana; (54) Sagoatoa; (55) Larcapungo; (56) Huicutambo; (57) Carihuarazo; (58) Puñalica; (59) Huisla; (60) Tungurahua; (61) Mera; (62) Puyo; (63) Chimborazo; (64) Igualata; (65) Calpi; (66) Altar; (67) Tulabug; (68) Sangay. Cities include: Tulcán (T), Ibarra (I), Quito (Q), Latacunga (L), Ambato (A), Riobamba (R), Puyo (P), and Sto. Domingo (SD) (Hall et al, 2008)*

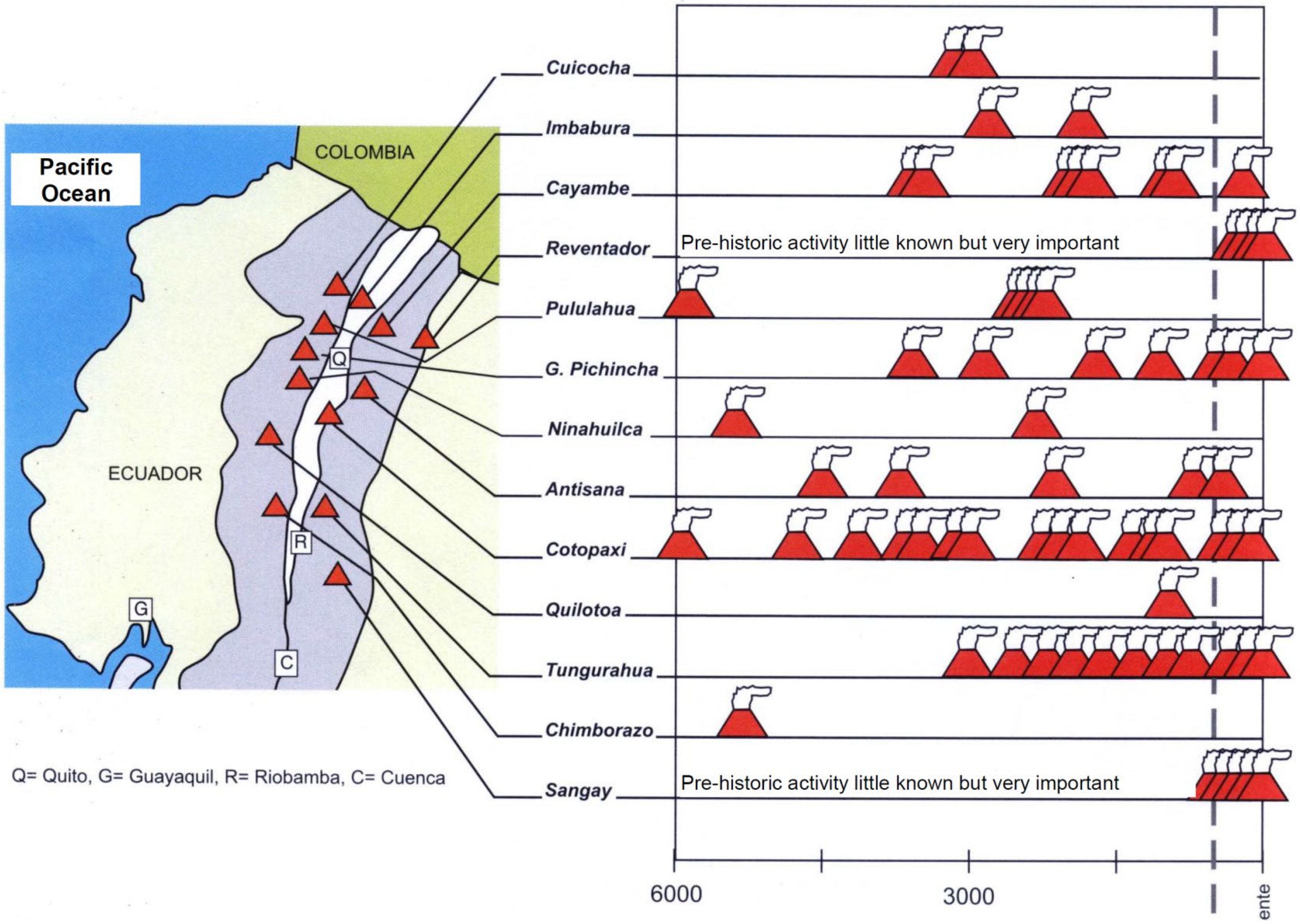


Figure 80: *Map of Ecuador's Volcanoes and chart of eruptive history. Modified from IGEPN volcanoes brochures (Leanard et al., 2005)*

DETAILED ITINERARY

Day 1: Saturday, March 9th, 2019 – Board flight

4:00AM: Leave Krebs Parking Lot
7:30AM: Arrive at Dulles Airport
9:08AM: Depart Washington Dulles (Copa Airlines Flight 357) to Panama City, Panama
2:10PM: Arrive in Panama City for layover
3:33PM: Depart Panama (Copa Airlines Flight 159) to Quito, Ecuador
5:31PM: Arrive in Quito, Ecuador – Jonathan should pick us up at the airport and bring us to the hotel. I am pretty sure we are staying in the Mariscal Sucre part of town.
Hotel Address and phone number.
7:00PM: Go out for a meal.

Day 2: Sunday, March 10th, 2019 – Quito City Tour, the Equator, and Pululahua Crater

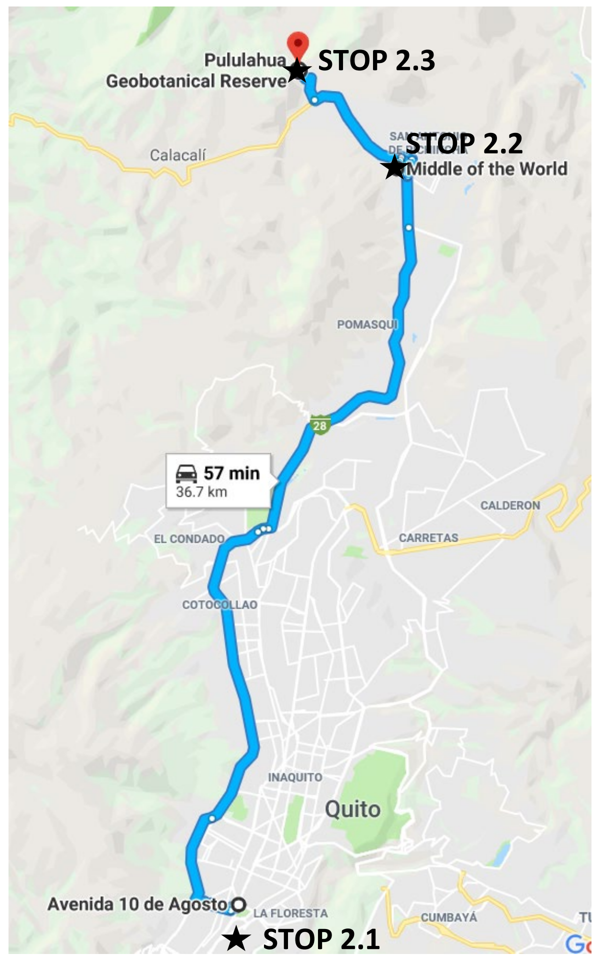
Breakfast – I think all the breakfast meals will be provided. They will likely be light breads, fruit, and coffee/tea.

Morning – City Tour of Quito and up the Cable cars for views of the city. Maybe a tour of the Institute Geofisco Escuela Politecnica National (IGEPN), this is the main volcano observatory for the Ecuadorian Andes.

Lunch – Cuy!

Afternoon – Mitad del Mundo (Equatorial Monument and Pululahua Crater viewpoint.

Evening – We are on our own for dinner.



STOP 2.1: *Quito*
From Wikipedia

Quito is the capital and the largest city of Ecuador, and at an elevation of 2,850 metres (9,350 ft) above sea level, it is the second-highest official capital city in the world, after La Paz, and the one which is closest to the equator. It is located in the Guayllabamba river basin, on the eastern slopes of Pichincha, an active stratovolcano in the Andes Mountains. With a population of 2,671,191 according to statistical projections (2019), Quito is the most populous city in Ecuador. It is also the capital of the Pichincha province and the seat of the Metropolitan District of Quito. The canton recorded a population of 2,239,191 residents in the 2010 national census. In 2008, the city was designated as the headquarters of the Union of South American Nations.

The historic center of Quito has one of the largest, least-altered and best-preserved historic centers in the Americas. Quito and Kraków, Poland, were among the first World Cultural Heritage Sites declared by UNESCO, in 1978. The central square of Quito is located about 25 kilometres (16 mi) south of the equator; the city itself extends to within about 1 kilometer (0.62 mi) of zero latitude. A monument and museum marking the general location of the equator is known locally as la mitad del mundo (the middle of the world), to avoid confusion, as the word ecuador is Spanish for equator.

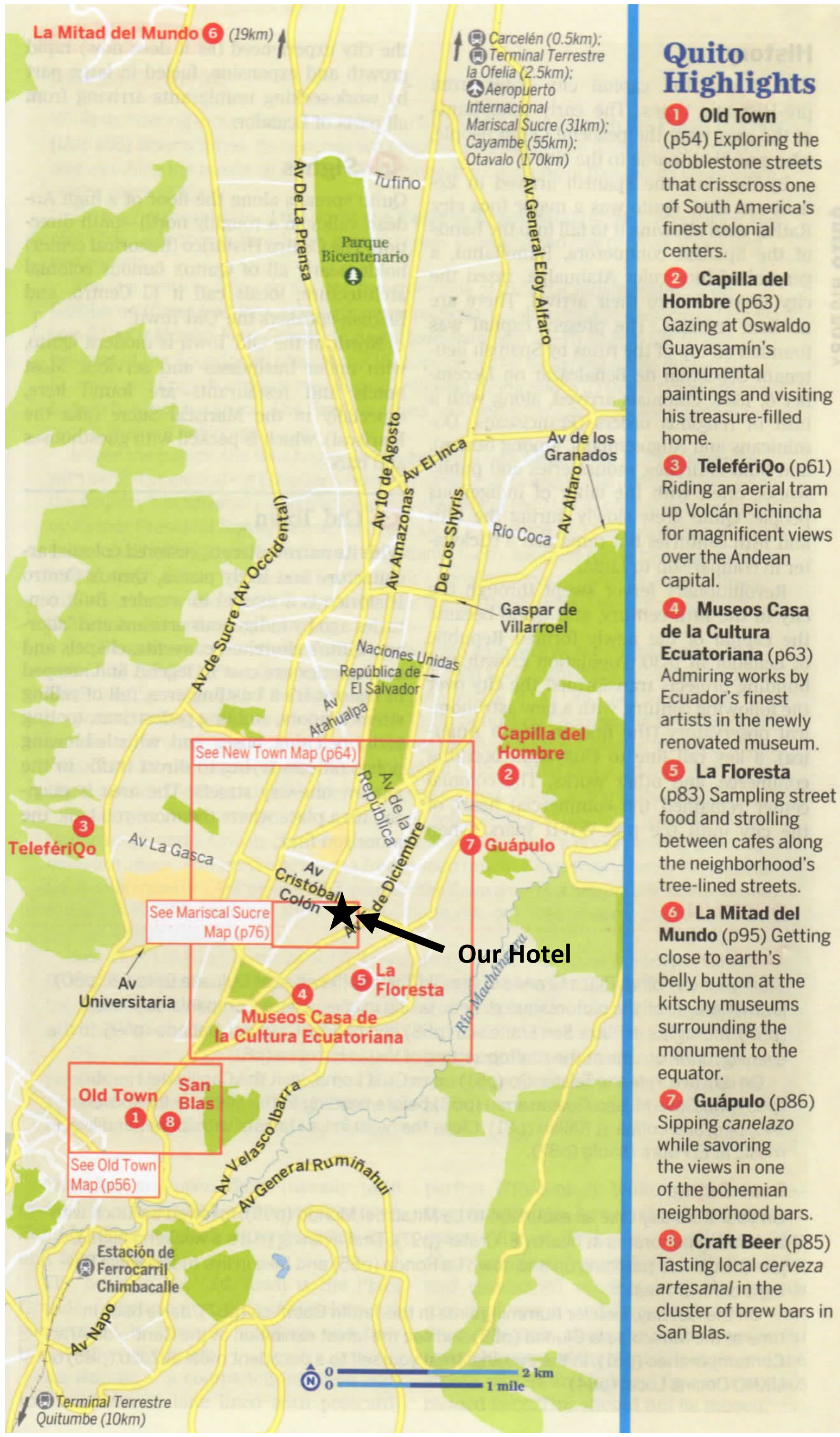


Figure 81: *Basic Map of Quito Area (Lonely Planet, 2018)*

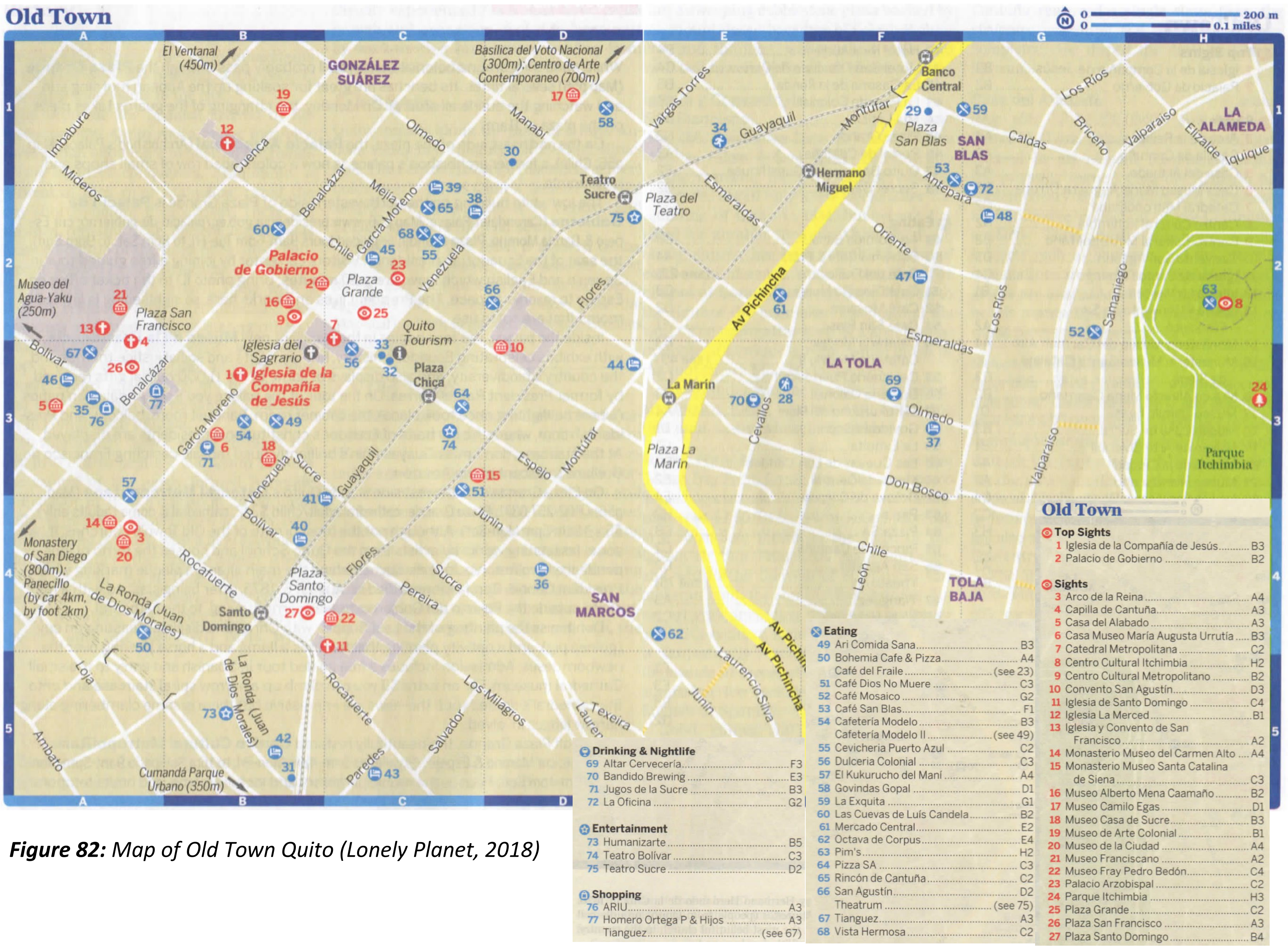
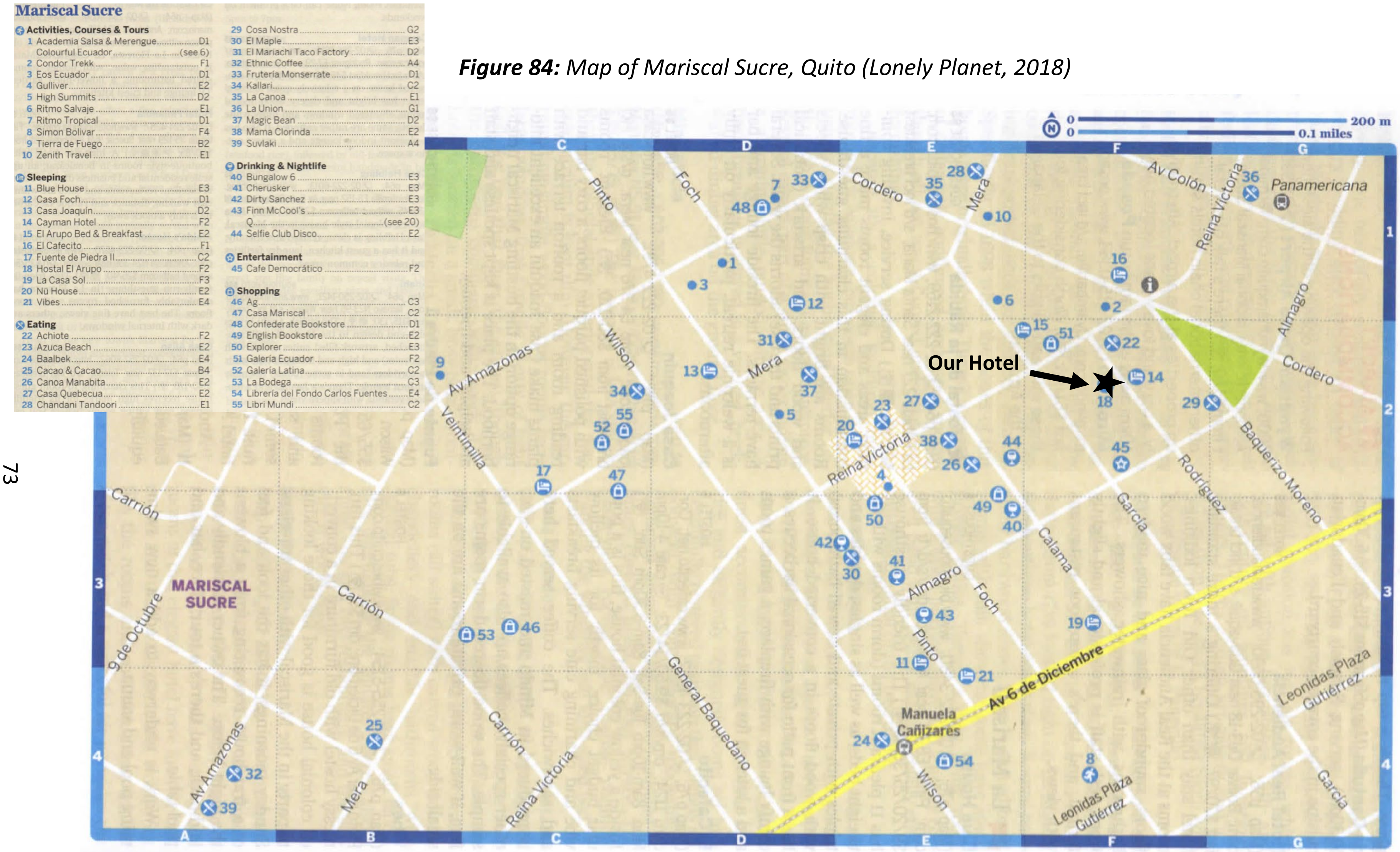


***Figure 82:** Map of Old Town Quito (Lonely Planet, 2018)*

Figure 83: *Map of New Town Quito (Lonely Planet, 2018)*

Figure 84: *Map of Mariscal Sucre, Quito (Lonely Planet, 2018)*



STOP 2.2: *Mitad del Mundo*
From Wikipedia

The Ciudad Mitad del Mundo (Middle of the World City) is a tract of land owned by the prefecture of the province of Pichincha, Ecuador. It is located at San Antonio parish of the canton of Quito, 26 km north of the center of Quito. The grounds contain the Monument to the Equator, which highlights the exact location of the Equator (from which the country takes its name) and commemorates the eighteenth century Franco-Spanish Geodesic Mission which fixed its approximate location; they also contain the Museo Etnográfico Mitad del Mundo, Ethnographic Museum Middle of the Earth, a museum about the indigenous people ethnography of Ecuador.

The 30-meter-tall monument was constructed between 1979 and 1982 by Pichincha's Province Council to replace an older, smaller monument built by the Government of Ecuador under the direction of the geographer Luis Tufiño in 1936. It is made of iron and concrete and covered with cut and polished andesite stone. The monument was built to commemorate the first Geodesic Mission of the French Academy of Sciences, led by Louis Godin, Pierre Bouguer and Charles Marie de La Condamine, who, in the year 1736, conducted experiments to test the flattening at the poles of the characteristic shape of the Earth, by comparing the distance between a degree meridian in the equatorial zone to another level measured in Sweden. The older monument was moved 7 km to a small town near there called Calacalí.

The UNASUR headquarters is currently under construction in this place. Contrary to popular belief, there are only two points of interest positioned exactly on the equator: the Catequilla archaeological site, and the Quitsato Sundial.

Figure 85: *The Monument to the Equator (Monumento a la Mitad del Mundo)*

Latitude discrepancy

Based on data obtained by Tufiño, it was believed that the equator passed through those two sites. However, according to readings based on the World Geodetic System WGS84, used in modern GPS systems and GIS products, the equator actually lies about 240 meters north of the marked line.Over the years, countless tourists have had their pictures taken straddling the line drawn down the center of the east-facing staircase and across the plaza.

Figure 86: *Ciudad Mitad del Mundo as seen from the west from the 30-meter-high terrace of the museum*

The pyramidal monument, with each side facing a cardinal direction is topped by a globe which is 4.5 meters in diameter and weighs 5 tons. Inside the monument is a small museum that displays a variety of indigenous items pertaining to Ecuadorian culture: clothing, descriptions of the various ethnic groups, and examples of their activities.

Ciudad Mitad del Mundo contains other attractions such as a planetarium, a miniature model of Quito, and restaurants. On weekends, Ciudad Mitad del Mundo's Central Plaza hosts varied musical and cultural events for tourists. Also, there are diverse local handcraft stores and local food served at several cafés along a colonial small town.

STOP 2.3: *Pululahua Crater*

The following is from:

Andrade, D. and Molina, I., 2006, Pululahua Caldera: Dacitic Domes and Explosive Volcanism. Fourth Conference Cities on Volcanoes International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) – Quito, Ecuador, Excursion A3, 12 pgs.

Introduction

The Pululahua Volcanic Complex (PVC) [0° 2' N, 78° 27' W] is a group of dacitic lava domes emplaced on the Cordillera Occidental of Ecuador, ~15 km north of Quito and less than 5 km north from the inactive Casitahua Volcano (Fig. 1). Together with the volcanic complexes of Chiles-Cerro Negro, Chachimbiro and Cotacachi-Cuicocha, to the north, and Pichincha, Atacazo-Ninahuilca, Iliniza and Quilotoa, to the south, the PVC defines the Volcanic Front of the Ecuadorian Arc (Hall & Beate, 1991) (Fig. 1). The PVC is characterized by the presence of a quasi-rectangular (3x2 km) caldera, with a mean depth of ~250 m. In addition, it presents a dozen dacitic lava domes distributed both inside and outside the caldera (Fig. 2). With respect to other Ecuadorian volcanoes, the PVC has remained relatively forgotten because of its modest size and altitude (3356 masl), as already noted in the XIXth century by T. Wolf (1892), who described the Pululahua as a volcano which "does not call the attention from a far, because its wide and deep crater is not placed at the high summit of a big mount [...] but is a sink at the rise top of the Cordillera".

Although several descriptions and studies had been carried out on the PVC (Hall, 1977; Aguila 1986; Hall & Hillebrandt, 1988; Papale & Rosi 1993; Hall & Mothes, 1994), still much of its history and structure were not clear. Moreover, upon compilation, these data gave place to confusions.

Thus, while Hall (1977) suggested the ancient existence of a volcanic edifice which "constructed its cone" over the Cretaceous basement before the Holocene, Aguila (1986) concluded that the whole history of PVC comprises at least six Holocene periods of volcanic activity, all of which began with "the emplacement and edification of a precursor dome".

Additionally, Hall (1977) and Issacson & Zeidler (1999) obtained radiocarbon ages of 2,305±65 and 2,285 yBP, respectively, for the complex pumice-rich sequence of recent Pululahua deposits, which were interpreted by Hall & Mothes (1994) as belonging to "explosive eruptions that occurred inside the caldera" of PVC. However, Papale and Rosi (1993) pointed out that the PVC caldera was formed during explosive eruptions that deposited the same pumice-rich sequence, but beginning in 2,485±130 after a radiocarbon age obtained by Villalba (1988). Finally, Geotermica Italiana-INEMIN (1989) had obtained a radiocarbon age of ~2,650 for the paleo-soil underlying the pumice-rich sequence.

More recently, Andrade (2002 & 2003) has carried-out a new compilation of previous data and a new chrono-stratigraphic and petrographic study at Pululahua, which has been used in this field guide.

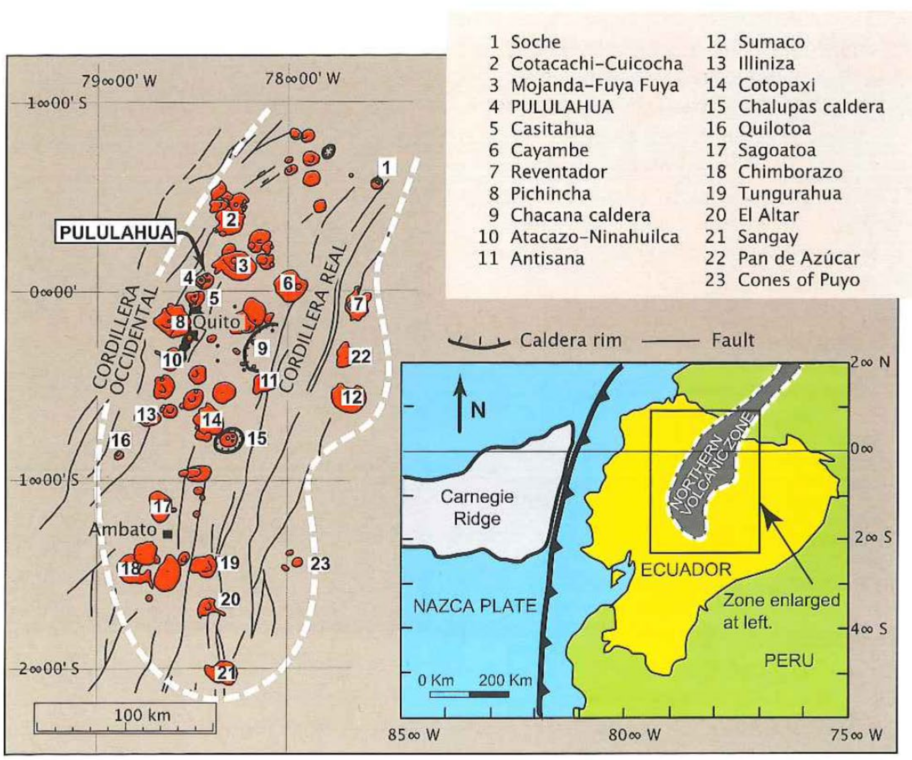


Figure 1. The Ecuadorian Volcanic Arc is the consequence of the Nazca plate subducting underneath the South-American plate. The main volcanoes are labelled with numbers. Pululahua Volcanic Complex belongs to the Volcanic Front.

Volcanic History and Structural Development

The PVC was constructed over two different types of basement. To the east and south (Fig. 2), the PVC deposits lie discordant over tectonically tilted Plio-Pleistocene volcaniclastic and fluvio-lacustrine formations. The base of these formations has been dated at 2.6±0.06 Ma, while the top is younger than 0.5±0.06 Ma (Ego, 1995).

To the west and north, the basement of PVC displays Cretaceous units of the Cordillera Occidental of Ecuador, which mainly represent an oceanic terrain (pillow basalts, sandstones, flysch and black siltstones) accreted to the continent during the Maastrichtian (Fig. 2) (Aspden et al., 1992). Topographically, the Cretaceous formations correspond to a very irregular terrain and represent an important barrier which has limited the flow deposits of PVC to the Blanco and Charhuayacu Rivers in the west and north respectively, and to the Ambuasí river to the south (Fig. 2).

The inactive Casitahua volcano is located less than 5 km south of PVC (Fig. 2). Two K-Ar dates on lavas from Casitahua have yielded 2.25±0.25 Ma (Ego, 1995) and 1.4 Ma (INEMIN-Geotermica Italiana-ESPE, 1989), which means that this volcano was contemporary with the Pliocene basement volcaniclastic formations. The structure of Casitahua volcano currently presents an eroded horse-shoe shaped avalanche caldera open to the NW. Casitahua lavas are ortho and clinopyroxene-bearing andesites, which makes them substantially different from PVC lavas. Chemically, Casitahua presents andesites and dacites, enriched in K_2O and depleted in Al_2O_3 with respect to PVC lavas of similar composition (Fig. 3).

With respect to local tectonics, the PVC zone is controlled by two important regional faults: the Quito fault to the east, and the Nono fault to the west (Figs. 2). The Quito fault is a 40 km-long reverse structure whose northern termination is less than 5 km eastwards from PVC (Soulas el al., 1991; Ego, 1995). This is an active fault and has given place to important historical earthquakes in the city of Quito (Soulas et al., 1991).

The Nono fault is a large but poorly known structure, only recently recognized by Soulas et al. (2001). Anyway, it seems clear that this fault limits the vent emplacements of PVC to the west (Figs. 2). The simultaneous activity of both the Quito and Nono faults seem to have intensely fractured the basement formations of the PVC, which has been profited by the ascending magmas that reached the surface through different paths. Moreover, the rectangular shape of the PVC caldera seems to have been in some way controlled by the simultaneous action of these two faults (Fig. 2).

Thus, PVC's history and structure has been divided into four main Series (Fig. 2): i) a group of pre-caldera ancient domes and their deposits (Series I); ii) a group of pre-caldera younger domes and their deposits (Series II); iii) a complex sequence of pumice-rich deposits, associated with the caldera formation (Series III); and, iv) a group of post-caldera domes and their deposits (Series IV).

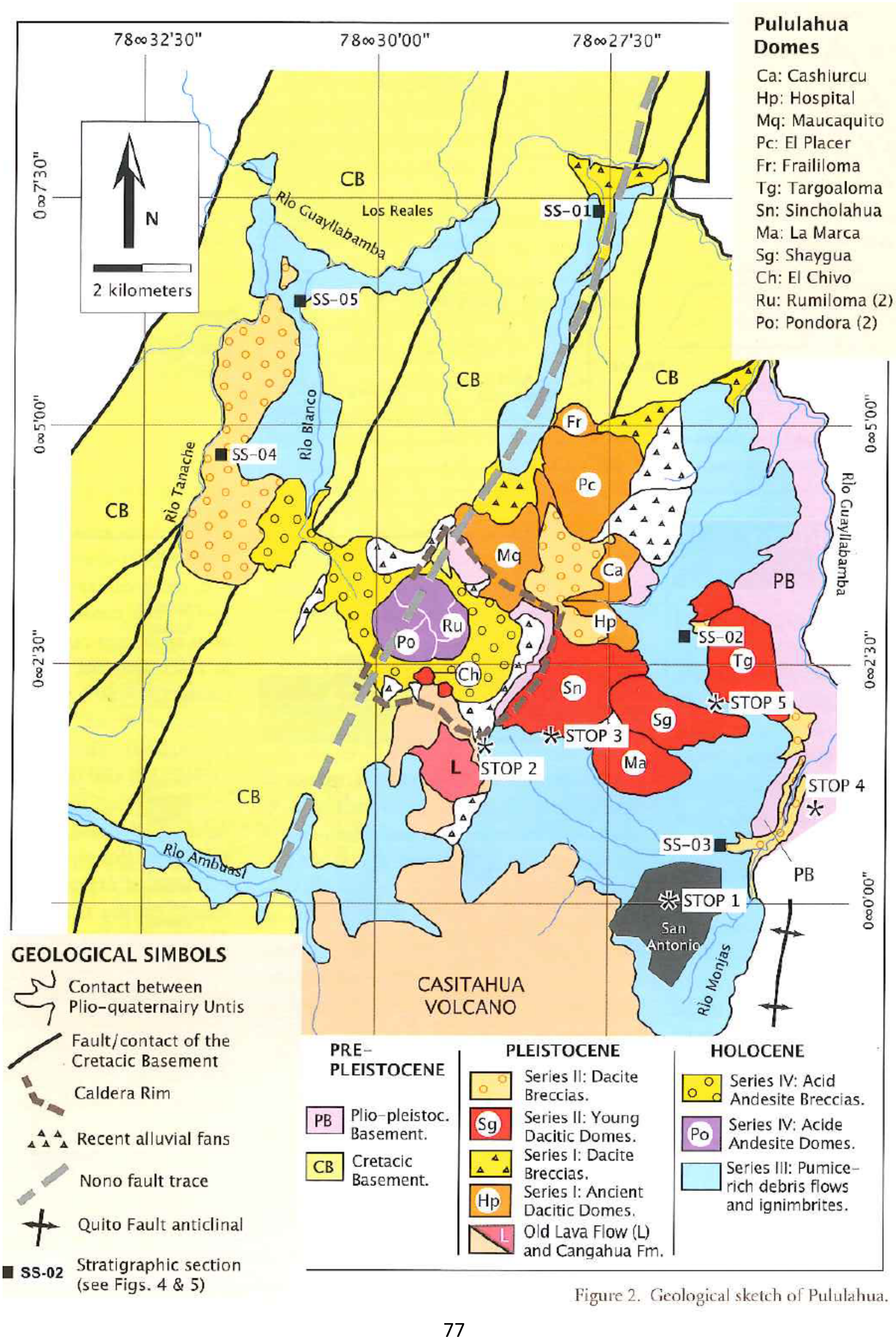


Figure 2. Geological sketch of Pululahua.

Volcanic History and Structural Development

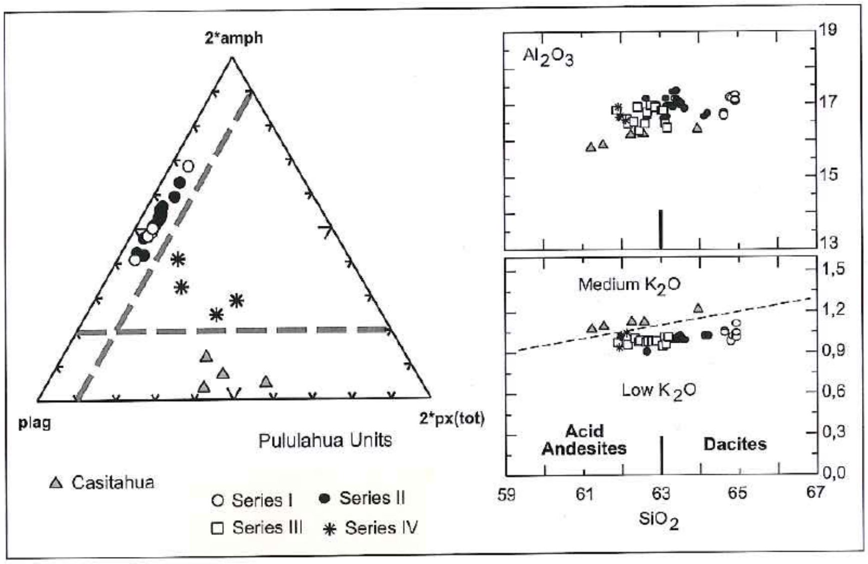


Figure 3. Diagrams showing some petrographic and geochemical characteristics of the Pululahua Series and Casitahua volcano. Note the clear differences between Pululahua and Casitahua, and among the four Pululahua Series.

Series I: pre-caldera ancient domes

It is conformed by the domes: Cashiurcu, El Hospital, Maucaquito, El Placer and Fraililoma which are emplaced to the north and north-east of the caldera (Fig. 2). All these domes are plagioclase and black amphibole-bearing dacitic lavas (63.3-64.9% SiO_2) (Fig. 3). The maximum height corresponds to the Maucaquito dome with 3250 m and with a relief of 670 m over the caldera bottom. This group of domes is characterized by featuring irregular morphologies which means that they have been affected by erosion and tectonic activity.

The deposits belonging to the growth of the Series I-domes are represented exclusively by "block and ash flow" monolithic breccias, rich in amphibole-bearing dacites (30-55% vol.), or by reworked deposits of similar composition. None of these deposits present vesiculated rocks (dacitic pumice) to account for important explosive activity during this period (Figs. 2 & 4). This means that the domes were emplaced during mainly effusive eruptions.

In some places it is possible to find the domes and deposits of Series I partially covered by the Upper Cangahua Fm (younger than 50 ka) or by deposits belonging to the Series II-domes growth.

Series II: pre-caldera younger domes

It is conformed by the domes: Trigoladera, Sincholahua, Shaygua, La Marca and El Chivo, located to the east and south-east of the caldera (Fig. 2). All these domes are plagioclase and amphibole-bearing dacitic lavas (62.7-64.2% SiO_2), with some traces of clinopyroxene (Fig. 3), and are characterized by having quasi-conic, more regular morphologies, being in general less affected by erosion than the Series I- domes. Moreover, none of the Series II-domes are covered by the Cangahua Fm.
In hand sample, the Series II dacites are almost undistinguishable from those of Series I dacites, although chemically it is clear that the former are slightly depleted in SiO_2 than the later (Fig. 3).

The deposits associated with the growth of the Series II-domes are distributed to the east, south-east and west of the PVC (Figs. 2 & 4). They consist exclusively of monotonous sequences of monolithic breccias, rich in black amphibole-bearing, grey and red dacites (30 – 60% vol.). The youngest dacite breccia observed at PVC has been dated at 10,800±800 yBP (OLADE, 1980) and 11,940±300 yBP (Hall & Mothes, 1994).

As it was the case for Series I, none of the studied sections of Series II deposits shows evidence of explosive activity (pumicious strata) during the growth of the domes. This means that all the ancient (Series I) and younger (Series II) pre-caldera domes of PVC were formed during effusive eruptions of degassed dacitic magmas.

All around PVC, the monolithic dacite breccias associated with the growth of the Series I and II domes are covered by a thick (0.8 – 3.0 m) paleo-soil layer. Interbedded within this paleo-soil, an amphibole-bearing pumice layer may be commonly found. This layer (labeled as "Episode 0" in Figs. 4 & 5) represents a pyroclastic flow deposit

(0.8 - 1.6m thick) and is the onlyevidence for explosive activity at PVC prior to the period of caldera formation . The age of this eruption is estimated at shortly before 6750 yBP; this is about 5 ka later than the pre-caldera domes formation (Series I and II).

To the south, in the Ambuasí river valley (Fig. 2), there is no evidence of deposits belonging to Series I or II.

Series III: syn-caldera deposits

This is a complex sequence of pumice-rich layers that mantles the surface all around PVC with pyroclastic flow, surge, debris flow and tephra fall-out deposits.

All these deposits are characterized by containing acid-andesitic pumice (61.9-63.2% SiO_2) with phenocrysts of plagioclase and green amphibole (Fig. 3), and have been interpreted as representing the caldera formation events.

The entire eruptive sequence associated with the caldera formation at PVC has been divided into four "Episodes" by means of major erosional surfaces observed within the pumice rich sequence. These surfaces represent relatively long periods (years to decades) of pauses in the volcanic activity given that thin (< 6 cm) bio-perturbed ash layers, slightly affected by pedogenesis, have developed on top of them (Fig. 5).

Episode 1

is characterized by the presence of a basa plinian fall-out layer, composed of whit pumice and basement lithics (Papale 8 Rosi, 1993). At least two additional sub plinian fall-out layers and a small-scal pumice pyroclastic flow can be found over lying the basal fall-out. At the base of thi sequence, a radiocarbon date on wood ha given an age of 2575±45 yBP. The curren total volume of these deposits has been cal culated at around 1.48 km³ (Papale & Rosi 1993).

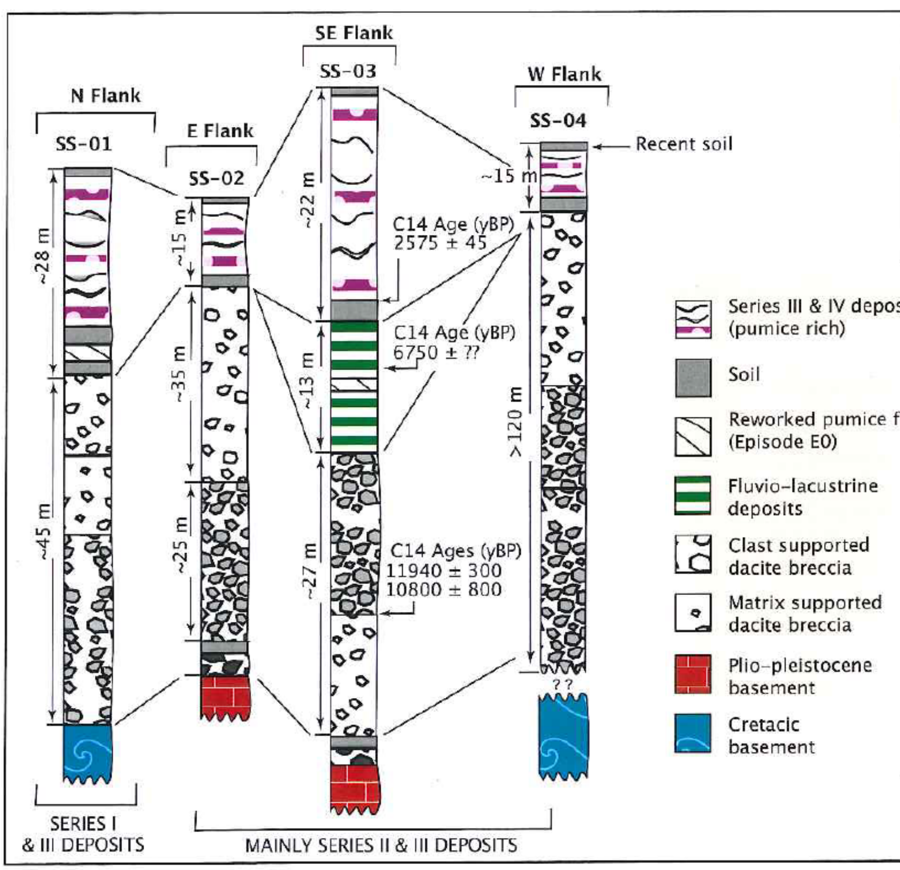


Figure 4. Selected stratigraphic sections arounc Pululahua showing the typical distribution o deposits that belong to the Series I, II and II around the volcano. Vertical scale changes fron column to column. See Figure 2 for stratigraphi section location.

Volcanic History and Structural Development

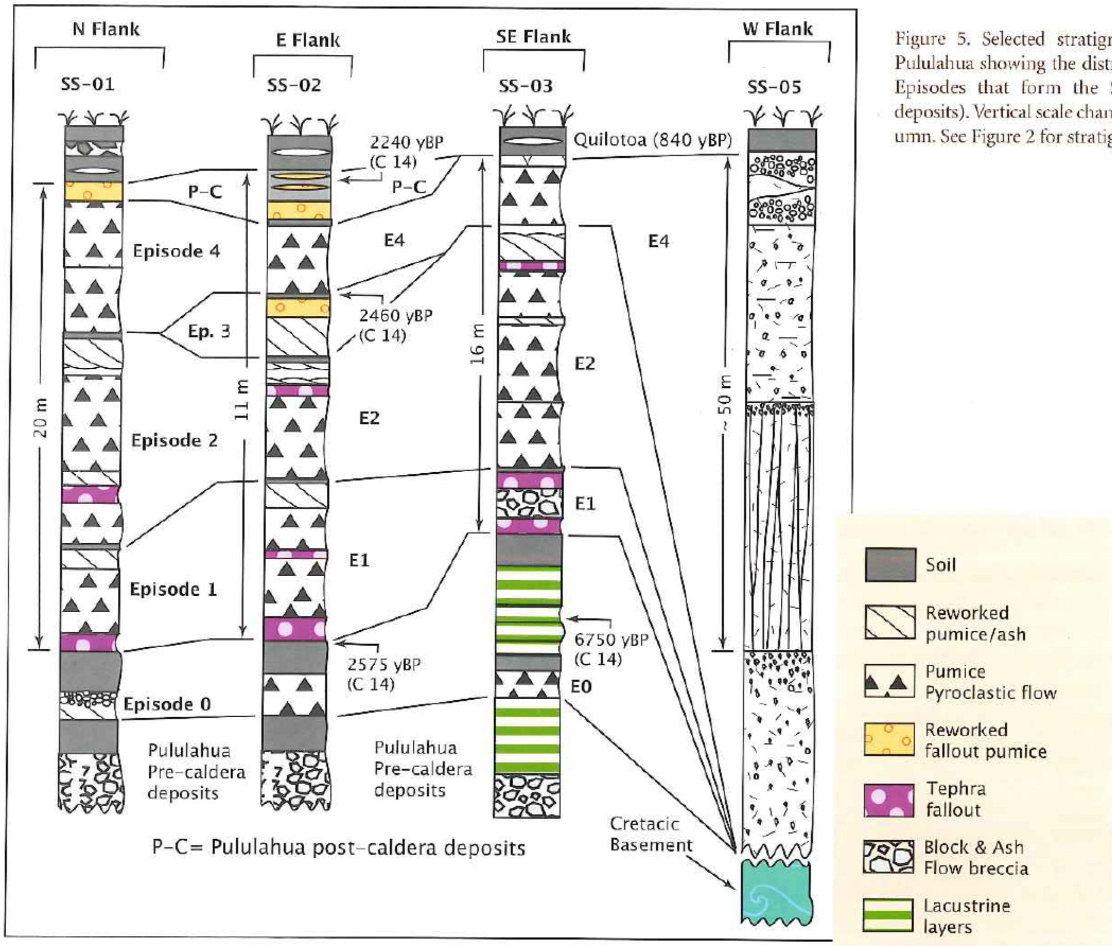


Figure 5. Selected stratigraphic sections around Pululahua showing the distribution of the different Episodes that form the Series III (syn-caldera deposits). Vertical scale changes from column to column. See Figure 2 for stratigraphic section location.

Episode 2
deposits are represented by pumice-rich light-grey pyroclastic flows and subplinian lithic-rich fall-outs. Pumice pyroclastic flows are often associated with co-ignimbritic or surge layers which contain accretionary lapilli. These features are the most important markers of Episode 2 deposits (Fig. 5). The current total volume of Episode 2 deposits is about 1 km^3.

Episode 3
sequence is small and characterized by presenting mainly reworked deposits, such as rounded pumice-rich debris flows and ash layers. However, some primary deposits such as small-scale pumice pyroclastic flows are found at the base as well.

Episode 4
deposits are represented by pumice-rich surges, pyroclastic flows and debris flows. These layers are characterized by their pink, creamy and reddish colors. West of PVC, along the río Blanco Valley, pyroclastic flows are massive slightly welded ignimbrites with a total maximum thickness of up to 80 meters (Figs. 2 & 5). On the northern, southern and eastern slopes, pink pyroclastic flows and surges are less massive and thinner, but are widespread over the plains. The current total volume of these deposits has been estimated at 1.76 km^3. At the base of Episode 4, a radiocarbon date has yielded 2460±70 yBP (Fig. 5). We believe that the PVC caldera formation process was finished with the occurrence of Episode 4.

Potencial Hazards

Series IV post-caldera domes

This Series is represented by the intra-caldera Rumiloma and Pondoña domes and their associated deposits (Fig. 2). In fact, up to four post-caldera domes are recognized inside the caldera, all of them constituted by plagioclase and amphibole-bearing acid andesites (61.9-62.1% SiO_2) with traces of ortho and clinopyroxene (Fig. 3). A total volume of 0.5-0.6 has been calculated for all of the post-caldera domes.

The extrusion of these domes partially refilled the caldera floor and was accompanied by moderate explosive activity, represented by a group of pumice lapilli fallout layers overlying the Series III deposits (Fig. 5). The pumice lapilli layers are usually reworked and are characterized by their light-yellow pumice fragments. At least four fall-out layers corresponding to Series IV have been found around the PVC. At the base of the upper fallout layer, a radiocarbon date yielded 2240±50 yBP.

All evidence of volcanic activity at PVC concludes with the extrusion of the post-caldera domes and the deposition of the light-yellow pumice fall-out layers. A recent brown soil layer (30-60 cm thick) overlies all the PVC deposits. Interbeded within the recent soil, a biotite-bearing fine white ash layer (< 20 cm thick) is commonly found, which corresponds to the 840 yBP eruption of Quilotoa caldera (Hall & Mothes, 1994) (Fig. 5).

Potencial Hazards

As showed above, PVC has had important volcanic activity during the Holocene. Short before 6750 yBP the first explosive eruption occurred and four additional highly explosive events took place between 2575 and 2460 yBP, which formed the PVC caldera (Figs. 4 & 5). Finally, at least four additional small-scale explosive eruptions occurred during the extrusion of post-caldera domes, between 2460 and 2240 yBP (Fig. 4). This means that a minimum of nine explosive eruptions have occurred at Pululahua during the last 7 ka.

Although since AD 1532 (arrival of Spanish Conquistadores to Ecuadorian territory) no volcanic activity has been observed at PVC, the previous descriptions permits us to forecast three main eruptive scenarios for future eruptions: 1) extrusion of a new intra-caldera lava dome; 2) destruction of current intra-caldera domes during a major explosive eruption similar to those of Series III; and, 3) extrusion of a new lava dome outside the caldera.

The extrusion of a new intra-caldera lava dome seems to be the most probable scenario given that the last four eruptions at PVC have had this character. If this was the case, all the zones inside the caldera and the western drainages could be menaced by pyroclastic block and ash flows and secondary debris flows, which would mainly affect the río Blanco. Moderate to important tephra fall-outs (< 20 cm) would affect the zone.

The occurrence of a major explosive eruption seems as well a probable scenario. As shown above, these eruptions have a mean recurrence period of 1300 years during the last 7000 years, though four of them took place in a short period of time between 2575 and 2460 yBP. Such an eruption would imply that all the zones close to PVC would be under potential risk by pyroclastic flows and surges, while distant zones to the west would be affected by important tephra or ash fall-outs (< 80 cm thick).

Finally, the extrusion of a new lava dome outside the caldera seems to be the least probable scenario given that the last event of this type took place ~11000 years ago, and since then the activity has been concentrated in the caldera zone. Areas close to the new dome's vent would be in danger by pyroclastic "block and ash" flows.

Independent from the eruption scenario, the potential endangered population and infrastructure are very important. The case of PVC deserves the installation and operation of a permanent instrumental monitoring system.

References

Águila, C. (1986). Geovulcanología del Complejo Pululahua - Casitahua y sus implicaciones geotérmicas; Provincia de Pichincha, Ecuador. Tesis Inédita, Universidad Central del Ecuador, 89 pp.

Andrade D. (2002). Estudio Geovolcanológico del Complejo Volcánico del Pululahua. Tesis de ingeniero de la Escuela Politécnica Nacional; Quito – Ecuador; 180 p.

Andrade D. (2003). Géochimie du Complexe Volcanique du Pululahua (Equateur): fusion partielle d'un manteau métasomatisé par des adakites. Mémoire de DEA - Université Blaise Pascal; Clermont-Ferrand – France ; 50 p.

Aspden J., Harrison S. & Rundle C. (1992). New geochronological control for the tectono-magmatic evolution of the metamorphic basement, Cordillera Real and El Oro Province of Ecuador. Journal of South American Earth Sciences, Vol. 6, No. 1/2, p. 77-96.

Crandell D.R. & Moullineaux D.R. (1973). Pine creek volcanic assemblage at Mount St. Helens, Washington. USGS Bulletin 1383-A, p. 1-23.

Ego, F. (1995). Accomodation de la convergence oblique dans une chaine de type cordilleraine: Les Andes d'Equateur. These de Doctorat. Université Paris XI Orsay; 281 pp.

Geotermica Italiana-INEMIN (1989). Mitigación del Riesgo Volcánico en el Area Metropolitana de Quito. Municipio del Distrito Metropolitano de Quito-Ecuador.

Hall M. & Beate B. (1991). El volcanismo Plio-Cuaternario en los Andes del Ecuador. In: El Paisaje Volcánico de la Sierra Ecuatoriana; Estudios de Geografía; Corporación Editora Nacional, Quito – Ecuador; pags. 5-13.

Hall, M. (1977). El volcanismo en el Ecuador. Publicación del I.P.G.H., Sección Nacional del Ecuador.

Hall M. & Hillebrandt C. (1988). Mapa de los peligros volcánicos potenciales asociados con el volcán Pululahua, Provincia de Pichincha (1:50000). Proyecto UNDRO-EPN, IG-EPN, Quito-Ecuador.

Hall M. & Mothes P. (1994). Tefroestratigrafía holocénica de los volcanes principales del Valle Interandino, Ecuador. En "El contexto geológico del espacio físico ecuatoriano", R. Marocco coord.; Corporación Editora Nacional, p. 47-67.

Instituto Ecuatoriano de Minería – Geotermica Italiana – Escuela Politécnica del Ejército. (1989). Mapa Geológico del Volcán Guagua Pichincha (escala 1:50000); (F. Barberi, Supervisor); Convenio de Cooperación Técnica Ecuador – Italia.

Isaacson J. & Zeidler J. (1999). Accidental history: Volcanic activity and the end of the Formative in Northwestern Ecuador. En "Actividad volcánica y pueblos Precolombinos en el Ecuador", Mothes P. Coord.; Edit. Abya-Yala, Quito-Ecuador; 205 pp; p. 41 - 72.

Papale P. & Rosi M. (1993). A case of no-wind plinian fallout at Pululagua caldera (Ecuador): implications for models of clast dispersal. Bulletin of Volcanology 55, p. 523-535.

Soulas J., Egüez A., Yepes H. & Pérez H. (1991). Tectónica activa y riesgo sísmico en los Andes ecuatorianos y el extremo sur de Colombia. Boletín Geológico Ecuatoriano. Vol 1, 1, p. 3-9.

Soulas J-P., Ramón P., Egüez A., Alvarado A., Yepes H. & Gajardo E. (2001). Evaluación de las Fallas Activas que cruzan el trazado del OCP. Estudios realizados por el Instituto Geofísico de la Escuela Politécnica Nacional para TECHINT LTD, 71 pp. (Not published)

Villalba F. (1988). Cotocollao: una aldea formativa del Valle de Quito. Museo Banco Central del Ecuador, Quito.

Wolf, T. (1975). Geografía y Geología del Ecuador. Editorial "Casa de la Cultura Ecuatoriana", Quito – Ecuador; 798 pp (1st. Ed., 1892).

Cover Picture by: P. Ramón
Field-guide pictures by: D. Andrade

STOP 1: Mitad del Mundo

General view of Pululahua and Casitahua volcanoes.

STOP 2: Pululahua caldera rim

Viewpoint of the inhabited Pululahua caldera and of pre- and post-caldera domes. The overall structure of the complex will be observed and discussed.

STOP 3: Sincholahua dome

Several quarries have been developed at Pululahua during the last decades and have exposed plenty of stratigraphic sections as well as the internal structure of several domes. At Sincholahua, which belongs to the "Series II - younger pre-caldera domes", it is possible to appreciate dacitic lava-flow structures, from macro to micro scale. Petrographically, Sincholahua and the all rest of the pre-caldera domes are very similar.

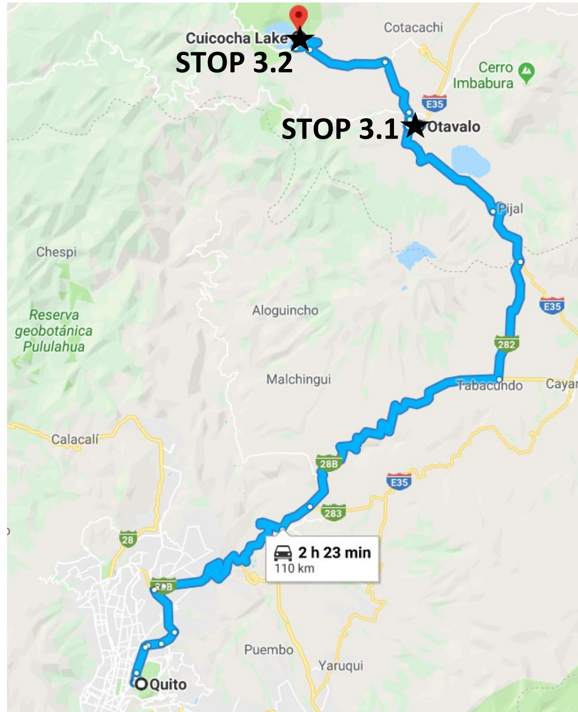
STOP 4: Catequilla anticline

Viewpoint of the Pululahua eastern slopes. The general history and the overall structure of the Pululahua complex will be observed and discussed here. Excellent view of the San Antonio basin, which has been filled with the deposits from all periods of Pululahua activity.

STOP 5: Gravel and sand quarry

In this quarry, as in several others around the complex, a very good synthesis of the entire Pululahua volcanic history can be reconstructed in just one outcrop. Detailed observations of the pre- and syn-caldera deposits will be made.

Day 3: Monday, March 11th, 2019 – Otavalo and Cuicocha Crater



Morning – The markets at Otavalo, it will be a good opportunity to pick up some junk.

Lunch – I think we are on our own, the markets should have a lot of options.

Afternoon – Cuicocha Crater Lake likely hike around the crater rim. Jon's notes also say surrounding areas, so there might be other stops.

Evening – We are on our own for dinner.

STOP 3.1: *Otavalo*

Figure 87: *Otavalo with Imbabura in the background*

From Wikipedia:

Otavalo, capital of Otavalo Canton, has a population largely made up of the Otavalo indigenous group. It is located in Imbabura Province of Ecuador. According to the 2010 census, the town has 39,354 inhabitants and has an elevation of 2,532 metres (8,307 ft). It is surrounded by the peaks of Imbabura (4,630 metres (15,190 ft)), Cotacachi (4,995 metres (16,388 ft)), and Mojanda volcanoes.

The Market

The indigenous Otavalo people are famous for weaving textiles, usually made of wool, which are sold at the famous Saturday market. Although the largest market is on Saturday, there is a very wide range of wares available throughout the week in the Plaza de los Ponchos, and the many local shops. The shops sell textiles such as handmade blankets, tablecloths, and much more. The Otavalo market consists of mushroom-shaped concrete umbrellas with benches. The market was designed and built in 1970 by Dutch architect Tonny Zwollo.

During the market's peak, almost one third of the town becomes full of stalls selling textiles, tagua nut jewelry, musical instruments, dream catchers, leather goods, fake shrunken heads, indigenous costumes, hand-painted platters and trays, purses, clothing, spices, raw foods and spools of wool. As the city has become more of a tourist attraction, many of the goods sold in the markets are mass-produced in nearby factories and sold in the market by middle-men.

Otavalo was an area made up principally of farming communities due to the rich volcanic soils in this area, but with the growth of tourism, the town has begun to focus more on the making of handicrafts which have made the Saturday market a popular stop with visitors to Ecuador. Tourism has become the town's main industry and as a result there are many more hotels, hostels, and tour operators than other similarly sized Ecuadorian towns, such as nearby Cayambe. Further, Otavaleño (people from Otavalo) have had notable success selling their goods abroad.

STOP 3.2: *Cuicocha Crater*
From Wikipedia

Cuicocha is a 3 km (2 mi) wide caldera and crater lake at the foot of Cotacachi Volcano in the Cordillera Occidental of the Ecuadorian Andes. Its name comes from the Kichwa indigenous language and means "Lago del Cuy" or Guinea Pig Laguna in English. It was given this name due to the guinea pig shape of the largest Island in the middle of the laguna. These animals play a significant part in the everyday life of Ecuadorians, as they reproduce rapidly and need a minimum of food and care to survive. They make for a high protein meal especially for populations living in high altitude.

The caldera was created by a massive eruption about 3100 years ago that generated about 5 cubic kilometers (6.54 billion cubic yards) of pyroclastic flow and covered the surrounding area in volcanic ash up to 20 cm (8 inches) deep. The volcano has been dormant since that time. In combination with other eruptions from nearby Imbabura, Mojanda, Cotacachi, and Cayambe, Cuicocha is responsible for the fertile soil of the Otavalo Valley.

Figure 88: *Lake Cuicocha with domes Yerovi (left) and Wolf (right)*

The Cuicocha Lake, a crater lake within the Cuicocha caldera contains four dacitic lava domes which form two steep forested islands: Yerovi, the smaller, and Teodoro Wolf, the larger. People are prohibited on both. The rim of the caldera is extremely steep — so steep, in fact, that the accumulation of sediment is insufficient for most hydrophyte vegetation. An older lava dome from the Pleistocene forms part of the eastern rim. The lake, which is 200 m (656 ft) deep at its deepest point, is highly alkaline and contains little life. It has no known outlet.

The intra-caldera islands, on the other hand, support some wildlife, most notably the silvery grebe, which lives around the reeds and feeds on small fish, frogs, crayfish, small water snakes, seeds of water plants, and insects. The bird is found in upper temperate and lower páramo zones throughout the Andes, but little is known about the species. In 1974 a census was taken of the population of grebes at Cuicocha and 44 birds were found.

Cuicocha forms the southern end of the Cotacachi-Cayapas Ecological Reserve. During the second day of Inti Raymi (or Sun Festival) every summer solstice, indigenous shaman use Cuicocha as a bath for ritual cleansing and purification.

Eruptive History *From Global Volcanism Program*

Data available for 4 Holocene eruptive periods.

Start Date	Stop Date	VEI
0650 (?)	Unknown	
0950 BCE (?)	Unknown	
1150 BCE ± 150 years	Unknown	5
2550 BCE (?)	Unknown	

Figure 89: *The scenic lake-filled Cuicocha caldera is located at the southern foot of the sharp-peaked Pleistocene Cotacachi stratovolcano (top center) about 100 km north of Quito. Farmer's fields encroach on the rim of the 3-km-wide caldera, which was created during a major explosive eruption about 3100 years ago. Dacitic lava domes form two forested islands in the caldera lake. Pyroclastic-flow deposits from the caldera-forming eruptions cover wide areas in now populated areas below the low-rimmed caldera. (Global Volcanism Program, 2019)*

Day 4: Tuesday, March 12th, 2019 – Hiking and Biking at Volcan Pichincha

Morning – This will be an early morning (at least 6AM). We will be taking 4x4 jeeps most of the way up Volcan Pichincha and the mountain biking down.

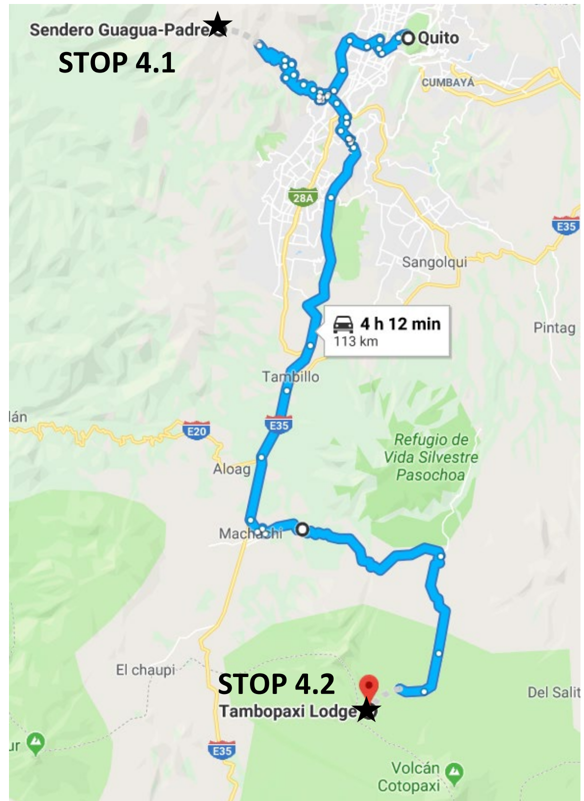
Lunch – Box lunch at the volcano.

Afternoon – After Pichincha we will head to Cotopaxi, where we will spend the night in the park.

Evening – Dinner at the Lodge.

Here are the accommodations:

Hosteria Tambopaxi Lodge
http://www.tambopaxi.com/en/
Telefonos: +(593 2) 6000365/ 6000366 / 0999448223
Email: tambopaxi@tambopaxi.com / reservas@tambopaxi.com



STOP 4.1: *Volcan Pichincha*

Geological Summary (*Global Volcanism Program, 2019*)

Guagua Pichincha and the older Pleistocene Rucu Pichincha stratovolcanoes form a broad volcanic massif that rises immediately to the W of Ecuador's capital city, Quito. A lava dome is located at the head of a 6-km-wide breached caldera that formed during a late-Pleistocene slope failure ~50,000 years ago. Subsequent late-Pleistocene and Holocene eruptions from the central vent in the breached caldera consisted of explosive activity with pyroclastic flows accompanied by periodic growth and destruction of the central lava dome. One of Ecuador's most active volcanoes, it is the site of many minor eruptions since the beginning of the Spanish era. The largest historical eruption took place in 1660, when ash fell over a 1000 km radius, accumulating to 30 cm depth in Quito. Pyroclastic flows and surges also occurred, primarily to then W, and affected agricultural activity, causing great economic losses. This volcano is located within the Quito, a UNESCO World Heritage property.

	VOLCANIC UNITS	ERUPTIVE STYLES and DEPOSITS	AGE (ka)	MAGMA COMPOSITION	ESTIMATED VOLUME (km^3)
GUAGUA PICHINCHA	**CRISTAL**	Dacitic extrusions and related pyroclastic flow deposits (four main cycles with plinian episodes)	3.7 ka to Present	61-66 wt.% SiO_2 1.5-1.9 wt.% K_2O 34-46 ppm Rb ***New magma batch***	~1
	Toaza sector collapse	*Debris avalanche deposit (DAD3)*	~4 ka	61-66 wt.% SiO_2 1.6-2.2 wt.% K_2O 37-53 ppm Rb ***New magma batch***	4 to 5
	TOAZA	Lava flows and domes *Block-and-ash flow deposits*	9.8 to 4 ka		
		Intense pyroclastic activity, *ashflow and blast events*	11 to 9.8 ka		
	GGP sector collapse	*Debris avalanche deposit DAD 2*	~11 ka	59-65 wt.% SiO_2 1.1-1.9 wt.% K_2O 38-42 ppm Rb ***New magma batch***	29 (cone) Total : 31-32
	MAIN GUAGUA PICHINCHA	*Blast events at ~22-23 ka* Summit dome complex and related pyroclastic deposits (Lloa fan)	47 to 22 ka		
		Singuna Pyroclastic event	~47 ka		
		Edification of a basal edifice: mainly effusive	~60 to 47 ka		
RUCU PICHINCHA	**TERMINAL RUCU**	Terminal cone Dominant explosive activity	- 150 ka	55-63 wt.% SiO_2 0.8-1.3 wt.% K_2O 11-30 ppm Rb	8 - 10
	Rucu sector collapse	*Avalanche deposit in Quito basin*	~250 ka		
	UPPER RUCU	Upper cone. Mainly effusive.	430-450 ka		35 to 50
	LOWER RUCU	Basal stratocone Mainly effusive activity	~ 600 ka ~ 850 ka		160
	EL CINTO and LA ESPERANZA	Lava flow sequences and domes	1100-900 ka	58-63 wt.% SiO_2 0.7-1.2 wt.% K_2O 12-28 ppm Rb	

Figure 90: *Generalized chronostratigraphy showing the main stages of the PVC (Robin et al, 2010)*

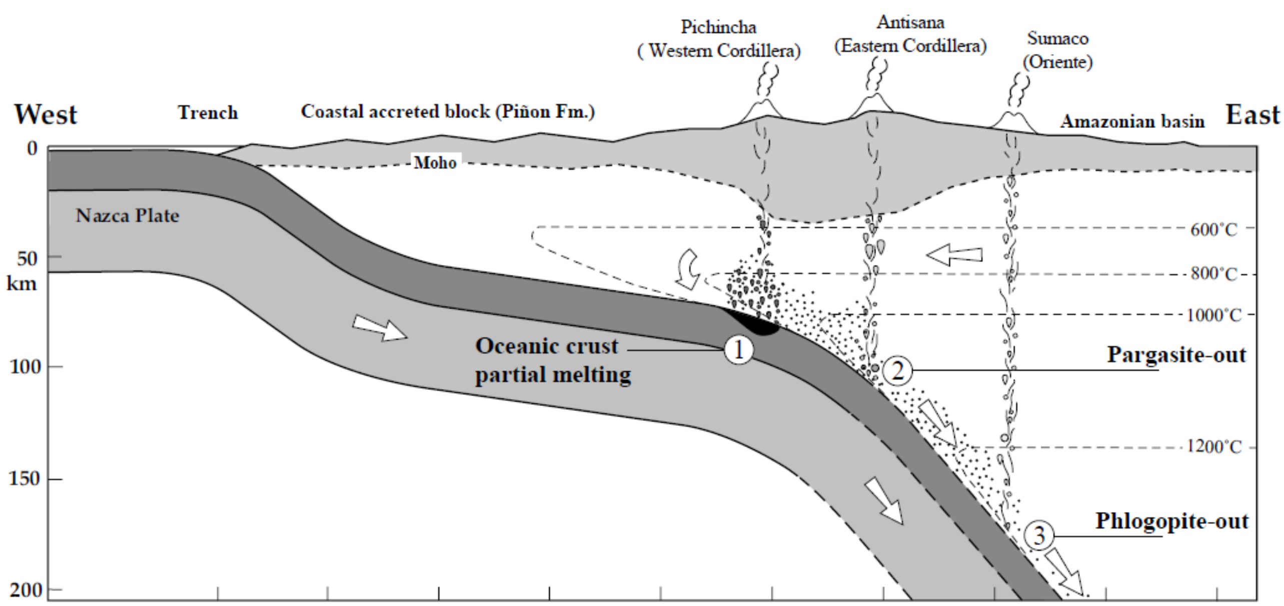


Figure 91: *Schematic petrogenetic model of the NVZ in Ecuador (Bourdon et al., 2003)*

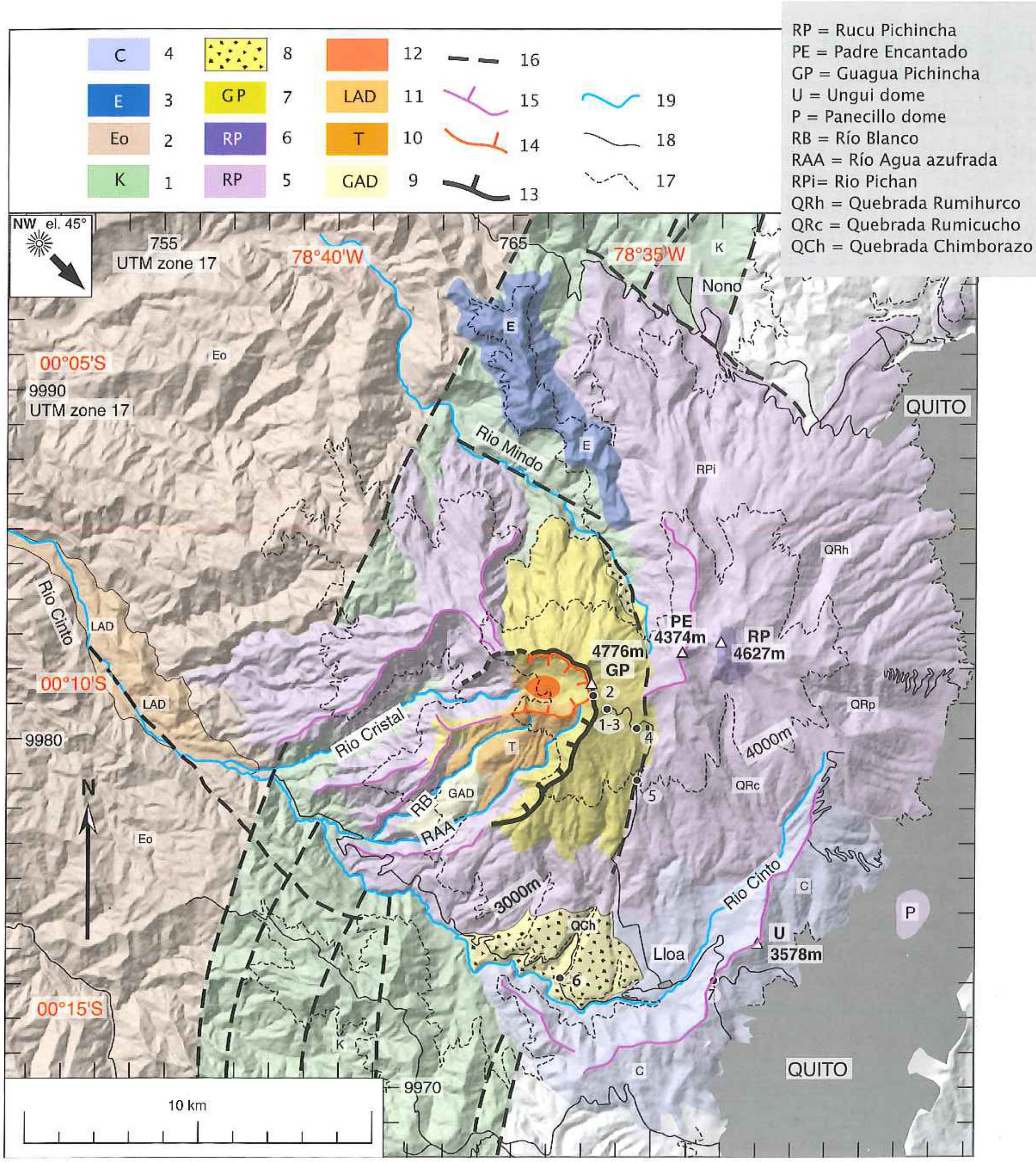


Figure 2. Geological sketch map of the Pichincha Volcanic Complex. Digital information, provided by M. Souris (IRD), was generated from 1:50000 topographic maps of Instituto Geográfico Militar, Quito. Western Cordillera basement (Hughes et al., 1998) corresponding to (1) Pallatanga and (2) Silante unit. (3) Older volcanics corresponding to La Esperanza lava pile. El Cinto edifice: (4) Undifferentiated lava flows and domes. Rucu Pichincha edifice: (5) Undifferentiated lava flows and breccias; (6) Summital breccias. Guagua Pichincha edifice. (7) Basal edifice: lava flows and domes and related pyroclastic depostis; (8) Lloa and Rio Mindo "block-and-ash" fans; (9) Older Debris Avalanche deposit; (10) Toaza edifice: domes and related pyroclastic deposits; (11) Toaza debris avalanche deposit; (12) Intracalderic dome complex (Cristal domes). (13) Avalanche scar of Guagua Pichincha edifice; (14) Avalanche scar of Toaza edifice; (15) Escarpments; (16) Faults; (17) 3,000 and 4,000 m asl curves; (18) roads; (19) main rivers.

Figure 92: *Pichincha Volcanic Complex (Samaniego et al., 2006)*

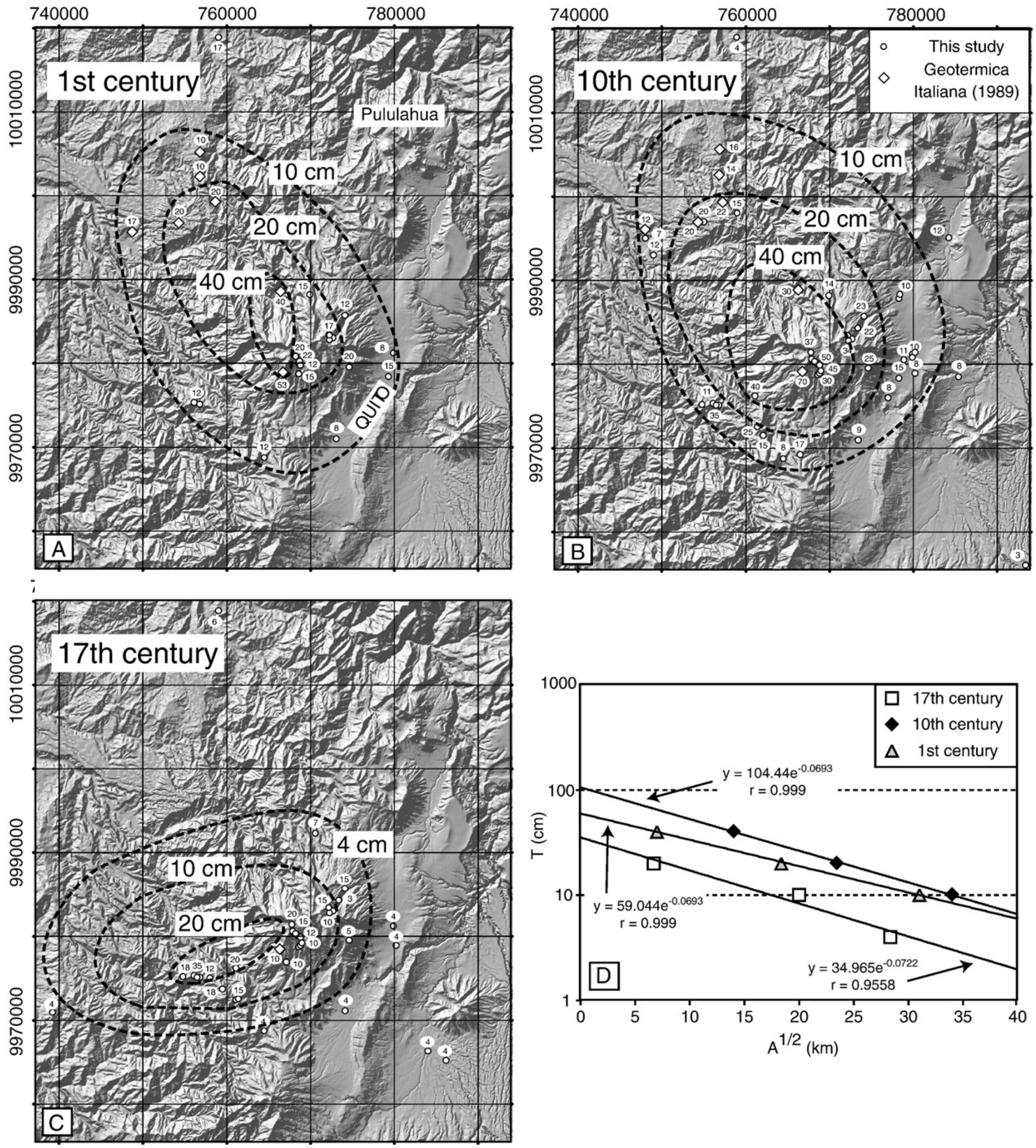


Figure 93: *Isopach maps of the three Plinian fallout deposits related to the 1st (A), 10th (B) and 17th (C) centuries eruptions of Pichincha. D: LogT versus* $A^{1/2}$ *diagram (Fierstein and Nathenson, 1992) for the three Plinian fallout deposits. (Robin et al., 2008)*

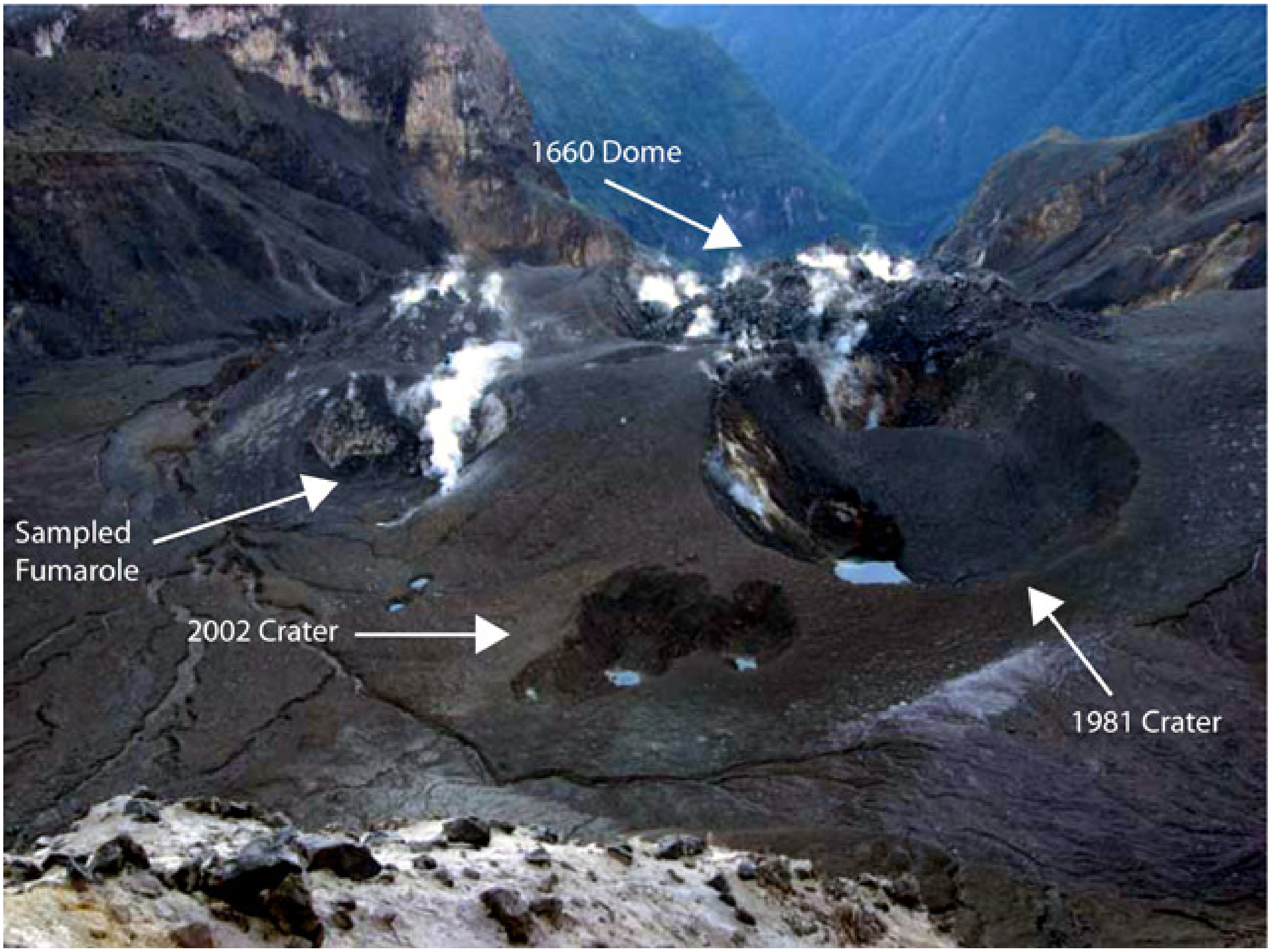


Figure 94: *Photograph of Guagua Pichincha's crater taken in May 2008, showing the still-active year 1660 dome and adjacent crater floor. The area is heavily pockmarked with explosion craters (labeled). Note sampled fumarole (bottom left). (GVP, 2019)*

STOP 4.2: *Cotopaxi National Park (from Wikipedia.com)*

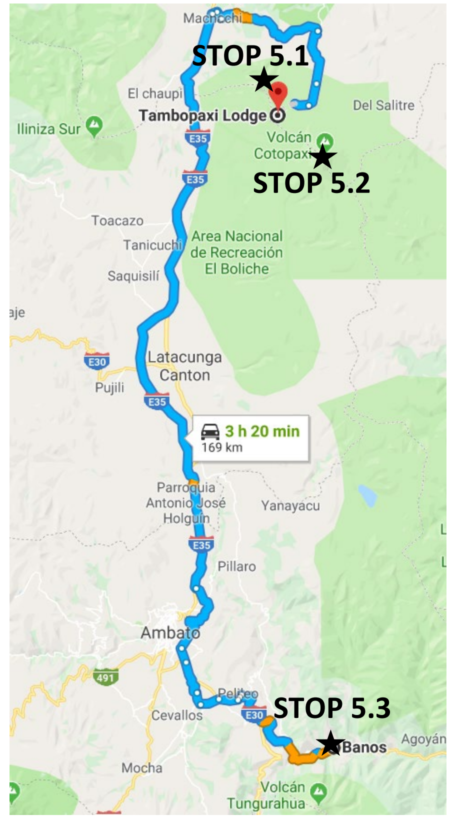
Cotopaxi is an active stratovolcano in the Andes Mountains, located in the Latacunga canton of Cotopaxi Province, about 50 km (31 mi) south of Quito, and 33 km (21 mi) northeast of the city of Latacunga, Ecuador, in South America. It is the second highest summit in Ecuador, reaching a height of 5,897 m (19,347 ft). It is one of the world's highest volcanoes.

Since 1738, Cotopaxi has erupted more than 50 times, resulting in the creation of numerous valleys formed by lahars (mudflows) around the volcano. The last eruption lasted from August 2015 to January 2016. Cotopaxi was officially closed by the authorities to climbing until it reopened on October 7, 2017.

Figure 95: Cotopaxi (Wikipedia, 2019)

Figure 96: *Map of Cotopaxi National Park*

Day 5: Wednesday, March 13th, 2019 – Rumiñahui, Cotopaxi, and Baños



Morning – We will spend most of the day in the park. In the morning we will hike around Rumiñahui.

Lunch – Box lunch at the volcano.

Afternoon – Hike around Cotopaxi, go up to the glaciers. When we finish up here, we will head to Baños.

Evening – We are on our own for dinner in Baños.

Here are the accommodations in Baños:

Napolitano Apart Hotel
Av. Oriente 470
Baños, Ecuador
+593 992936175
https://www.tripadvisor.com/Hotel_Review-g312857-d2348401-Reviews-Napolitano_Apart_Hotel-Banos_Tungurahua_Province.html

STOP 5.1: *Volcan Rumiñahui (from Wikipedia)*

Rumiñahui (/ruːmiˈnjɑːwiː/ roo-mee-NYAH-wee, Kichwa rumi stone, rock, ñawi eye, face, "stone eye", "stone face", "rock eye" or "rock face", Hispanicized spelling Rumiñahui) is a dormant, heavily eroded stratovolcano 4,721 meters (15,489 ft) above sea level. Situated in the Andes mountains 40 km south of Quito, Ecuador, it is overshadowed by its famous neighbor Cotopaxi.

STOP 5.2: *Volcan Cotopaxi (from Wikipedia)*

Cotopaxi is an active stratovolcano in the Andes Mountains, located in the Latacunga canton of Cotopaxi Province, about 50 km (31 mi) south of Quito, and 33 km (21 mi) northeast of the city of Latacunga, Ecuador, in South America. It is the second highest summit in Ecuador, reaching a height of 5,897 m (19,347 ft). It is one of the world's highest volcanoes. Since 1738, Cotopaxi has erupted more than 50 times, resulting in the creation of numerous valleys formed by lahars (mudflows) around the volcano. The last eruption lasted from August 2015 to January 2016. Cotopaxi was officially closed by the authorities to climbing until it reopened on October 7, 2017.

Description

On a clear day, Cotopaxi is clearly visible on the skyline from Quito and is part of the chain of volcanoes around the Pacific plate known as the Pacific Ring of Fire. It has an almost symmetrical cone that rises from a highland plain of about 3,800 m (12,470 ft), with a width at its base of about 23 km (14 mi). It has one of the few equatorial glaciers in the world, which starts at the height of 5,000 m (16,400 ft). At its summit, Cotopaxi has an 800 × 550 m wide crater which is 250 m (820 ft) deep. The crater consists of two concentric crater rims, the outer one being partly free of snow and irregular in shape. The crater interior is covered with ice cornices and rather flat. The highest point is on the outer rim of the crater on the north side.

History

Name

Many sources claim that Cotopaxi means shining pile or mountain in an indigenous language, but this is unproven. According to locals who speak Qichua, “coto” means moon and “paxi” means neck. This refers to the crater of Cotopaxi that looks like a crescent moon. The mountain was honored as a "Sacred Mountain" by local Andean people, even before the Inca invasion in the 15th century. It was worshiped as “rain sender”, that served as the guarantor of the land's fertility, and at the same time its summit was revered as a place where gods lived.

Historic eruptions

With 87 known eruptions, Cotopaxi is one of Ecuador's most active volcanoes. The first recorded eruption of Cotopaxi was in 1534. Cotopaxi's most violent eruptions in historical times occurred in the years 1742, 1744, 1768, and 1877. The 1744 and 1768 events destroyed the colonial town of Latacunga. In the 26 June 1877 eruption, pyroclastic flows descended all sides of the mountain melting the entire ice cap, with lahars traveling more than 100 km into the Pacific Ocean and western Amazon basin draining the valley. The city of Latacunga was again leveled completely due to the mudslide deposits.

The eruption on 19 June 1742 was witnessed by the scientists Pierre Bouguer and Charles-Marie de La Condamine, members of the French Geodesic Mission, as they descended from nearby Guagua Pichincha. There was a major eruption from 1903 to 1904, and minor activity persisted until at least 1940 and possibly 1942. (Note that direct observations of minor eruptions can be difficult because of bad weather, hence the uncertainty about the 1942 "eruption.") The same source also reported increased thermal/seismic, non-eruptive activity in 1975 and 2002. In the increased activity of 2002, fumarolic activity and sulfuric emissions increased and ice around the inside and on the southeastern side of the cone started to melt. However, no actual eruption was observed.

In 2015, two large phreatic (steam) eruptions in the morning of the 14th of August marked a new phase of volcanic activity. The volcano "remains in a very abnormal situation. In August, 2,100 earthquakes were recorded and emission rates of sulfur dioxide reach approximately 20,000 tonnes per day". The government estimates some 300,000 people are at risk from the volcano in the provinces of Cotopaxi, Tungurahua, Napo and Pichincha.

Climbing

The first European who tried to climb the mountain was Alexander von Humboldt in 1802; however, he only reached a height of about 4,500 m (14,760 ft). In 1858 Moritz Wagner investigated the mountain, but he could not reach the summit either. On November 28, 1872, German geologist Wilhelm Reiss and his Colombian partner, Angel Escobar, finally reached the summit of Cotopaxi. In 1873 it was summitted by German Geologist Moritz Alphons Stübel and four Ecuadorians, Rafael Jantui, Melchor Páez, Vicente Ramón and Eusebio Rodriguez. In 1880 British mountaineer Edward Whymper and the Italian guides Jean-Antoine Carrel and Louis Carrel made the third recorded ascent of Cotopaxi and spent a night on the summit. Painters Rudolf Reschreiter [de] and Hans Meyer reached the summit in 1903 and many of Reschreiter's paintings feature a view of Cotopaxi. In the late 20th century, summiting Cotopaxi became a major tourist draw. The José F. Ribas Refuge (Refugio José Félix Ribas) was built in 1971 at an elevation of 4,800 m (15,750 ft) and enlarged in 2005.

A tragedy occurred here on Easter Sunday 1996 when an avalanche partially buried the Refuge and dozens of tourists. The glacier above the Refuge was probably weakened by an earthquake that had shaken the entire Province of Cotopaxi for several days prior to the avalanche. In the warm midday sun a huge portion of the ice wall broke loose. Being Easter there were many day visitors on the mountain who were buried in the ice and snow. Those trapped in the Refuge broke windows on the downhill side to climb to safety, but 13 people died on the slope above. The Refuge itself is located in a valley and consequently vulnerable to future avalanches.

Climbing Cotopaxi to the summit is quite popular with up to 100 climbers attempting it on weekends. Today, mountain guide companies offer regular guided climbs of the mountain. Climbers grade the conventional route alpine PD (Peu Difficile) or WS (Wenig Schwierig) — or PD/WS+ (indicating "Mildly Difficult PLUS"). Use of crampons and ice axes are mandatory as snow and ice slopes of up to 50 degrees are encountered and climbers should be on belay and use aluminum ladders to cross one or two of the crevasses. A 4WD track goes up from the national park entrance to a carpark at 4600 m altitude on north side, just below the José F. Ribas Refuge. This stone mountain hut — owned and operated by Grupo Ascensionismo del Colegio San Gabriel — is situated 200 m higher at 4800 m (a 40-80 minute uphill hike). Here climbers can spend the night and begin their summit bid in the early morning without any intermediate camps. (Typically no more than about half of those attempting to summit Cotopaxi make it to the top after a daunting — though non-technical — six-hour scramble.) Summiting normally starts around 12:30 am to reach the summit at latest 7:30 am and then return to the hut before the snow melts and glacier crevasses move/evolve. As of July 28, 2014, the Ribas Refuge is under construction. Tour operators shuttle their clients up to the top of the 4WD track once in the afternoon for a glacier skills class, and then again to start the climb around midnight, spending the intervening hours eating dinner and resting at a hostel lower down by the lakes. Adventure tourism operators in Quito also offer mountain biking tours from the Refuge downhill along the dirt track.

Recent activity

In April 2015, the volcano began to show signs of unrest, and came back to life. There was a large increase in earthquakes (including harmonic tremors) and SO_2 emissions. IGEPN reported slight deformation of the edifice, suggesting an intrusion of magma under the volcano. As of 25 July, the unrest continued, and the most recent significant eruption was a phreatic (ash and steam) eruption that occurred on August 14 and 15, 2015. Ash was deposited heavily in areas close to the volcano (including damaging farmlands on the flanks of neighboring volcanoes such as El Corazon) and thinly as far as Quito, affecting southern and central areas of the city.

Future Cotopaxi eruptions pose a high risk to the local population, their settlements and fields. The main danger of a significant eruption of Cotopaxi would be the flash-melting of its summit glacier, resulting in devastating lahars which would travel down the flanks of the volcano, guided by river valleys whose origins lie at the volcano. Danger from normal, explosive eruptive activity is limited to within Cotopaxi National Park however, the great distances that lahars, of the significant size that Cotopaxi's glacier could produce, greatly increases the hazard areas to include all river valleys leading from the volcano. If there were to be a very large explosion, it would destroy (to the north) many of the settlements within the valley in the suburban area of Quito (pop. more than 2,000,000). Another city which would be in great danger is the regional capital Latacunga which is located in the south valley and has been destroyed at least twice in recent history (1768, 1877) by lahars caused by volcanic activity.

• Cotopaxi's eruptive begins around 0.5 Ma ago with rhyolitic magmatism; only during the past 4100 years has andesitic magma become important.

• The Barrancas Rhyolite Series represents the earliest recognized Cotopaxi activity, comprised of obsidian dikes and domes, extensive ash flows and tephra falls, dated at between 420 and 560 ka BP.

• Following the Barrancas activity, a long period of erosion resulted in the formation of a clastic fan with interbedded andesitic lavas from Morurcu and other vents. The thick lava and alluvial sequence observed along the Rio Pita and down to Selva Algre came from Cotopaxi, or perhaps from the pre-caldera Chalupas edifice.

• During a long repose of Cotopaxi, estimated at ~400 ka, wind-reworked deposits of fine ash and glacial material of regional origin (Cangahua Fm.) and the large Chalupas ash flow (200 ka) were deposited in the area.

• Starting at 13,200 yBP and continuing to 4100 yBP, Cotopaxi had six important rhyolitic episodes, a large flank collapse, and an immense lahar, represented by the F Series and the Colorado Canyon Episode, respectively. Minor andesitic activity is associated with these episodes.

• The last 4100 years have been characterized by andesitic eruptions, with only a minor rhyolitic contribution at 2100 yBP.

• Historically, eruption cycles roughly average one per century, usually resulting in a VEI =3-4 eruption with pyroclastic flows that extend 6-12 km from the crater, regional tephra falls, short lava flows and long-distance, highly destructive lahars.

Age	Principal Eruptions	Sub-plinian to Plinian Tephra Falls	Pyroclastic Flows	Lahars	Lava Flows	VEI
1880 AD	1	1				2-3
1877	2	1	Yes	many	Yes	4
1853-1854	2	1	Yes	many	1	3-4
1768	1	1	Yes	many	1 ?	4
1766	1	1	Yes	many		3
1744	1	1	Yes	many		4
1743	1	1	Yes	many		3-4
1742	3	2	Yes	2 grps		4
1532-34 AD	2	2	Yes	2 grps	1	3-4
~900 yBP	4	3	Yes	many		3-4
1000 yBP	2	2	Yes	2 grps		> 4
1180 yBP	1	1	Yes	many		3-4
1210 yBP	1	1	Yes	2 grps	1	4
1770 yBP	1	1	?	many	several	4
1880 yBP	1	1	Yes	2 grps	1	> 4
1880 - 2000	1	1	Yes	many		4
~2000 yBP	1	1	Yes	?		4
TOTAL	26	22	>14 times	>20 times	>7 times	

Table 1: Synthesis of eruptive activity of Cotopaxi volcano

Figure 97: *Recent Activity at Cotopaxi (Mothes, 2006)*

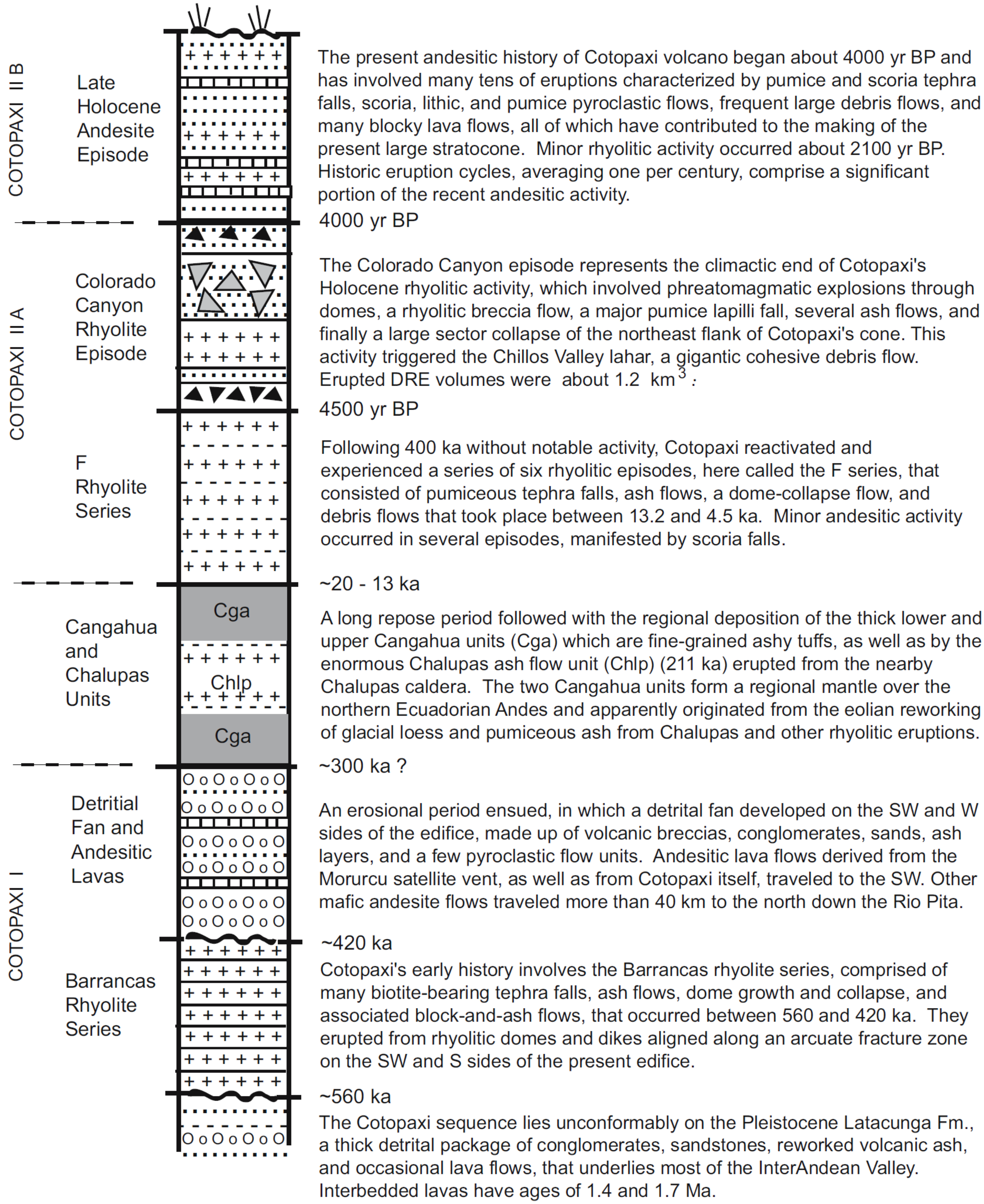


Figure 98: *Brief synthesis of the stratigraphic history of Cotopaxi volcano, separated into Cotopaxi I, II A, and II B eruptive periods (Hall & Mothes, 2008 – Figure 3)*

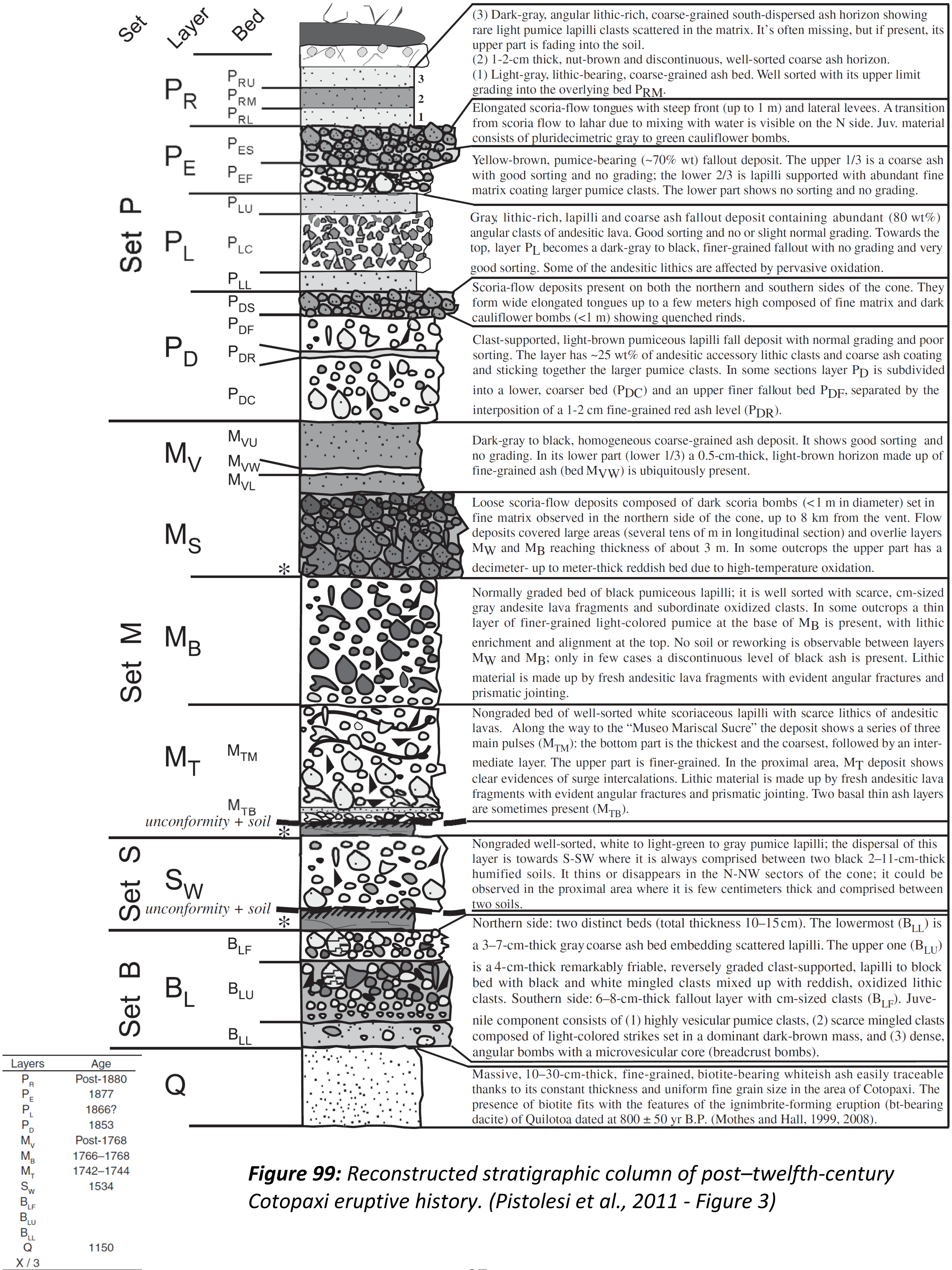


***Figure 99:** Reconstructed stratigraphic column of post–twelfth-century Cotopaxi eruptive history. (Pistolesi et al., 2011 - Figure 3)*

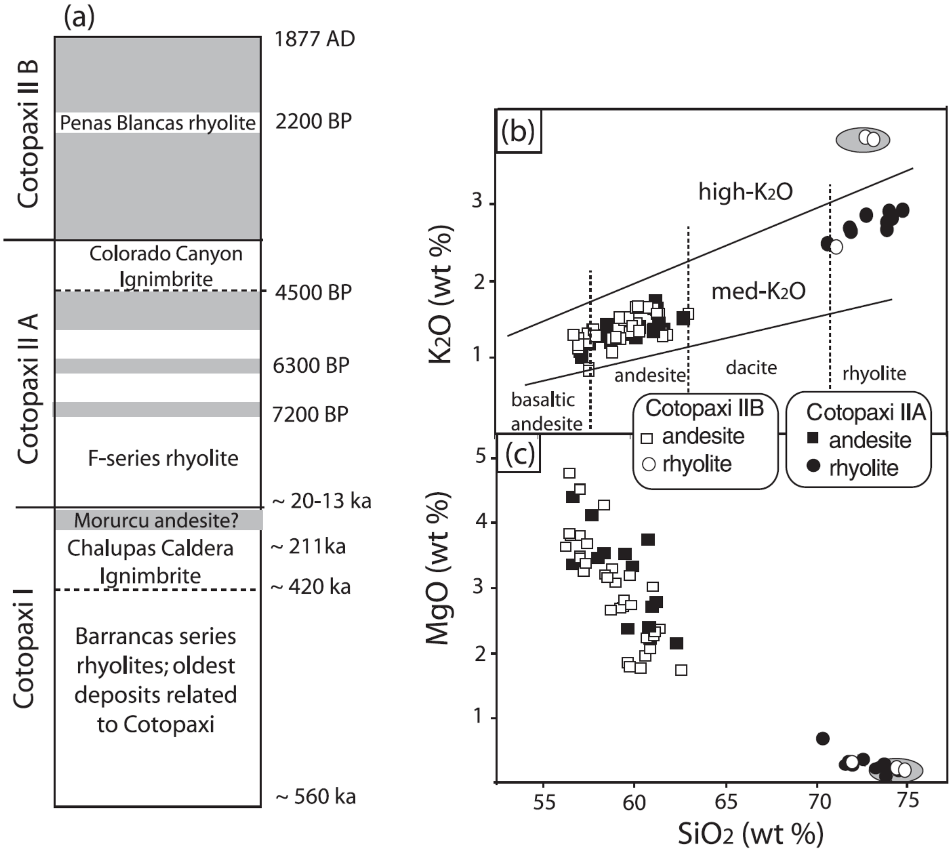


Figure 100: *(a) Generalized stratigraphic column of the Cotopaxi deposits (Hall & Mothes, 2008). Gray and white regions represent generalized andesite and rhyolite sequences. (b) wt % K_2O vs SiO_2, showing the rock name classification of LeMaitre et al. (1989) and (c) wt % MgO vs SiO_2 showing the compositional range of the Cotopaxi IIA and IIB sequences. The dashed lines separate the fields for basaltic andesite, andesite, dacite and rhyolite. The shaded region represents the range of Chalupas Caldera rhyolites. (Garrison et al., 2011 – Figure 2)*

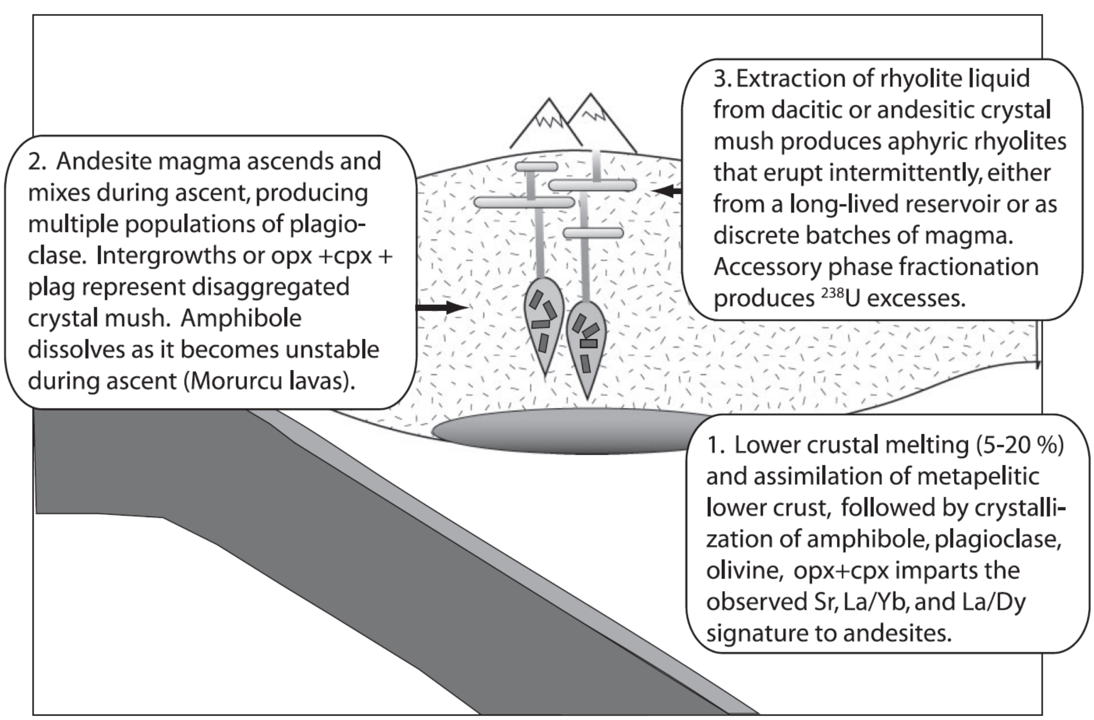


Figure 101: *Schematic petrogenetic model used to explain the geochemical variation among the Cotopaxi andesites and rhyolites (Garrison et al., 2011 – Figure 14)*

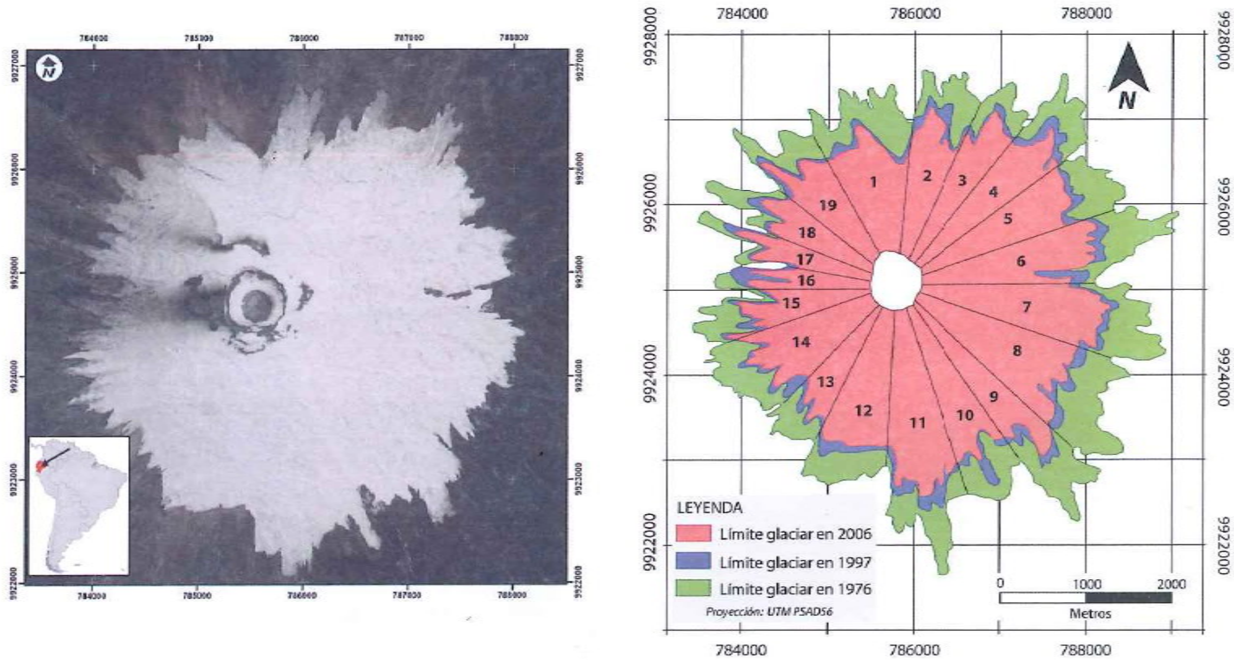


Figure 102: *Aerial Photograph of Cotopaxi from 1997 and a map showing the recession of glaciers from 1976 to 2006. (Ordonez, 2013 - Figure 2)*

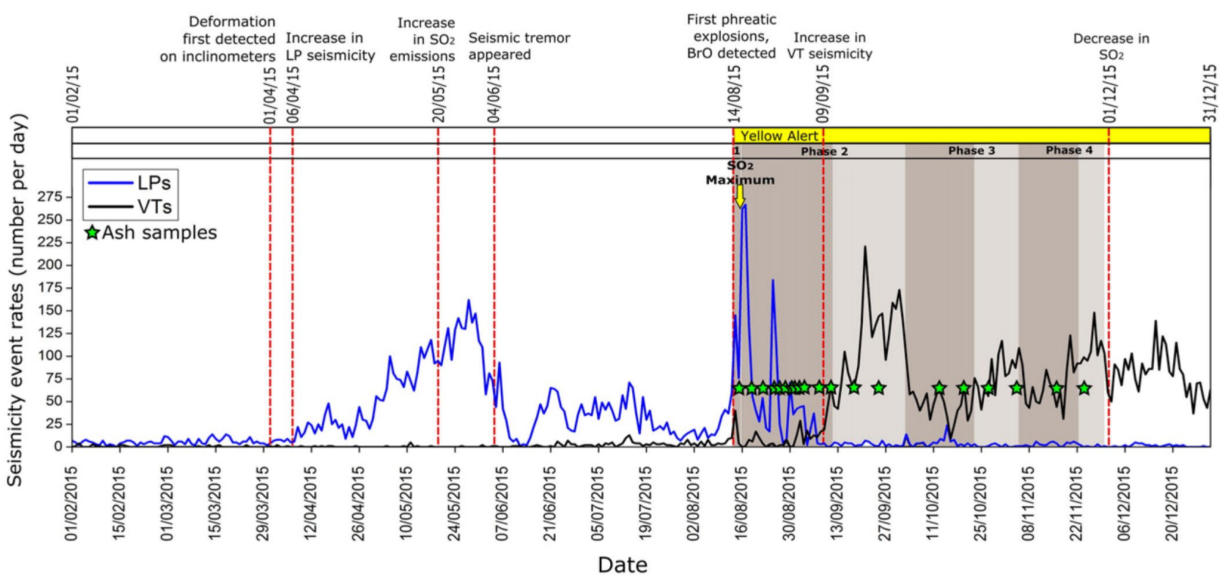


Figure 103: *Time line of events. Daily LP and VT seismicity event rates recorded by the seismic monitoring network of the Instituto Geofísico on Cotopaxi. Grey shaded areas show the 4 phases of ash emissions after the initial explosion on the morning of August 14 (the and the yellow arrow indicates the maximum SO2 emission during this period of unrest. Red dashed lines indicate important changes in geophysical monitoring parameters and are indicated in the text. The green stars denote the sample collection dates. (Gaunt et al., 2016 – Figure 2)*

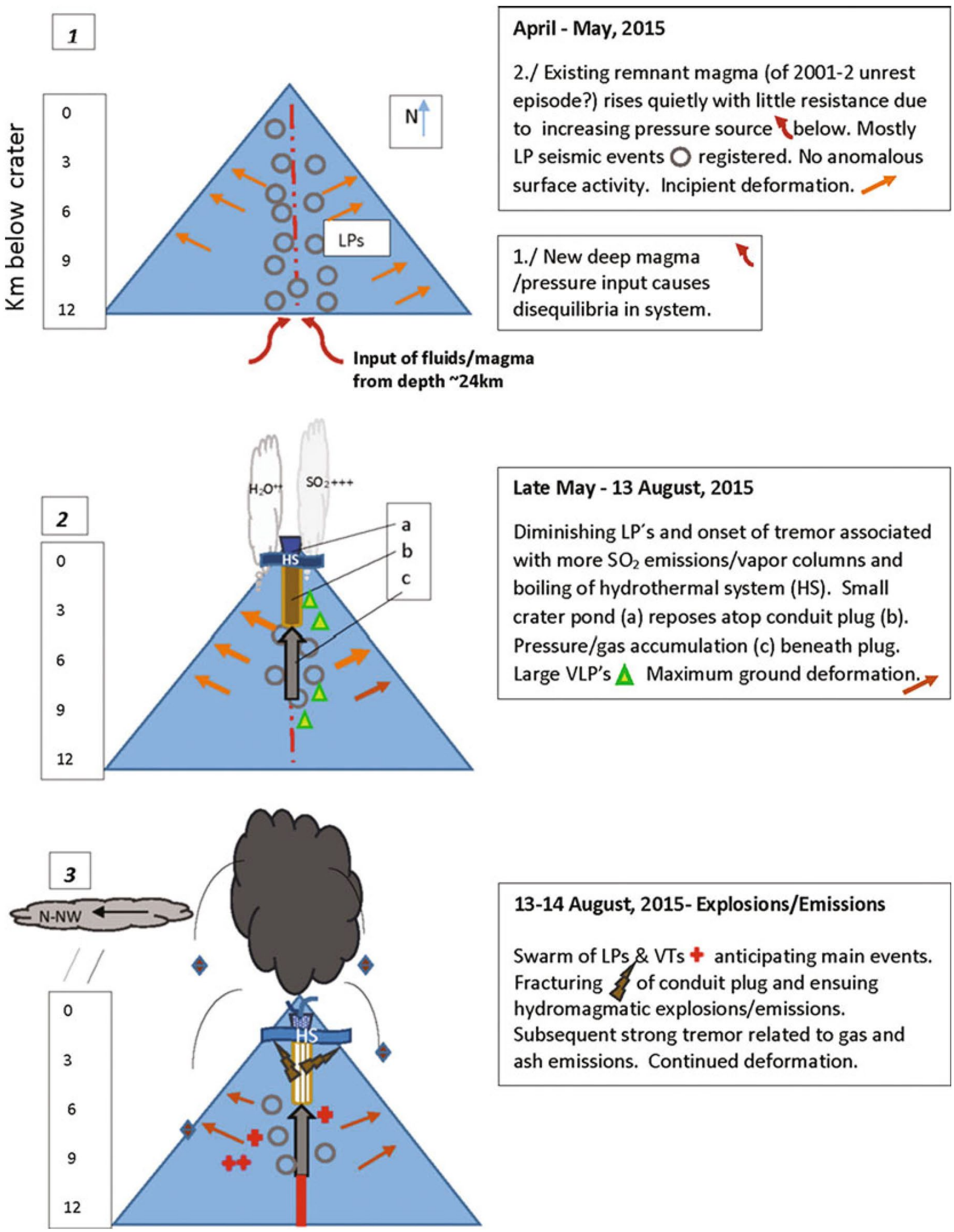
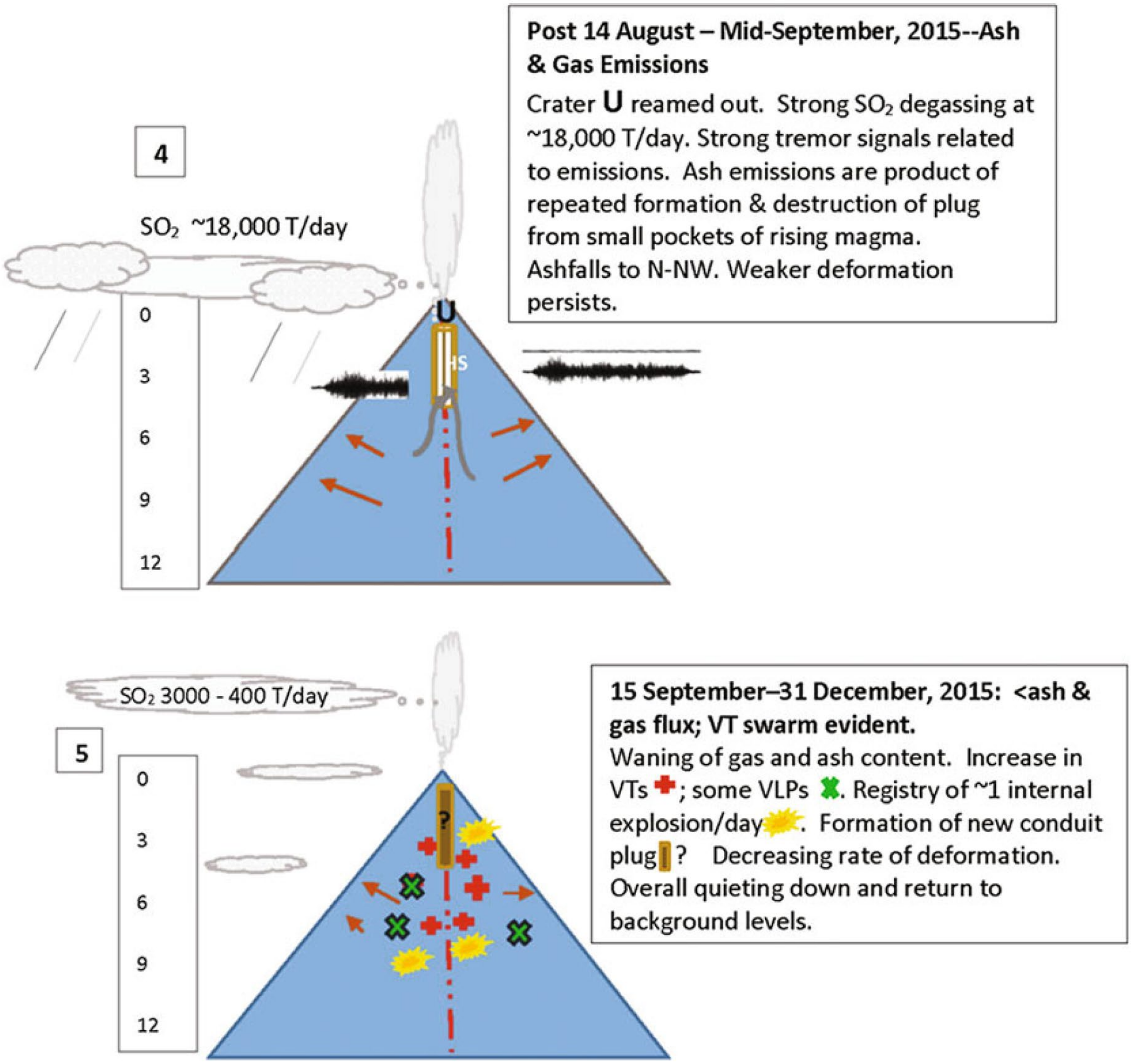


Figure 104: *Cartoons synthesizing the internal and superficial processes observed from April to December, 2015 (Mothes et al., 2017 - Figure 18)*


Post 14 August – Mid-September, 2015--Ash & Gas Emissions
Crater U reamed out. Strong SO_2 degassing at ~18,000 T/day. Strong tremor signals related to emissions. Ash emissions are product of repeated formation & destruction of plug from small pockets of rising magma. Ashfalls to N-NW. Weaker deformation persists.
4
SO_2 ~18,000 T/day
0
3
6
9
12
U
HS
SO_2 3000 - 400 T/day
5
0
3
6
9
12
?
15 September–31 December, 2015: <ash & gas flux; VT swarm evident.
Waning of gas and ash content. Increase in VTs; some VLPs. Registry of ~1 internal explosion/day. Formation of new conduit plug ? Decreasing rate of deformation. Overall quieting down and return to background levels.

STOP 5.3: *Baños (from Wikipedia)*

Figure 105: *Baños from the east.*

Baños de Agua Santa

Province	Tungurahua
Canton	Baños
Government	
• Type	Mayor and council
• Mayor	Marlon Fabricio Guevara Silva
Elevation	1,820 m (5,971 ft)
Population (2010)	
• Total	14,653

Baños de Agua Santa, commonly referred to as Baños, is a city in eastern Tungurahua Province of Ecuador. Baños is the second most populous city in Tungurahua, after the capital Ambato, and is a major tourist center. Baños is known as the "Gateway to the Amazon," as it's the last city still located in the mountain region before reaching the jungle and other towns that are located in the Amazon River basin. Baños is located at an elevation of 1,820 metres (5,971 feet) on the northern foothills of the Tungurahua volcano, whose activity has been characterized by frequent powerful ash explosions and lava flows that can be seen from Banos.

Etymology

Baños de Agua Santa (Spanish for Baths of Holy Water), is named after the hot springs located around the city which have a reputation of having healing properties due to the various minerals they contain.

History

The city is also a Roman Catholic religious center, as some Catholic believers say that the Virgin Mary appeared nearby a waterfall. Due to this belief, a sculpture of the virgin, called Virgen de Agua Santa, was placed in the city's cathedral. The history of the town has been intimately linked to the highly-active Tungurahua volcano. In October 1999, all 17,000+ residents were forced to evacuate the city for weeks.

Geography

Baños is located on the northern foothills of the Tungurahua volcano. Along with the town Pillaro, Baños is known as a good starting point for exploring the remote Llanganates National Park and its attractions including Cerro Hermoso. The city itself has a main central park across from the cathedral. Nearby waterfalls include Virgen de Agua Santa, Inés María, Agoyán, El Manto de la Novia, Pailón del Diablo and Machay.

Economy

Baños is a popular tourist destination in Ecuador due to its natural environment (it is home to more than 60 waterfalls) and its adventure sports. Locals and visitors alike undertake rafting, kayaking, canyoning, bridge jumping, hiking, biking and horseback riding. Baños is also known for its production of taffy made from cane sugar, and for small shops that sell parrot sculptures made of balsa wood.

Climate

Under the Köppen climate classification, Baños has a subtropical highland climate

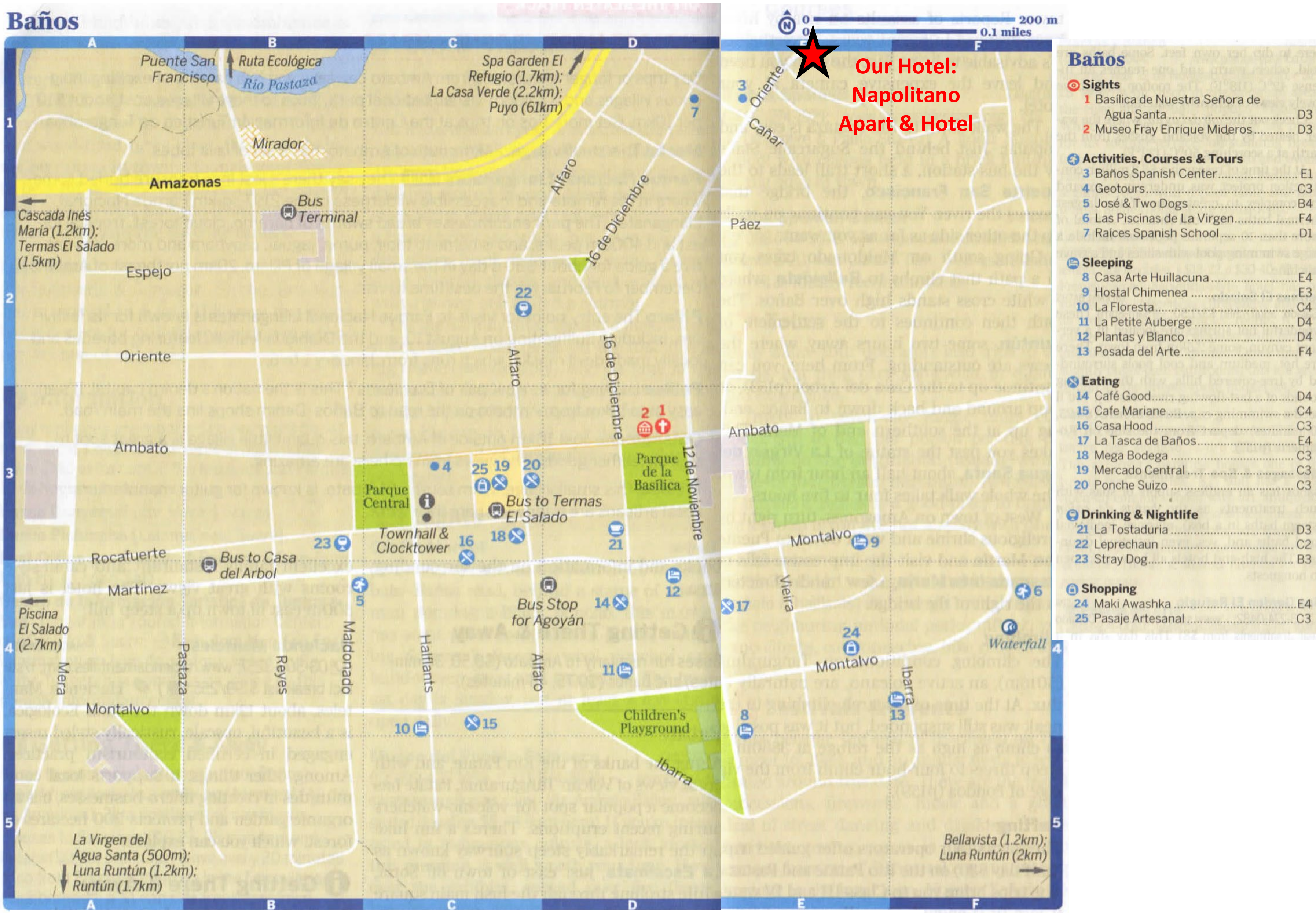


Figure 106: *Map of Banos (Lonely Planet, 2018)*

Day 6: Thursday, March 14th, 2019 – Biking to Rio Verde and Hiking around Tungurahua

Morning – Mountain Biking to Rio Verde, visiting several waterfalls along the way.

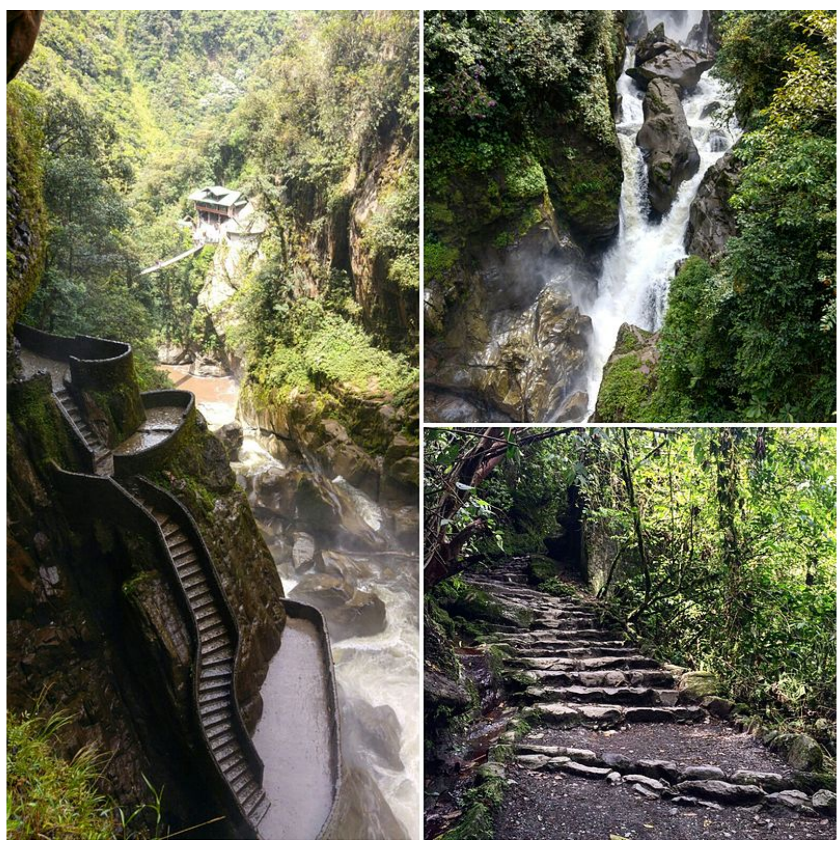
Lunch – Fish for trout and have lunch.

Afternoon – Hiking on Tungurahua and viewpoints of the deposits. And likely the hot springs of Baños.

Evening – We are on our own for dinner in Baños.

STOP 6.1: *Biking to Rio Verde*

Rio Verde Waterfall (alternatively called Cascade Pailón Devil) is a waterfall in the Andes of South American country of Ecuador. It is one of the several waterfalls that are obtained following the route of the Pastaza River in the Province of Tungurahua. It is a tourist attraction popular for the vegetation that surrounds it and the rocks that divide the waterfall. It is approximately 80 meters high, and about 20 meters deep. It also has the most amazing hand-carved bleachers in the world that lead to a gazebo with splendid views. The nearest town is known as Baños, the most important tourist town of Ecuador and is located about 20 kilometers away.



STOP 6.2: *Volcan Tungurahua*
(from Wikipedia)

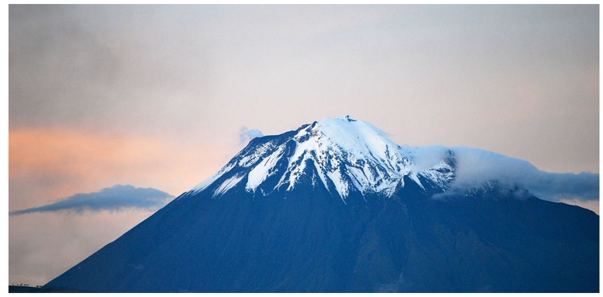


Figure 107: *View of Tungurahua from Riobamba (Sept 2011)*

Tungurahua, (/tʊŋɡʊˈrɑːwə/; from Quichua tunguri (throat), rahua (fire): "Throat of Fire" or from Panzaleo) is an active stratovolcano located in the Cordillera Oriental of Ecuador. The volcano gives its name to the province of Tungurahua. Volcanic activity restarted on August 19, 1999, and is ongoing as of 2013, with several major eruptions since then, the last starting on 1 February 2014.

Etymology

According to one theory the name Tungurahua is a combination of the Quichua tunguri (throat) and rahua (fire) meaning "Throat of Fire". According to another theory it is based on the Quichua uraua for crater. Tungurahua is also known as "The Black Giant" and, in local indigenous mythology it is allegedly referred to as Mama Tungurahua ("Mother Tungurahua").

Figure 108: *Tungurahua Eruption Feb 1, 2014*

Geography and geology

Tungurahua 5,023 meters (16,480 ft) is located in the Cordillera Oriental of the Andes of central Ecuador, 140 kilometers (87 mi) south of the capital Quito. Nearby notable mountains are Chimborazo (6,310 meters (20,700 ft)) and El Altar (5,319 meters (17,451 ft)). It rises above the small thermal springs town of Baños de Agua Santa (1,800 meters (5,900 ft)) which is located at its foot 8 kilometers (5.0 mi) to the north. Other nearby towns are Ambato (30 kilometers (19 mi) to the northwest), Baños and Riobamba (30 kilometers (19 mi) to the southwest). Tungurahua is part of the Sangay National Park.

Glacier

With its elevation of 5,023 meters (16,480 ft), Tungurahua just over tops the snow line (about 4,900 meters (16,100 ft)). Tungurahua's top is snow-covered and did feature a small summit glacier which melted away after the increase of volcanic activity in 1999.

Volcanism

Today's volcanic edifice (Tungurahua III) is constructed inside its predecessor's (Tungurahua II) caldera which collapsed about 3000 (±90) years ago. The original edifice (Tungurahua I) collapsed at the end of the Late Pleistocene.

Historical volcanic activity

Tungurahua's eruptions are strombolian. They produce andesite and dacite. All historical eruptions originated from the summit crater and have been accompanied by strong explosions, pyroclastic flows and sometimes lava flows. In the last 1,300 years Tungurahua entered every 80 to 100 years into an activity phase of which the major have been the ones of 1773, 1886 and 1916–1918.

Recent volcanic activity

In 2000, after a long period of quiescence, the volcano entered an eruptive phase that continues to this day (as of April 2014). The renewed activity in October 1999 produced major ashfall and led to the temporary evacuation of more than 25,000 inhabitants from Baños and the surrounding area Activity continued at a medium level until May 2006, when activity increased dramatically, culminating in violent eruptions on 14 July 2006 and 16 August 2006. The 16 August 2006 eruption has been the most violent since activity commenced in 1999. This eruption was accompanied by a 10 kilometers (6.2 mi) high ash plume which spread over an area of 740 by 180 kilometers (460 by 110 mi), depositing ash and tephra to the southwest of the volcano. Several pyroclastic flows were generated that killed at least five people, and destroyed a number of hamlets and roads on the eastern and northwestern slopes of the volcano.

A further eruption and evacuation occurred on 4 December 2010. Ecuador's National Agency of Risk Control issued a "red alert", later downgraded to orange. The Ecuadorean Institute for Geophysics reported a rapid increase in seismic activity, a number of explosions and an ash cloud reaching 2 kilometers (1.2 mi) in height. Another eruption occurred on 18 December 2012 forcing evacuation of those living on the volcano's slopes. The volcano erupted again in July 2013. On 1 February 2014, the volcano erupted again

***Figure 109**: Tungurahua spews hot lava and ash at night, 1999*

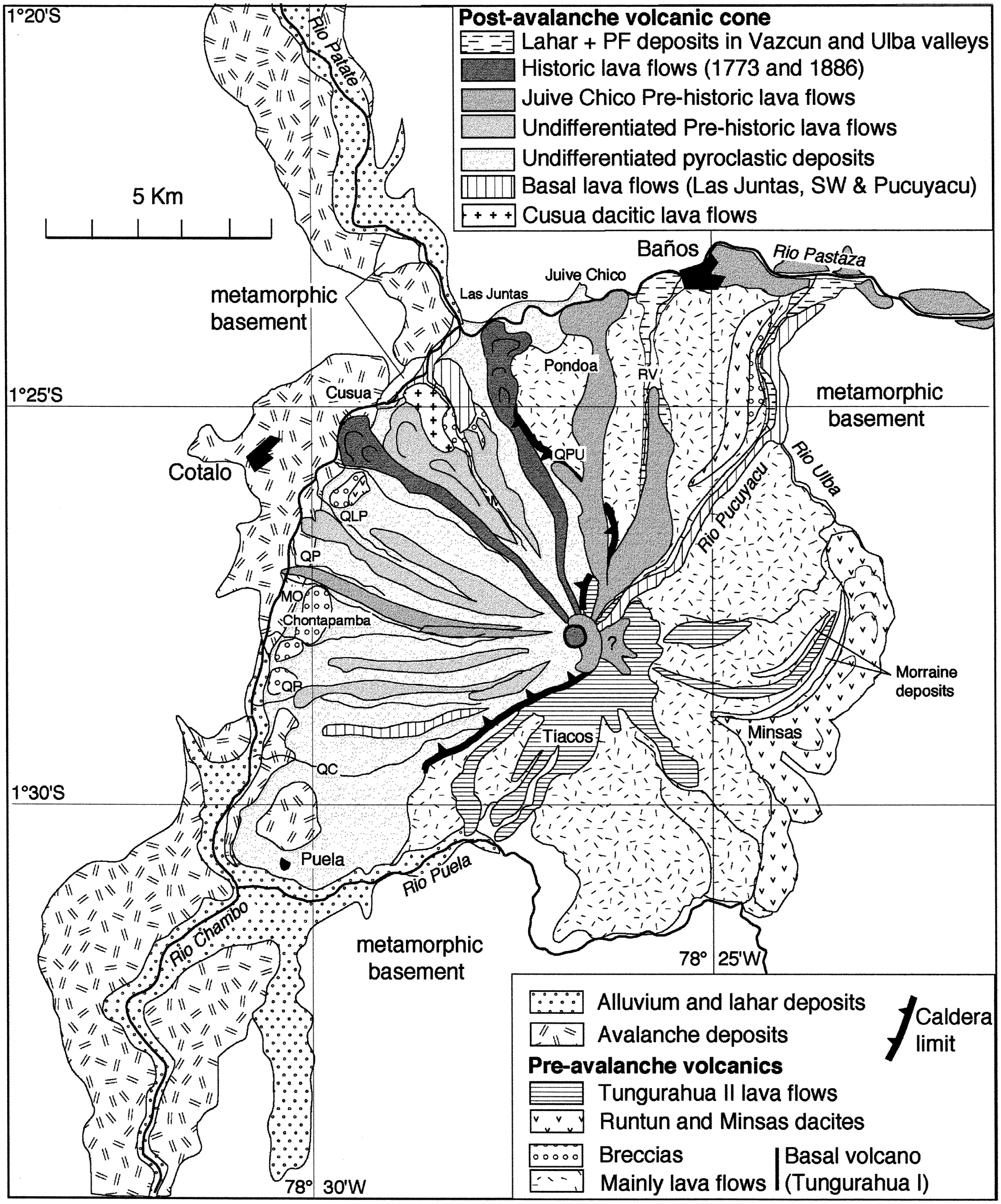


Figure 110: *Simplified Geologic Map of Tungurahua Volcano (Hall et al., 1999 - Figure 7)*

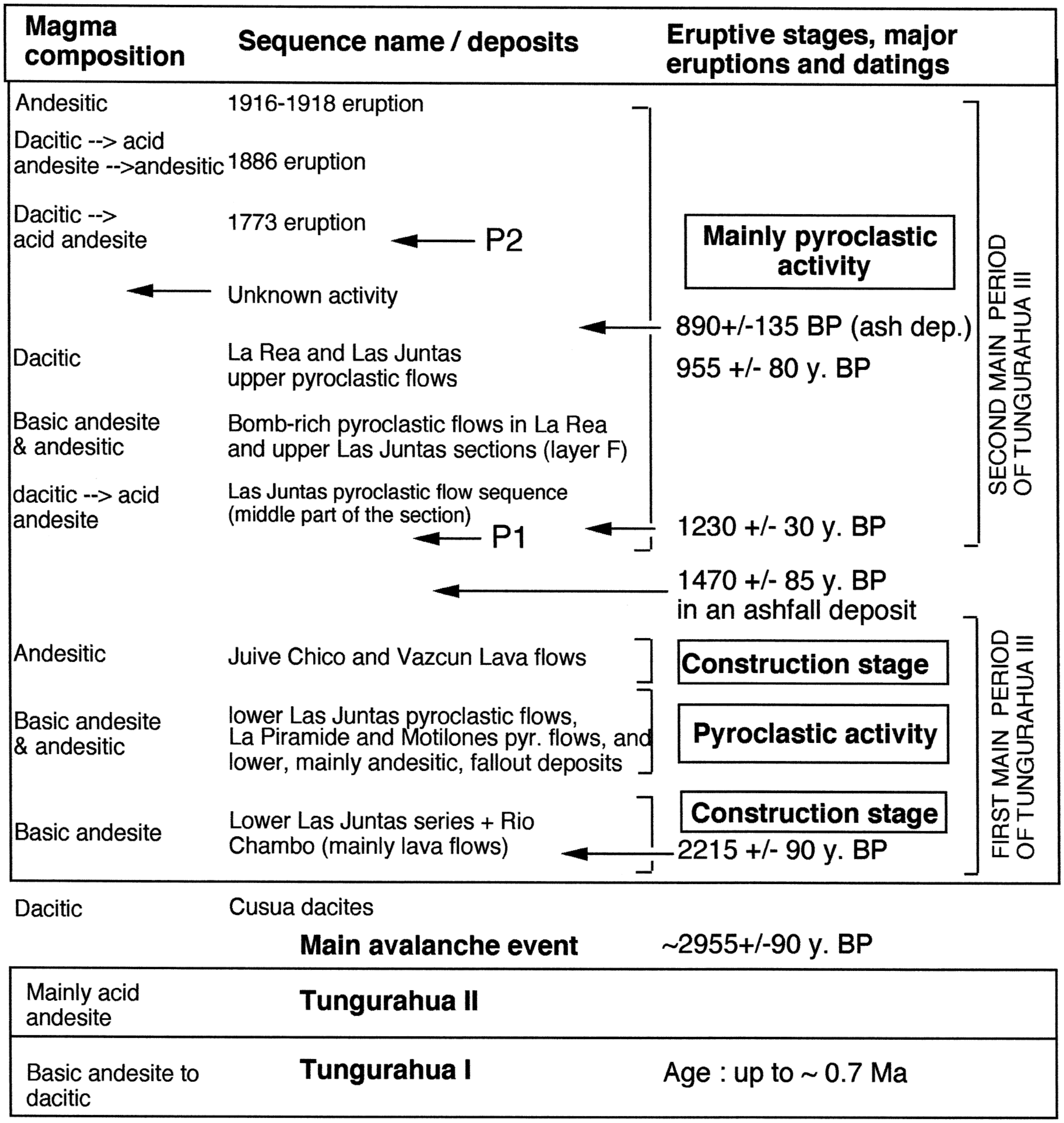


Figure 111: *Generalized stratigraphy of Tungurahua volcano with special emphasis to the post avalanche Tungurahua cone. (Hall et al., 1999 - Figure 10)*

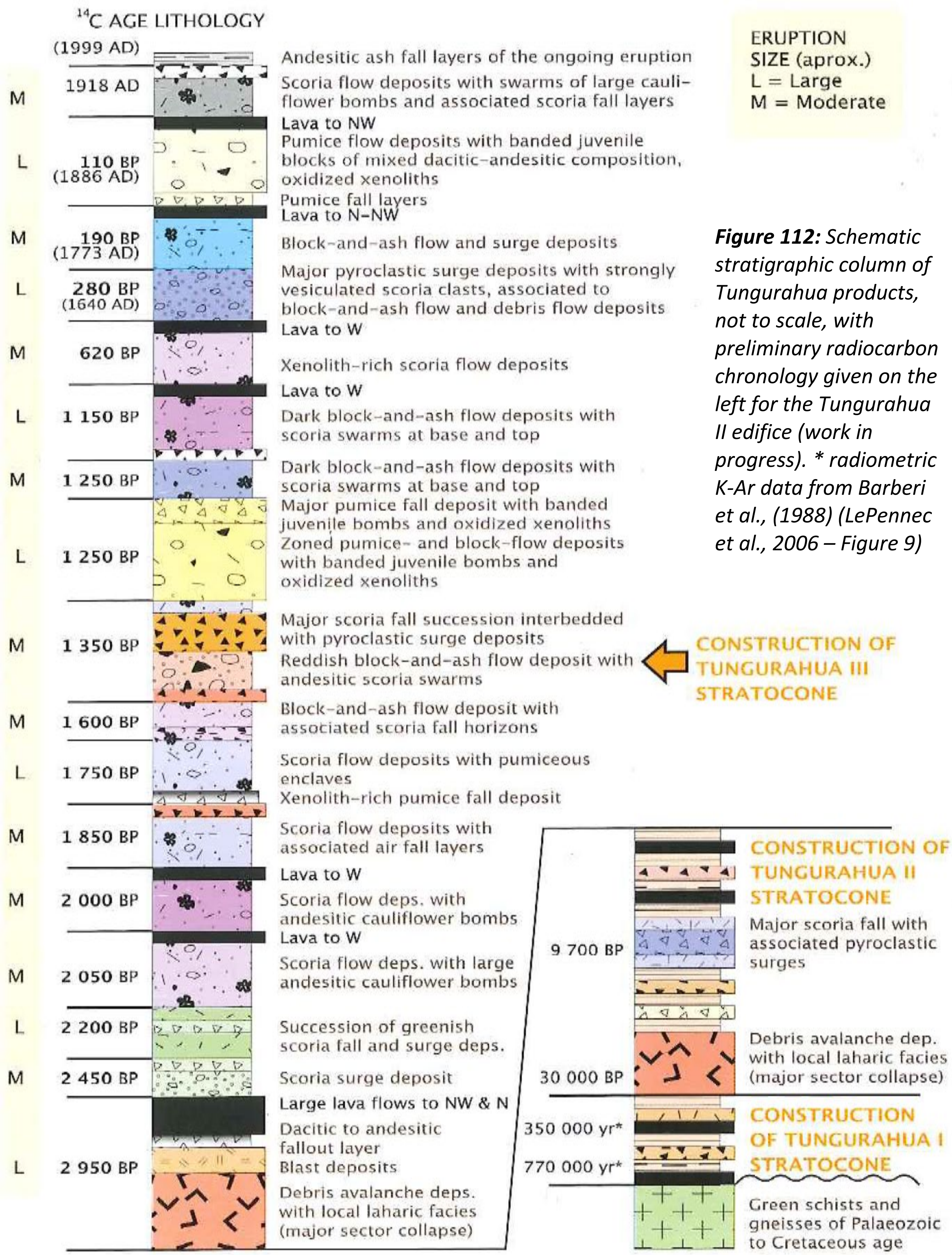


***Figure 112:** Schematic stratigraphic column of Tungurahua products, not to scale, with preliminary radiocarbon chronology given on the left for the Tungurahua II edifice (work in progress). * radiometric K-Ar data from Barberi et al., (1988) (LePennec et al., 2006 – Figure 9)*

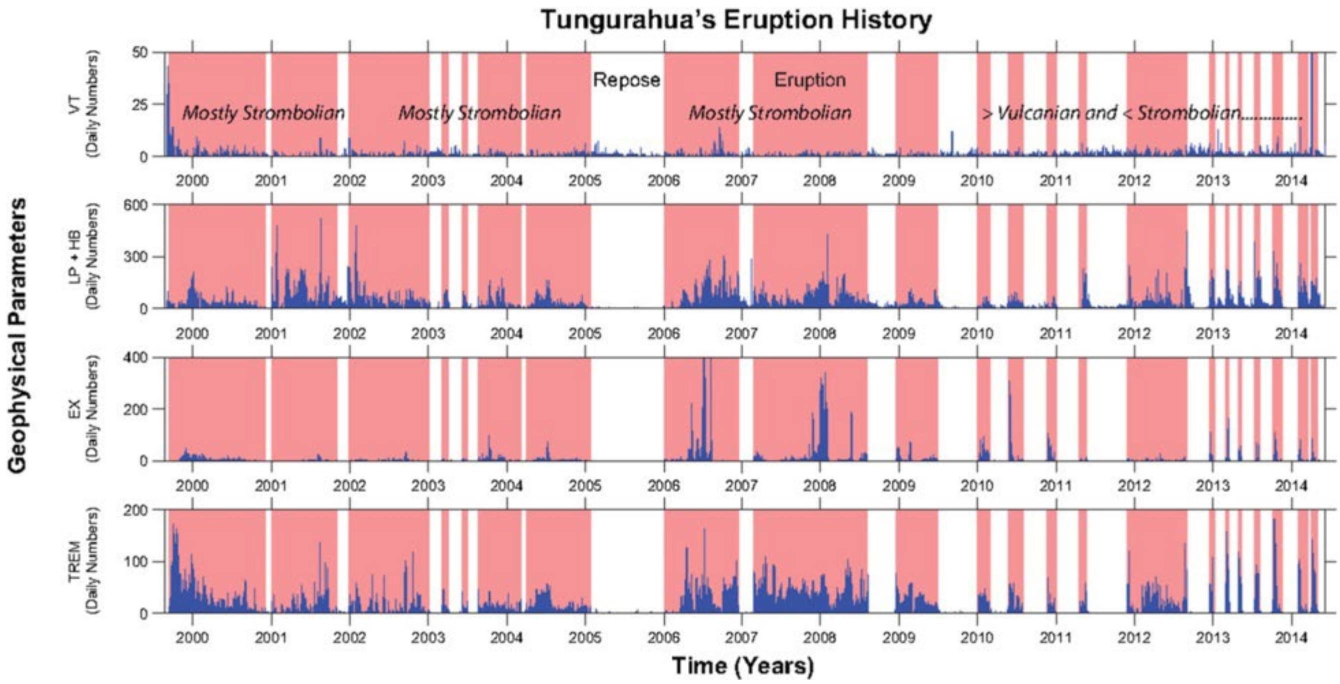


Figure 113: *A timeline of Tungurahua´s eruptive activity 1999–2014. Shown on the left margins are the daily numbers of seismic events: VT = volcano-tectonic; LP + HB = long period and hybrids; EX = explosions and TREM = volcanic tremor. Eruptive activity is represented by light pink color, while repose is represented by white. The activity was predominantly Strombolian-style through 2010. Vulcanian style was more predominant between 2010 to present.*

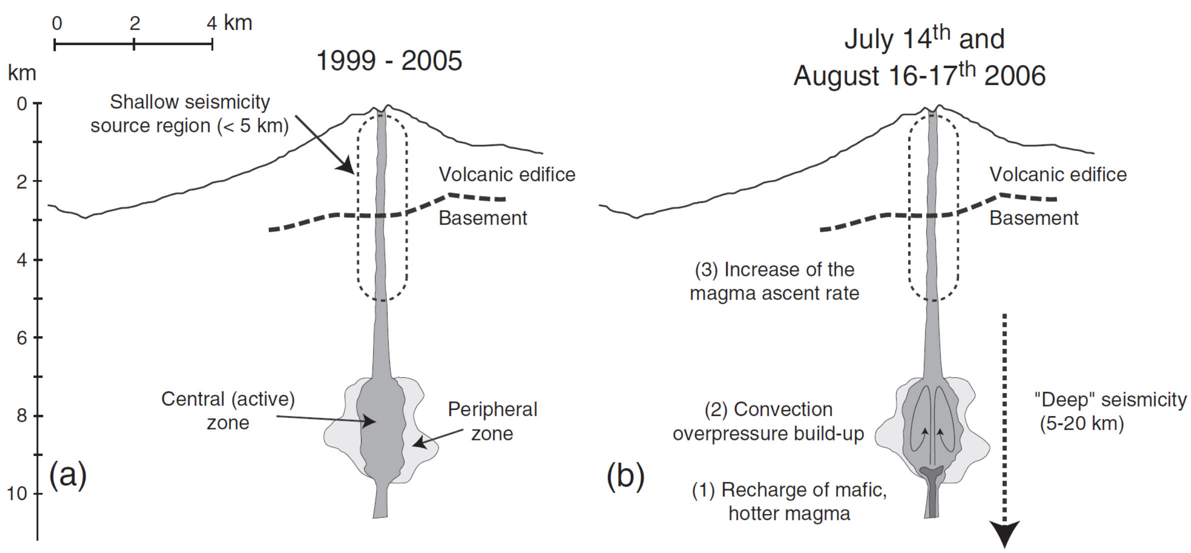
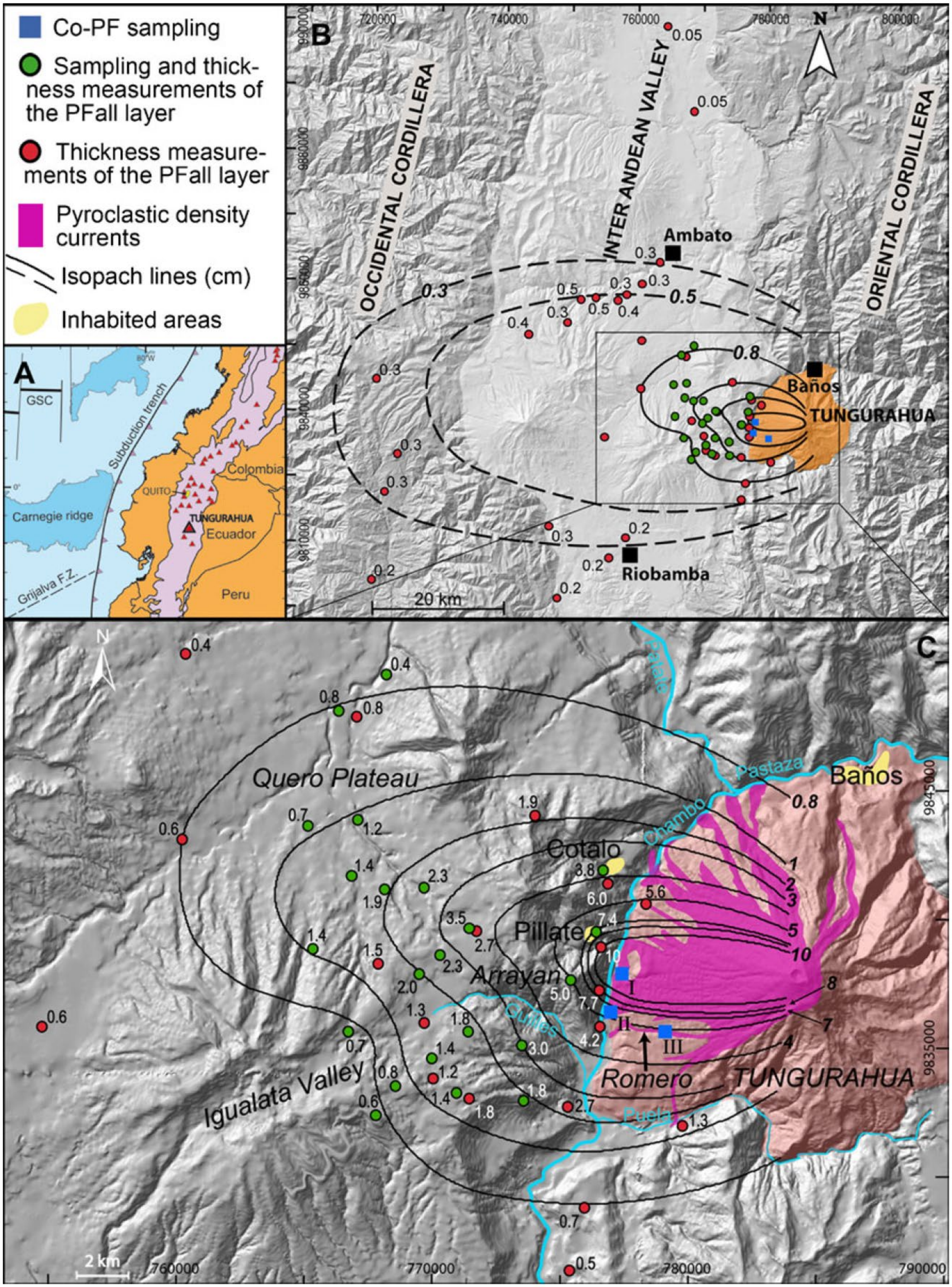


Figure 114: *Sketch model summarizing the magmatic processes operating in the Tungurahua plumbing system during the 1999–2005 eruptive phases (a), and the 2006 eruptions (b). The contact between the volcanic edifice and the metamorphic basement comes from the tomographic study of Molina et al. (2005), and the volcanic seismic events source zone from unpublished reports of the IG-EPN. Note the vertical and horizontal scales are not the same and the reservoir form and size are schematic. (Samaniego et al., 2011 – Figure 11)*

Figure 115: *(Next page) Location map of the Tungurahua volcano in Ecuador. b Area sampling and thickness measurements of the PFall layer from the August 2006 eruption. c Map of the proximal depositional area showing the distribution of pyroclastic density current deposits (after Kelfoun et al. 2009). The sampling locations of the Co-pyroclastic flow deposits are labeled from I to III. b, c Numerical labels thickness values in centimeters. Solid lines isopach contours of the PFall layer in centimeters (dashed lines for distal isopachs). Red dots sites of thickness measurements only. Green dots sites of thickness measurements and tephra sampling. (Eychenne et al., 2012 – Figure 1)*


Co-PF sampling
Sampling and thickness measurements of the PFall layer
Thickness measurements of the PFall layer
Pyroclastic density currents
Isopach lines (cm)
Inhabited areas
A
GSC
Subduction trench
Colombia
QUITO
Carnegie ridge
TUNGURAHUA
Ecuador
Grijalva F.Z.
Peru
B
OCCIDENTAL CORDILLERA
INTER ANDEAN VALLEY
ORIENTAL CORDILLERA
Ambato
Baños
TUNGURAHUA
Riobamba
20 km
C
Quero Plateau
Cotalo
Pillate
Arrayan
Igualata Valley
Romero
TUNGURAHUA
Baños
Pastaza
Chambo
Patate
Quilles
Puela
2 km

STOP 6.3: *Hot Springs of Baños*

The following is from https://ecuadorabroad.com/complete-guide-to-hot-springs-in-banos-ecuador/ They have a nice write up on a lot of the hot springs. I just grabbed the text for the local cheap one in town, there are others outside of town that are much fancier.

Termas de la Virgen

This one is the most popular with the locals. It's also the one that you're most commonly going to see when you flip through Google Images. It has a tendency to be pretty crowded, especially during peak season and on holidays and weekends.

The nice thing about this facility is that the water (usually) is hot. They have a really hot pool that's right beside showers that feed water from the freezing cold waterfall, so if you like to do the cold/hot thing then you'll hardly find a better place to do it. They usually have a medic station just feet away from this area. This way they can keep an eye on the people that are braver than they should be.

Hours

The pool opens at 5 am, and if you come this early (technically possible) you'll rarely find it overly crowded. The pool is flushed daily at 4 pm and reopens at 6 pm until 9:30 pm. Keep in mind though that in Ecuador, times aren't really set in stone. There is a bit of random fluctuation, more so in the evening hours, although I've rarely had a problem with this facility.

Cost

The entrance fee during daytime hours is $2 for adults, $1 for children aged 3-16, and $1 for the "incapacitados", aka, infirm. For the evening, the entrance fee goes up to $3 for adults, $1.50 for kids and infirm. I'm not actually sure what constitutes as infirm. This might just mean senior.

Cleanliness

I'd rate this one a 4/10. It's nice that the pools are flushed and rinsed daily, but after decades of mineral buildup, it's really hard to scrub everything with anything less than a jackhammer. The change rooms are a little funky and I'd definitely recommend bringing some flip flops for walking around in. Really, though, that's good advice for any type of pool.

All that said, the water itself is really nice, especially early in the day. If you have any aches from all the adventure sports, you will definitely get some relief here. The pins and needles you'll feel jumping between scalding hot and freezing cold water is enough to tame the toughest of aches. If you want the hottest water, go in the evening. That's when they open the lower pools, which are smaller but much more extreme.

Bring sandals, a water bottle, a swimming cap, and a towel. You can buy water and a cap onsite but it's a little bit more expensive. There's a really good bag check onsite too so I've never had a problem handing over my cell phone, nor have I heard of problems. I'd still be cautious with large wads of cash, if that's more your traveling style (never recommended).

Overall experience: 3/5. A lot of people love this one, and lot of people compare it to spas they've been to in Europe and can't understand why a $2 admission doesn't give you an immaculate Swedish facility. For the price, it's good**.**

Day 7: Friday, March 15th, 2019 – Tungurahua, Chimborazo, and Quilotoa

Morning – Loop drive around Chimborazo including the old road which circles around Tungurahua, where you'll see the deposits from the past 20 years.

Lunch – Box lunch

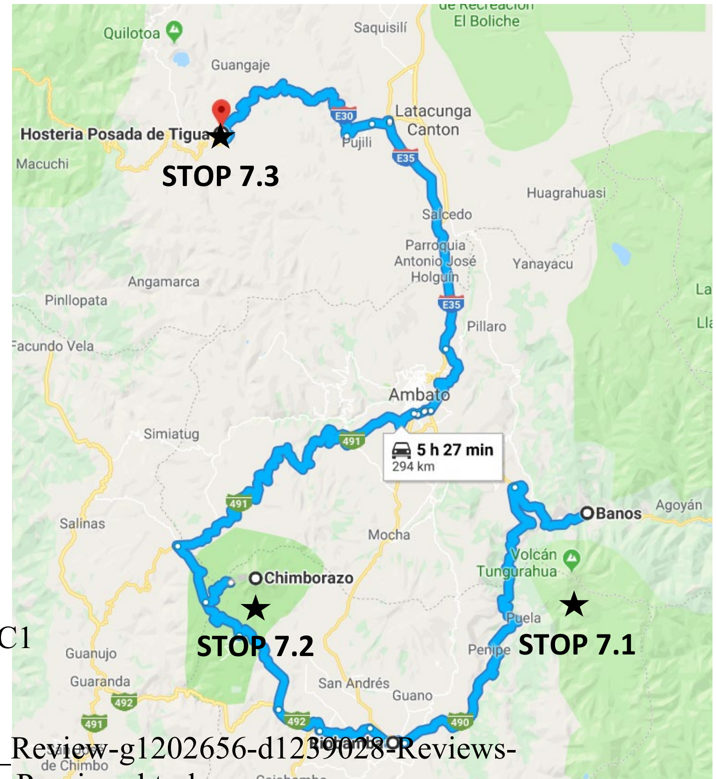
Afternoon – Drive up to the Quilotoa, where we will stay the night.

Evening – Dinner at the hostel.

Here are the accommodations:

Hosteria Posada De Tigua
Quito y Julio Hidalgo El Remanso C1
Tigua 050103, Ecuador

https://www.tripadvisor.com/Hotel_Review-g1202656-d1239028-Reviews-Posada_De_Tigua-Tigua_Cotopaxi_Province.html



STOP 7.1: *Volcan Tungurahua (again)*

Figure 116: *Cartoon modified from that which was published in Quito´s "El Comercio" newspaper on 12 July, 2006 in which the director of the Instituto Geofísico is handed an order from the assistant of the Tungurahua governor. The order states that the IG director must abstain from reporting on Tungurahua´s eruptive activity and that the governor will give the reports in such a way that tourism will not suffer. (Mothes et al., 2015 – Figure 4)*

STOP 7.2: *Chimborazo (from Wikipedia)*

Chimborazo is a currently inactive stratovolcano in the Cordillera Occidental range of the Andes. Its last known eruption is believed to have occurred around 550 C.E. With a peak elevation of 6,263 m (20,548 ft), Chimborazo is the highest mountain in Ecuador. It is the highest peak near the equator. Chimborazo is not the highest mountain by elevation above sea level, but its location along the equatorial bulge makes its summit the farthest point on the Earth's surface from the Earth's center.

Figure 117: *Chimborazo*

Geography

Location

Chimborazo is in the Cordillera Occidental of the Andes of central Ecuador, 150 km (93 mi) south-southwest of the capital Quito. It is a neighbor to 5,018 m high Carihuairazo. Chimborazo's summit rises 2,500 m above the surrounding highlands (~3,500 to 4,000 m) with a ≈20 km wide base.

Under clear conditions, the summit of Chimborazo can be seen from the coastal city Guayaquil, nearly 140 km away. The nearest cities are Riobamba (~30 km to the southeast), Ambato (~30 km to the northeast) and Guaranda (~25 km to the southwest). Chimborazo is surrounded by the Reserva de Produccion Faunistica Chimborazo, which forms a protected ecosystem to preserve the habitat for the Andes native camelids of vicuña, llama and alpaca.

Chimborazo is at the main end of the Ecuadorian Volcanic Arc, north west of the town of Riobamba. Chimborazo is in la Avenida de los Volcanes (the Avenue of Volcanoes) west of the Sanancajas mountain chain. Carihuairazo, Tungurahua, Tulabug, and El Altar are all mountains that neighbor Chimborazo. The closest mountain peak, Carihuairazo, is 5.8 mi (9.3 km) from Chimborazo There are many microclimates near Chimborazo, varying from desert in the Arenal to the humid mountains in the Abraspungo valley.

Glaciers

The top of Chimborazo is completely covered by glaciers, with some north-eastern glacier arms flowing down to 4,600 m. Its glacier is the source of water for the population of the Bolivar and Chimborazo provinces of Ecuador. Chimborazo glacier's ice mass has decreased over the past decades, which is thought by some to be due to the combined influences of global warming, ash covers from recent volcanic activity of Tungurahua, and the El Niño phenomenon.

As on other glaciated Ecuadorian mountains, Chimborazo's glacial ice is mined by locals (the so-called Hieleros from Spanish Hielo for Ice) to be sold in the markets of Guaranda and Riobamba. In earlier days, the people transported ice for cooling uses down to coastal towns such as Babahoyo or Vinces.

Elevation

With an elevation of 6,263 m (20,548 ft), Chimborazo is the highest mountain in Ecuador and the Andes north of Peru; it is higher than any more northerly summit in the Americas.

Farthest point from Earth's center

The summit of Mount Everest is higher above sea level, but the summit of Chimborazo is widely reported to be the farthest point on the surface from Earth's center, with Huascarán a very close second. The summit of the Chimborazo is the fixed point on Earth that has the utmost distance from the center – because of the oblate spheroid shape of the planet Earth, which is "thicker" around the Equator than measured around the poles. Chimborazo is one degree south of the Equator and the Earth's diameter at the Equator is greater than at the latitude of Everest (8,848 m (29,029 ft) above sea level), nearly 27.6° north, with sea level also elevated. Despite being 2,585 m (8,481 ft) lower in elevation above sea level, it is 6,384.4 km (3,967.1 mi) from the Earth's center, 2,163 m (7,096 ft) farther than the summit of Everest (6,382.3 km (3,965.8 mi) from the Earth's center). However, by height above sea level, Chimborazo is not the highest peak of the Andes.

Geology

Chimborazo is an ice-capped inactive volcano in Ecuador. Chimborazo is a double volcano composed of one volcanic edifice on top of another. Chimborazo shows four summits; Whymper, Veintimilla, Politecnica, and Nicolas Martínez. The Whymper peak is the highest point on the mountain at 6,263 meters. The Veintimilla peak is about 6,230 m (20,440 ft) high. The Politecnica peak is 5,820 m (19,094 ft) high. The last peak, Nicolas Martínez, is 5,570 m (18,274 ft) high and was named after the father of Ecuadorian mountaineering. The volcano is categorized as a stratovolcano. This type of volcano is characterized as having low slopes at the bottom that gradually get steeper the higher up the mountain. Chimborazo has a circumference of 78 miles (126 km) and a diameter of 30 miles (48 km). Chimborazo's upper elevations are covered in glaciers that are decreasing in size due to climate change and falling ash from the nearby volcano, Tungurahua. In addition to the glaciers, the volcano is covered with craters. The volcano is dominantly andesitic to dacitic. This means that the lava is blocky, or flowing down the sides of the volcano, or somewhere in between. Chimborazo is 73.5 meters higher than the highest mountain in North America. Chimborazo is often associated with the nearby volcano Cotopaxi, although the two volcanoes have completely different structures.

Volcanism

Chimborazo is a dominantly andesitic-dacitic stratovolcano. About 35,000 years ago a collapse of Chimborazo produced a debris avalanche with an average thickness of forty meters. which underlies the city of Riobamba. It temporarily dammed the Rio Chambe, causing an ephemeral lake.

Chimborazo then erupted several times during the Holocene, the last time around 550 AD ± 150 years. The eruptions after the collapse were primarily andesitic, or blocky, coagulated lava flow. These eruptions produced pyroclastic surges that went down as far as 3800 meters altitude. There have been at least seven eruptions in the past 10000 years. Chimborazo is officially considered inactive, but studies show that there may be an eruption in the future. The average time between eruptions for Chimborazo is 1000 years, and the last eruption was 1400 years ago.

History

Until the beginning of the 19th century, it was thought that Chimborazo was the highest mountain on Earth (measured from sea level), and such reputation led to many attempts on its summit during the 17th and 18th centuries. In 1746, the volcano was explored by French academicians from the French Geodesic Mission. Their mission was to determine the sphericity of the Earth. Their work along with another team in Lapland established that the Earth was an oblate spheroid rather than a true sphere. They did not reach the summit of Chimborazo.

In 1802, during his expedition to South America, Alexander von Humboldt, accompanied by Aimé Bonpland and the Ecuadorian Carlos Montúfar, tried to reach the summit. From his description of the mountain, it seems that before he and his companions had to return suffering from altitude sickness they reached a point at 5,875 m, higher than previously attained by any European in recorded history (Incans had reached much higher altitudes previously; see Llullaillaco). In 1831, Jean Baptiste Boussingault and Colonel Hall reached a new "highest point", estimated to be 6,006 m. Other failed attempts to reach the summit followed.

On 4 January 1880, the English climber Edward Whymper reached the summit of Chimborazo. The route that Whymper took up the mountain is now known as the Whymper route. Edward Whymper, and his Italian guides Louis Carrel and Jean-Antoine Carrel, were the first Europeans to summit a mountain higher than 20,000 feet (6,100 m). As there were many critics who doubted that Whymper had reached the summit, later in the same year he climbed to the summit again, choosing a different route (Pogyos) with the Ecuadorians David Beltrán and Francisco Campaña.

Etymology

Several theories regarding the origin of the name Chimborazo exist. In many dialects of Quichua or Quechua, "chimba" means "on the other side" as in "on the other side of the river" or "on the opposite bank." Other dialects pronounce this word "chimpa." Also, "razu" means "ice" or "snow." Local Quichua speakers will say that Chimborazo is a Hispanicized pronunciation of "chimbarazu," meaning "the snow on the other side." Another theory suggests it is a combination of the Cayapa Schingbu for Women and the Colorado/Quichua Razo for Ice/Snow resulting in Women of Ice. According to another, Chimbo is Jívaro for Throne of Master/God resulting in Icethrone of God. The locals also used to call the mountain Urcurazu, with the Quichua Urcu for Mountain resulting in Mountain of Ice. In local indigenous mysticism, Chimborazo represents Taita (Father) whereas neighbouring Tungurahua is seen as Mama, hence Taita Chimborazo and Mama Tungurahua.

Mountaineering

As Ecuador's highest mountain, Chimborazo is a very popular climb and can be climbed year round with the best seasons being December–January and July–August.

Routes

The easiest (Grade: PD) and most climbed routes are the Normal and the Whymper route. Both are western ridge routes starting at the Whymper hut and leading via the Ventemilla summit to the main (Whymper) summit. There are several other less used and more challenging routes on the other mountains faces and ridges leading to one of Chimborazo's summits: Main (Whymper, Ecuador), Politecnico (Central), N. Martinez (Eastern). The mountain is contained on the IGM (Instituto Geografico Militar) 1:50000 Map Chimborazo (CT-ÑIV-C1).

Climbing

El Castillo is the most popular route up the volcano. This route is usually climbed December to February and June to September. This route involves climbing the west side of the volcano. The route starts at Whymper hut to a saddle above El Castillo. From the saddle, there is a glacier ridge then you go to the Veintemilla summit. Veintemilla summit is often the turnaround point for climbers. There is a 30-minute snow filled basin between Veintemilla summit and Whymper summit. Whymper summit is the highest point of the mountain. The El Castillo route takes around eight to twelve hours to ascend and about three to five hours to descend. Climbing Chimborazo is dangerous due to risk of avalanches, the severe weather conditions, and the fact that it is covered in glaciers. Climbing should begin at night in order to reach the summit before sunrise when the snow melts increasing the chance of avalanche and rockfall. The climb itself demands skill. The climb is often on black ice in which crampons and other high tech climbing equipment are required. On November 10, 1993 three parties of climbers, one ascending and two descending, were caught in an avalanche on the steep slopes below the Veintimilla summit. This avalanche buried ten climbers in a crevasse at 18,700 feet (5,700 m). These climbers comprised six French, two Ecuadorans, one Swiss, and one Chilean. After the ten climbers were buried in snow, it took twenty people and ten days to find their bodies. This is considered the worst climbing accident in Ecuador to date

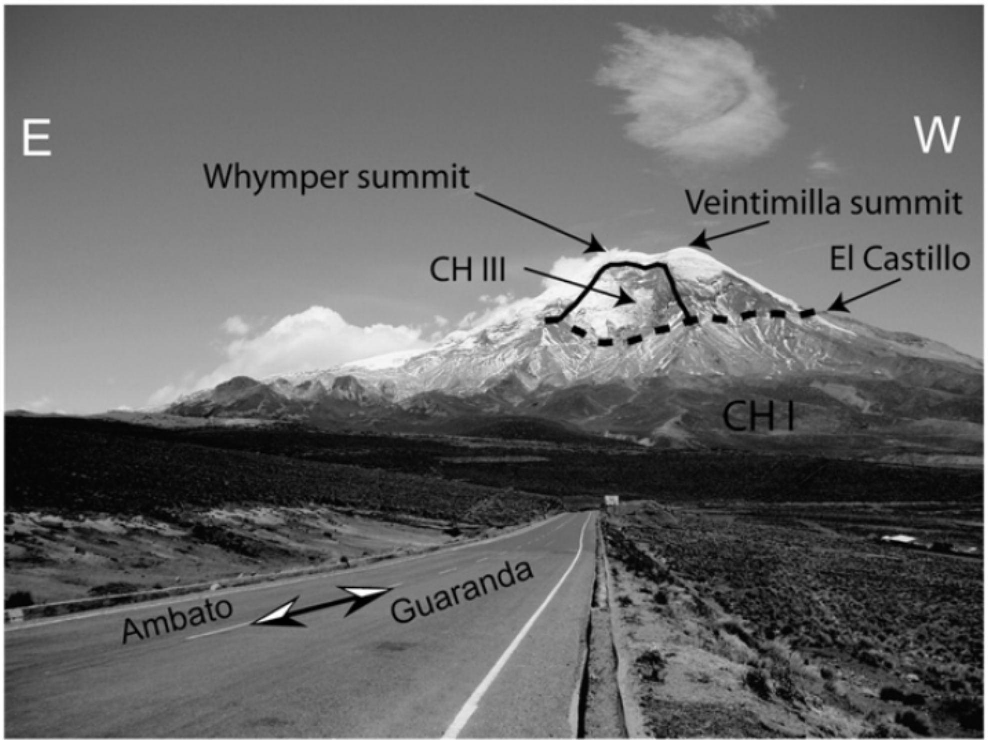


Figure 118: *View of the northern flank of the volcano. The dashed line corresponds to the CHI avalanche scar and the black line underlines the small caldera avalanche on the northern flank. (Barba et al., 2008 – Figure 2)*

	Volcanic units	Eruptive styles and deposits	Age	Magma composition
Young Cone (CH-III)	Holocene explosive activity	Recurrent, low-magnitude, andesitic activity (at least 7 eruptions since 7 ka)	1–8 ka	Andesitic tephra
	Río Colorado debris avalanche	Small-volume debris avalanche, deposit directed to the north	>12–14 ka	
	Western-plateau fallout deposits	Sequence of powerful fallout deposits displaying erosional unconformities and interlayered with glacial deposits	14–35 ka	Andesitic scoriae and pumice (56–60 wt.% SiO_2) with scarce andesitic–dacitic pumice (62–64 wt.% SiO_2)
	Murallas Rojas stage	Edification of the main summit: lava flows and related pyroclastic deposits		Two-pyroxene and olivine andesites (56–60 wt.% SiO_2)
Intermediary Edifice (CH-II)	Río Blanco ashflow	Ash-flow deposits to the north (Río Blanco) and south (Tintatacto)	42–43 ka	
	Politécnica and Martínez stage	Edification of a mainly effusive edifice	~35–48 ka	Two-pyroxene andesites (59–63 wt.% SiO_2) and subordinate dacites (64–67 wt.% SiO_2)
	Guano stage	Post-avalanche lava flows and related pyroclastic deposits (Aucacán sequence)	~60 ka	Two-pyroxenes andesites (60–63 wt.% SiO_2)
Basal Edifice (CH-I)	Riobamba debris avalanche	Huge debris avalanche deposit directed to the south–east	~60–65 ka	
	Peñas Blancas ashflow	Ash-flow deposits in the Río Ambato		Biotite-bearing rhyolite 70 wt.% SiO_2)
	El Castillo stage	Upper lava flows and viscous lava flow sequence (Templo Machay and Condor Palta sequence)	65–95 ka	Two-pyroxene andesites (57–60 wt.% SiO_2) and amphibole-bearing andesites and dacites (63–64 wt.% SiO_2)
	Abraspungo stage	Lower lava flows	~100–120 ka	Two-pyroxene andesites (57–61 wt.% SiO_2)
Carihuairazo volcano	Lavas from the lower south–east and west flanks		205–230 ka	Two-pyroxenes andesites

Figure 119: Generalized chronostratigraphy showing the main eruptive stages of Chimborazo volcano (Samaniego et al., 2012 - Table 2)

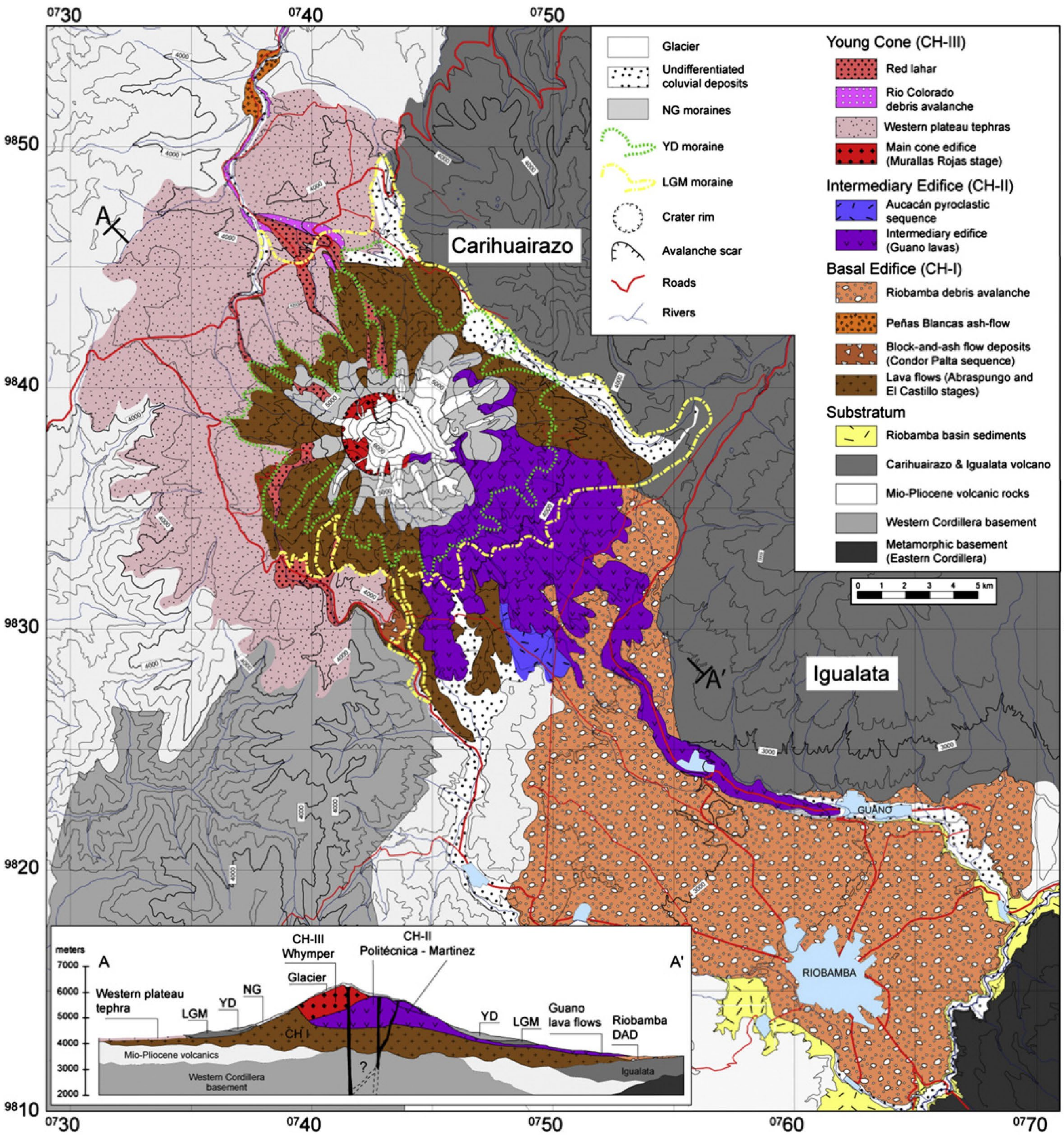


Figure 120: *Geological Sketch map of Chimborazo volcano (Samaniego et al., 2012 - Figure 5)*

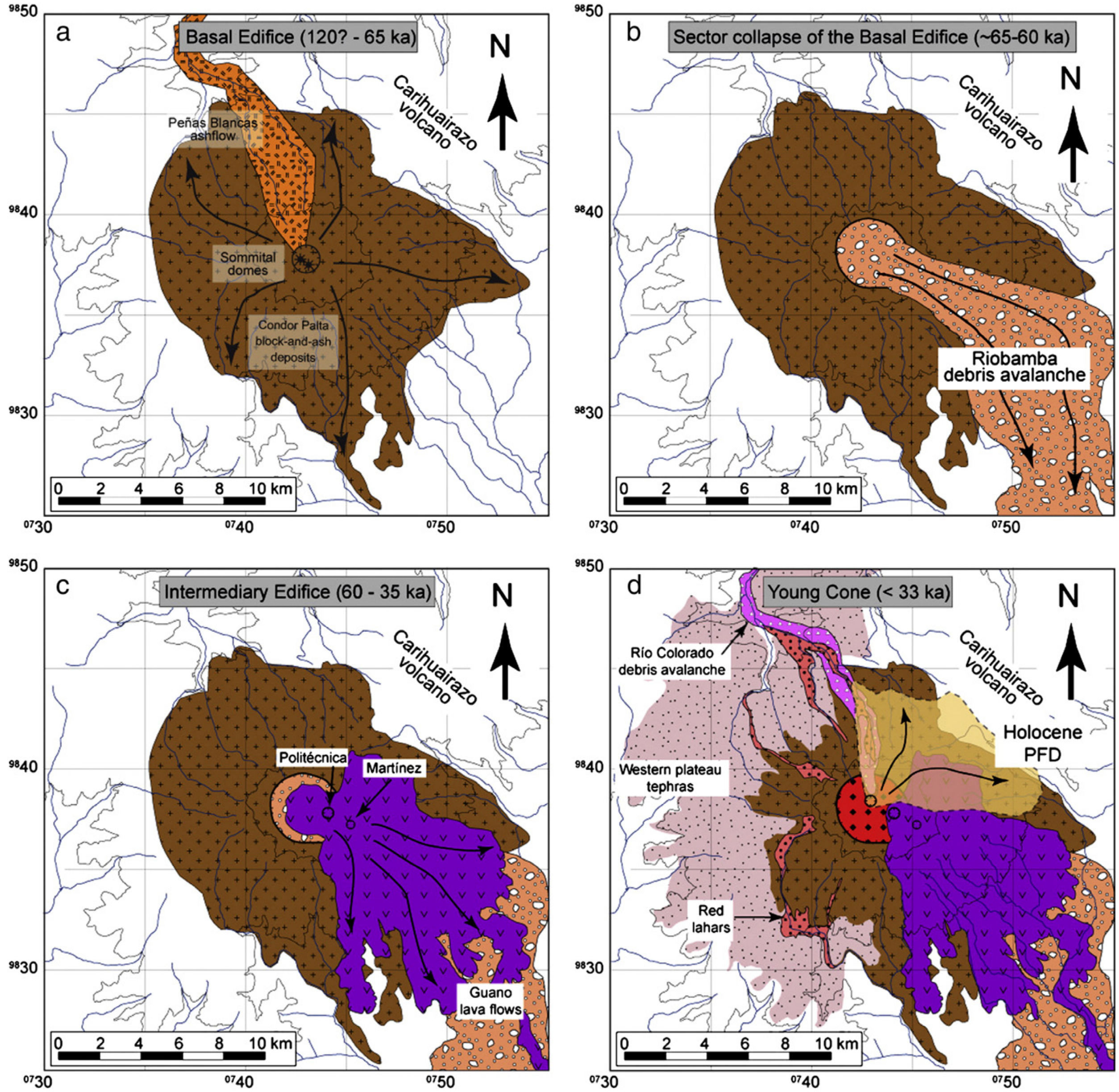


Fig. 12. Sketch diagrams showing the main development stages of Chimborazo volcano. (a) Basal Edifice and siliceous activity (ash-flow activity and domes). (b) Sector collapse affecting the Basal Edifice. (c) Post-avalanche activity and construction of the Intermediary Edifice. (d) Young Cone and sector collapse.

Figure 121: *These are both from Samaniego et al. (2012) - Captions given*

Table 4
Magma eruptive rates at Chimborazo volcano.

Edifice	Units	Volume (km^3)	Density (kg/m^3)	Volume DRE (km^3)	Total volume DRE (km^3)	Lifespan	Eruptive rate (km^3/ka)	Main cone-building stages	Peak eruptive rate (km^3/ka)
Basal Edifice (CH-I)	Abraspungo and El Castillo stages	50.4–66.4	2200[a]	39.6–52.2	44.6–58.1	120–60 ka	0.74–0.97	95–65 ka (30 ka)	1.19–1.55
	R-DAD	7.2–8.4	1950[b]	5.0–5.9		(60 ka)		80% CH-I	
Intermediary Edifice (CH-II)	Politécnica stage (Politécnica and Martínez peaks)	12.2–20.8	2200[a]	9.6–16.3	10.5–17.6	60–35 ka (25 ka)	0.42–0.70	48–33 ka (15 ka) 90% CH-II	0.63–1.06
	Guano lava flows	1.0–1.5	2500	0.9–1.3					
Young Cone (CH-III)	Murallas Rojas stage (Whymper peak)	2.2–4.2	2200[a]	1.7–3.3	2.7–4.4	35–0 ka (35 ka)	0.08–0.13	30–14 ka (16 ka) 95% CH-III	0.16–0.26
	Western plateau tephra deposits	1.8–2.1	1500	1.0–1.1					
Whole Chimborazo					57.8–80.1	120 ka	0.48–0.67		

[a] Williams and Finn (1985).
[b] Glicken (1996).

STOP 7.3: *Quilotoa Region (from Wikipedia)*

Figure 122: *Quilotoa Crater from the crater rim*

Quilotoa is a water-filled caldera and the most western volcano in the Ecuadorian Andes. The 3-kilometre (2 mi)-wide caldera was formed by the collapse of this dacite volcano following a catastrophic VEI-6 eruption about 600 years ago, which produced pyroclastic flows and lahars that reached the Pacific Ocean, and spread an airborne deposit of volcanic ash throughout the northern Andes. This last eruption followed a dormancy period of 14,000 years and is known as the 1280 Plinian eruption. The fourth (of seven) eruptive phase was phreatomagmatic, indicating that a Crater lake was already present at that time. The caldera has since accumulated a 250 m (820 ft) deep crater lake, which has a greenish color as a result of dissolved minerals. Fumaroles are found on the lake floor and hot springs occur on the eastern flank of the volcano.

Quilotoa is a tourist site of growing popularity. The route to the "summit" (the small town of Quilotoa) is generally traveled by hired truck or bus from the town of Zumbahua 17 km to the South, or more commonly by bus from Latacunga. Visitors no longer have to pay two US dollars each to look from the lip of the caldera. There are a number of simple hostels in the immediate area offering services such as mules and guides. Activities include a four to five-hour hike around the caldera (whose diameter is just over 3 km). The caldera rim is highly irregular and reaches its maximum elevations (3810 m to the N, 3894 m to the NW and 3915 m to the SE) at three lava domes. The 10 km hike is sandy and steep in places and can be quite taxing, particularly if there is fog.

It's a half-hour hike down from the viewpoint (and 1-2 hour hike back up the 280-meter vertical ascent), and very basic lodging down in its bowl. Camping is permitted at the bottom of the crater, but there is no potable water (except half-litre bottles sold at the hostel), and only a single pit toilet, located in the hostel.

The lake surface is located at 3,500 m asl. The total volume of water stored in Lake Quilotoa is 0.35 km^3. According to local inhabitants, the lake level has been slowly declining over the last 10 years. Travertine deposits occur along the shore up to 10 m above the lake level (in the year 2000).

The village of Quilotoa and the associated crater is also a popular destination within the Quilotoa Loop and is a common starting point for the Quilotoa Traverse, a multi-day village-to-village hiking route.

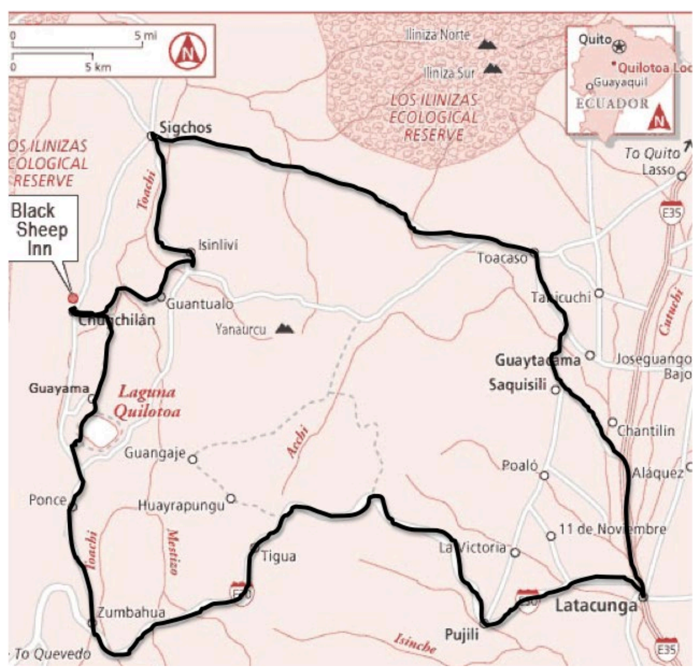


Figure 123: *Map of the Quilotoa hiking loop*

Day 8: Saturday, March 16th, 2019 – Quilotoa and Quito

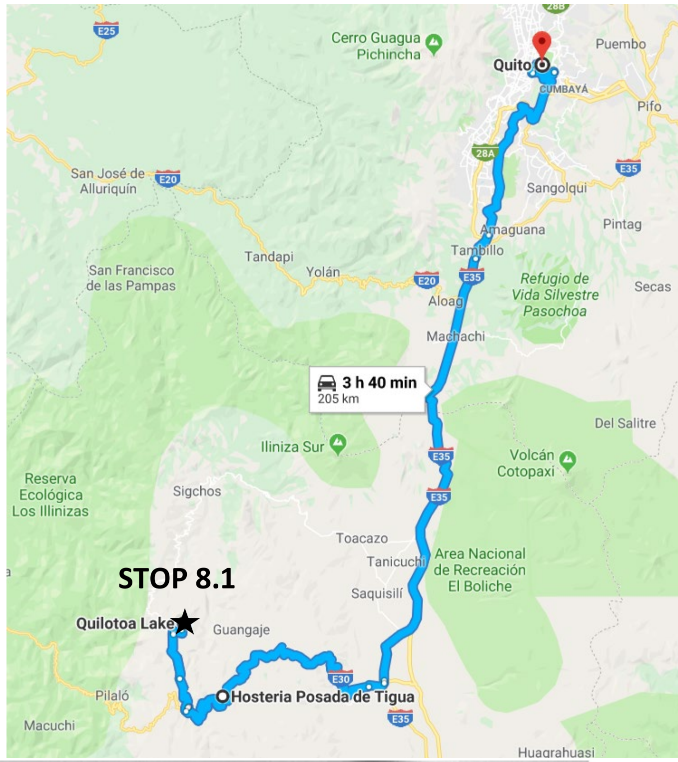
Morning – Quilotoa crater and hike down to lake.

Lunch – Box lunch

Afternoon – Return to Quito

Evening – We are on our own

Here are the accommodations:
Hosteria Posada De Tigua
Quito y Julio Hidalgo El Remanso C1
Tigua 050103, Ecuador



STOP 8.1: *Quilotoa Crater Lake*

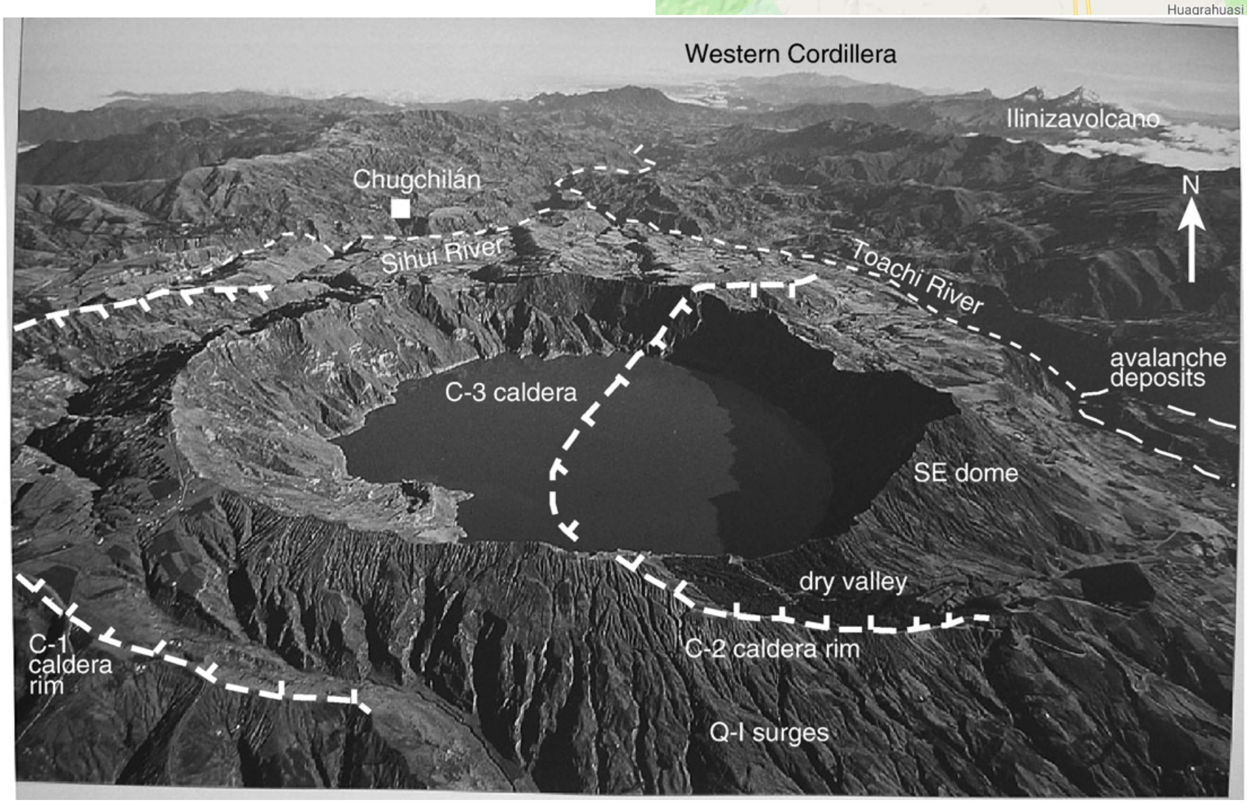


Figure 124: *An oblique photo of the Quilotoa edifice looking due north down the Toachi river valley past the present C-3 caldera with its alkaline lake. The series of calderas from C-1 to the present C-3 caldera are seen, as well as the debris avalanche deposits associated with the C-2 caldera collapse. The highly-rilled slopes in the foreground are covered by thin Q-I surge veneers. Photo by Jorge J. Anhalzer with permission. (Hall & Mothes, 2008 – Figure 1)*

From the Global Volcanism Program:

Quilotoa is a truncated, dacitic cone that is the westernmost of Ecuador's Andean volcanoes. It is located at the margin of the Western Cordillera, 35 km WNW of the city of Latacunga and contains a 3-km-wide caldera with steep-sided walls that rise 400 m above the surface of 240-m-deep caldera lake. More than a half dozen lava domes form an circular array along the caldera's perimeter. This small volcano has produced eight major explosive eruptions during the past 200,000 years. Its most recent major eruption about 800 radiocarbon years ago produced voluminous pyroclastic flows, lahars that reached the Pacific Ocean, and one of the largest airfall-tephra deposits of the northern Andes. Formation of the caldera was followed by extrusion of a small lava dome. Reports of historical eruptions from the caldera lake are somewhat ambiguous. Fumaroles are present on the lake floor and hot springs occur on the E flank.

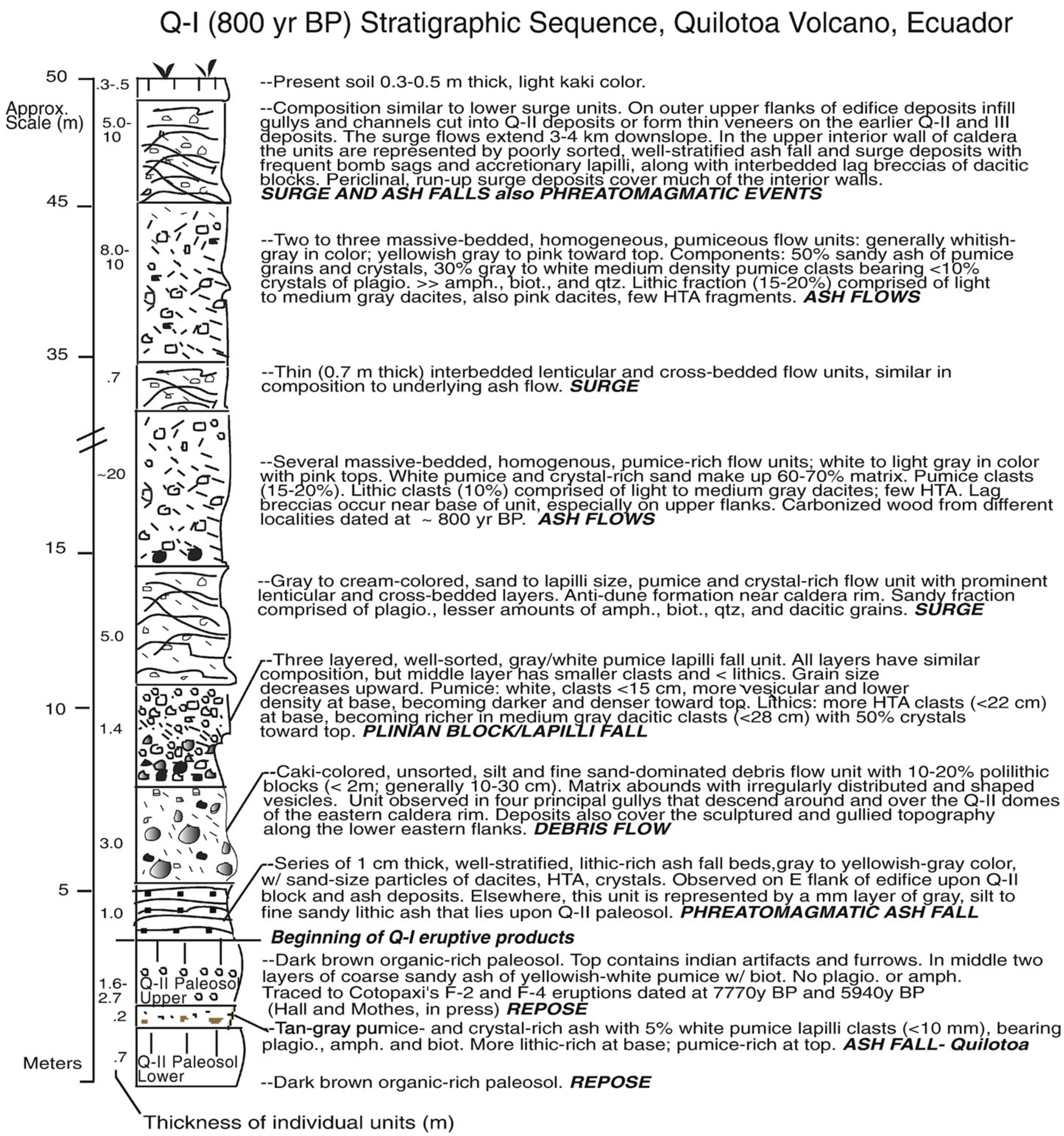


Figure 125: *Stratigraphic column representing Quilotoa's Q-I eruptive activity, starting at the Q-II paleosol and ascending the 800 yr BP eruption sequence. (Mothes & Hall, 2008 - Figure 2)*

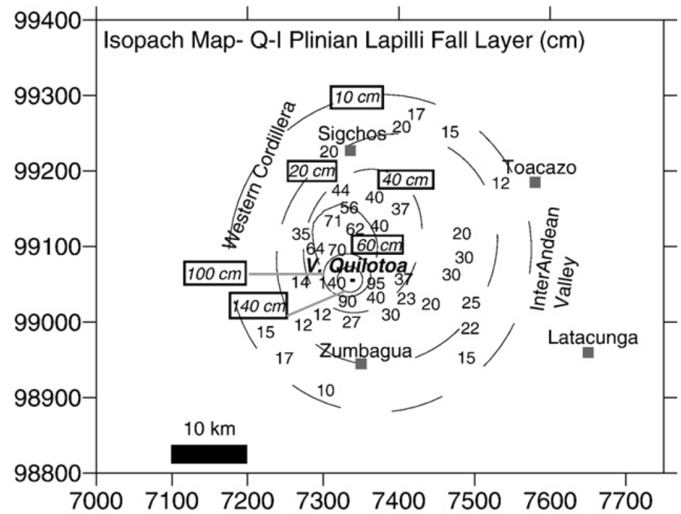


Figure 126: *Isopach map of the Q-I plinian lapilli layer showing a slight tendency to deposit to the NE toward Toacazo, where subsequent heavy deposition of the distal fine co-plinian layer makes distinction between the two layers difficult to distinguish beyond the 10 cm isopach. Note that the thicker fallout, also comprised of large clasts, had a more northern trajectory, while more distal layers were slightly influenced by NE-trending winds.*

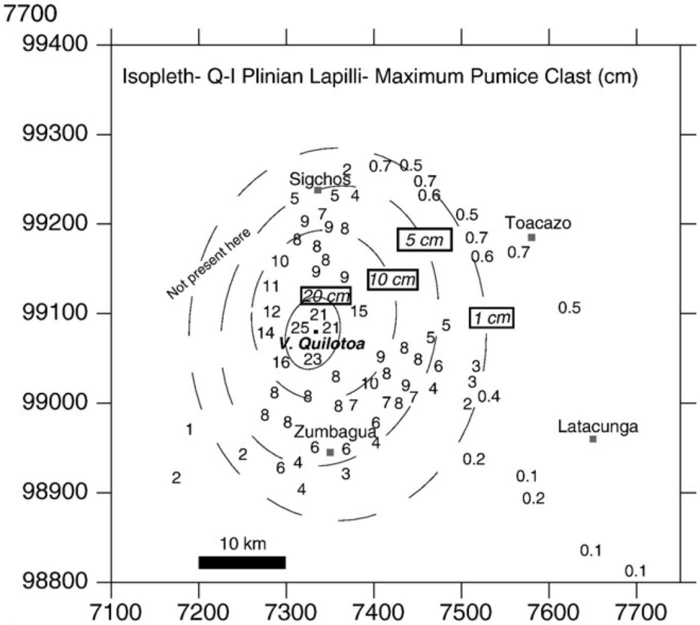


Figure 127: *Isopleth map showing the categories of size ranges of pumice clasts from the Q-I plinian lapilli fall layer.*

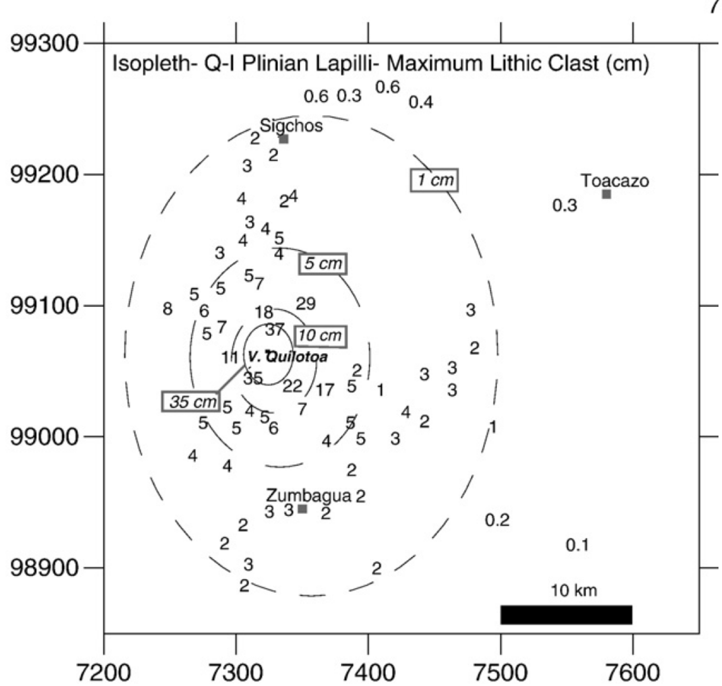


Figure 128: *Isopleth map showing the categories of size ranges of lithic clasts from the Q-I plinian lapilli fall layer.*

Day 9: Sunday, March 17th, 2019 – Fly back to DC

3:00 AM: Leave hostel for the airport

6:12 AM: Depart from Quito (Copa Airlines, Flight 210) to Panama City, Panama

8:14 AM: Arrive in Panama

9:15 AM: Depart for Washington Dulles (Copa Airlines, Flight 304)

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 (SiO2).
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.
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 (SiO2) 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 (SiO_2) 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.

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.

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.
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.
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.
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.
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.
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.
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.

REFERENCES

Andrade, D., Martin, H., and Monzier, M., 2014, Restricciones y un Posible Modelo Para la Génesis de los Magmas del Volcán Pululahua (Ecuador). Revista EPN, v. 33, no. 2, 10 pgs.

Andrade, D. and Molina, I., 2006, Pululahua Caldera: Dacitic Domes and Explosive Volcanism. Fourth Conference Cities on Volcanoes International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) – Quito, Ecuador, Excursion A3, 12 pgs.

Arellano, S.R., Hall, M., Samaniego, P., LePennec, J.-L., Ruiz, A., Molina, I., and Yepes, H., 2008, Degassing patterns of Tungurahua volcano (Ecuador) during the 1999–2006 eruptive period, inferred from remote spectroscopic measurements of SO2 emissions. Journal of Volcanology and Geothermal Research, v. 176, no. 1, pp. 151-162.

Baby, P., Rivadeneira, M., Barragán, R., and Christophoul, F., 2013, Thick-skinned tectonics in the Oriente foreland basin of Ecuador. Geological Society, London, Special Publications, v.377, pp. 59-76.

Barba, D., Robin, D., Samaniego, P., and Eissen, J.-P., 2008, Holocene recurrent explosive activity at Chimborazo volcano (Ecuador). Journal of Volcanology and Geothermal Research, v. 176, no. 1, pp. 27-35.

Bernard, B., van Wyk de Vries, B., Barba, D., Leyrit, H., Robin, C., Alcaraz, S., and Samaniego, P., 2008, The Chimborazo sector collapse and debris avalanche: Deposit characteristics as evidence of emplacement mechanisms. Journal of Volcanology and Geothermal Research, v. 176, no. 1, pp. 36-43.

Bernard, J., Kelfoun, K., LePennec, J.-L., Vargas, S.V., 2014, Pyroclastic flow erosion and bulking processes: comparing field-based vs. modeling results at Tungurahua volcano, Ecuador. Bulletin of Volcanology, v. 76, no. 9, pp. 858, 16 pgs.

Bourdon, E., Eissen, J.-P., Gutscher, M.-A., Monzier, M., Hall, M.L., and Cotton, J., 2003, Magmatic response to early aseismic ridge subduction: the Ecuadorian margin case (South America). Earth and Planetary Science Letters, v. 205, no. 3-4, pp. 123-138.

Bourdon, E., Eissen, J.-P., Gutscher, M.-A., Monzier, M., Samaniego, P., Robin, C., Bollinger, C., and Cotton, J., 2002, Slab melting and slab melt metasomatism in the Northern Andean Volcanic Zone : adakites and high-Mg andesites from Pichincha volcano (Ecuador). Bulletin of Society Geology France, v. 173, no. 3, pp. 195-206.

Coltori, M. and Ollier, C. D., 2000, Geomorphic and tectonic evolution of the Ecuadorian Andes. Geomorpholgy, v. 32, pp. 1-19.

Douillet, G.A., Pacheco, D.A., Kueppers, U., Letort, J., Tsang-Hin-Sun, È. Bustillos, J., Hall, M., Ramón, P., and Dingwell., D.B., 2013, Dune bedforms produced by dilute pyroclastic density currents from the August 2006 eruption of Tungurahua volcano, Ecuador. Bulletin of Volcanology, v. 75, no. 11, pp. 1-20.

Eychenne, J., LePennec, J.-L., Troncoso, L., Gouhier, M., and Nedelec, J-M., 2012, Causes and consequences of bimodal grain-size distribution of tephra fall deposited during the August 2006 Tungurahua eruption (Ecuador). Bulletin of Volcanology, v. 74, pp. 187-205.

Egbue, O. and Kellogg, J., 2010, Pleistocene to Present North Andean "escape". Tectonophysics, v. 489, pp. 248-257.

Hall, M.L. and Mothes, P., 2006, Cotopaxi Volcano: Rhyolites to Andesites from 0.5 Ma to the present. Fourth Conference Cities on Volcanoes International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) – Quito, Ecuador, Excursion C1, 24 pgs.

Hall, M.L. and Mothes, P., 2008, Quilotoa volcano - Ecuador: An overview of young dacitic volcanism in a lake-filled caldera. Journal of Volcanology and Geothermal Research, v. 176, no. 1, pp. 44-55.

Hall, M.L. and Mothes, P., 2008, The Rhyolitic-Andesitic Eruptive history of Cotopaxi Volcano, Ecuador. Bulletin of Volcanology, v. 70, pp. 675-702.

Hall, M.L., Robin, C., Beate, B., Mothes, P., and Monzier, M., 1999, Tungurahua Volcano, Ecuador: Structure, Eruptive History, and Hazards. Journal of Volcanology and Geothermal Research, v. 91, no. 1, pp. 1-21.

Hall, M.L., Samaniego, P., LePennec, J.L., and Johnson, J.B., 2008, Ecuadorian Andes volcanism: A review of Late Pliocene to present activity. Journal of Volcanology and Geothermal Research, v. 176, no. 1, pp. 1-6.

Garcia-Aristizabal, A., Kumagai, H., Samaniego, P., Mothes, P., Yepes, H., and Monzier, M., 2007, Seismic, petrologic, and geodetic analyses of the 1999 dome-forming eruption of Guagua Pichincha volcano, Ecuador. Journal of Volcanology and Geothermal Research, v. 161, no. 4, pp. 333-351.

Garrison, J.M., Davidson, J.P., Hall., M.L., and Mothes, P., 2011, Geochemistry and Petrology of the Most Recent Deposits from Cotopaxi Volcano, Northern Volcanic Zone, Ecuador. Journal of Petrology, v. 52, no. 9, pp. 1641-1678.

Gaunt, H.E., Bernard, B., Hidalgo, S., Proaño, A., Wright, H., Mothes, P., Criolloc, E., and Kueppers, U., 2016, Juvenile magma recognition and eruptive dynamics inferred from the analysis of ash time series: The 2015 reawakening of Cotopaxi volcano. Journal of Volcanology and Geothermal Research, v. 328, pp. 134-146.

Global Volcanism Program, 2013. Volcanoes of the World, v. 4.7.5. Venzke, E (ed.). Smithsonian Institution. Downloaded 13 Feb 2019. https://doi.org/10.5479/si.GVP.VOTW4-2013

Guevara, A., Valencia, L., Gallegos, B., Mena, F., and de la Torre, E., 2007, Evaluación de la Influencia de la Ceniza Volcánica Sobre Suelos Agricolas Aledaňos al Volcán Tungurahua. Resultados del Proyecto de Investigación PIC-CEREPS-068, 36 pgs.
Gutscher, M.-A., Malavieille, J., Lallemand, S., and Collot, J.-A., 1999, Tectonic segmentation of the North Andean margin: impact of the Carnegie Ridge collision. Earth and Planetary Science Letters, v. 168, pp.255-270.
Kelley, D.F., Uzunlar, N., Lisenbee, A., Beate, B., and Turner, H.E., 2017, A Capstone Course in Ecuador: The Andes/Galápagos Volcanology Field Camp Program. Journal of Geoscience Education, v. 65, pp. 250-262.
Leonard, G.S., Johnston, D.M., Williams, S., Cole, J.W., Finnis, K., and Barnard, S., 2005, Impacts and management of recent volcanic eruptions in Ecuador: lessons for New Zealand. Institute of Geological & Nuclear Sciences science report 2005/20, 59 pgs.
LePennec, J.-L., Hall, M.L., Robin, C., and Bartomioli, E., 2006, Tungurahua Volcano: Late Holocene Activity. Fourth Conference Cities on Volcanoes International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) – Quito, Ecuador, Excursion A1, 24 pgs.
LePennec, J.-L., Jaya, D., Samaniego, P., Ramón, P., Moreno-Yánez, S., Egred, J., and van der Plicht, J., 2008, The AD 1300–1700 eruptive periods at Tungurahua volcano, Ecuador, revealed by historical narratives, stratigraphy and radiocarbon dating. Journal of Volcanology and Geothermal Research, v. 176, no. 1, pp. 70-81.
LePennec, J.-L, Ramón, P., Robin, C., and Almeida, E., 2016, Combining historical and ^{14}C data to assess pyroclastic density current hazards in Baños city near Tungurahua volcano (Ecuador). Quaternary International, v. 394, pp. 98-114.
LePennec, J.-L, Ruiz, G.A., Ramón, P., Palacios, E.., Mothes, P., and Yepes, H., 2012, Impact of tephra falls on Andean communities: The influences of eruption size and weather conditions during the 1999–2001 activity of Tungurahua volcano, Ecuador. Journal of Volcanology and Geothermal Research, v. 217-218, pp. 91-103.
Lonely Planet, 2018, *Ecuador and the Galápagos Islands.* Lonely Planet Global Limited, Oakland, CA, 414 pgs. ISBN: 978-1-78657-062-8
Johnson, J., Ramón, P., Andrade, D., and Hall, M.L., 2006, Reventador Volcano: 2002 to present, explosive and effusive activity. Fourth Conference Cities on Volcanoes International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) – Quito, Ecuador, Excursion A5, 16 pgs.
Jordan, T.H. and Grotzinger, J., 2007, Understanding Earth (5th Edition): W.H. Freeman and Company Publishing, New York, NY, 752 pgs.
Martinod, J., Husson, L., Roperch, P., Guillaume, B., and Espurt, N., 2010, Horizontal subduction zones, convergence velocity and the building of the Andes. Earth and Planetary Science Letters, v. 299, pp. 299-309.
Mero, P.C., Franco, G.H., Briones, J., Caldevilla, P., Domínguez-Cuesta, M.J., and Berrezueta, E., 2018, Geotourism, and Local Development Based on Geological and Mining Sites Utilization, Zaruma-Portovelo, Ecuador. Geosciences, v. 8, no. 205, 18 pgs.
Mothes, P., 2006, Cotopaxi Volcano and the Surrounding Valleys. Fourth Conference Cities on Volcanoes International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) – Quito, Ecuador, Intrameeting Field Trip COV4, 32 pgs.
Mothes, P., 2014, Field Guide to the Chillos Valley, Cotopaxi Volcano and Latacunga Valley: Volcanoclastic Deposits, Eruptive History, and Mitigation Strategies. VUELCO Meeting and Summer School. Instituto Geofisico, escuela Politécnica Nacional, Quito, Ecuador, 30 pgs.
Mothes, P.A. and Hall, M.L.,2008, The plinian fallout associated with Quilotoa's 800 yr BP eruption, Ecuadorian Andes. Journal of Volcanology and Geothermal Research, v. 176, no. 1, pp. 56-69.
Mothes, P.A., Hall, M.L., and Janda, R.J., 1998, The enormous Chillos Valley Lahar: an ash-flow-generated debris flow from Cotopaxi Volcano, Ecuador. Bulletin of Volcanology, v. 59, pp. 233-244.
Mothes, P.A., Ruiz, M.C., Viracucha, E.G., Ramón, P.A., Hernández, S., Hidalgo, S., Bernard, B., Gaunt, E.H., Jarrín, P., Yépez, M.A., and Espín, P.A., 2017, Geophysical Footprints of Cotopaxi's Unrest and Minor Eruptions in 2015: An Opportunity to Test Scientific and Community Preparedness. Advances in Volcanology, 30 pgs. DOI: 10.1007/11157_2017_10
Mothes, P.A., Yepes, H.A., Hall, M.L., Ramón, P.A., Steele, A.L., and Ruiz, M.C., 2015, The scientific–community interface over the fifteen-year eruptive episode of Tungurahua Volcano, Ecuador. Journal of Applied Volcanology, v. 4, pp. 9, 15 pgs.
Morales-Rivera, A.M., Amelung, F., Mothes, P., Hong, S.-H., Nocquet, J.-M., and Jarrin, P., 2017, Ground deformation before the 2015 eruptions of Cotopaxi volcano detected by InSAR. Geophysical Research Letters, v. 44, pp. 6607-6615.
Ordónez, J., Samaniego, P., Mothes, P., and Schilling, S., 2013, Las Potenciales Zonas de Inundación por Lahares en el Volcán Cotopaxi. Field Guide for Cotopaxi, not sure the exact publication, 20 pgs.

Padrón, E., Hernández, P.A., Toulkeridis, T., Pérez, N.M., Marrero, R., Melián, G., Virgili, G., and Notsu, K., 2008, Diffuse CO2 emission rate from Pululahua and the lake-filled Cuicocha calderas, Ecuador. Journal of Volcanology and Geothermal Research, v. 176, no. 1, pp. 163-169.
Pindell, J.L. and Kennan, L., 2009, Tectonic evolution of the Gulf of Mexico, Caribbean and northern South America in the mantle reference frame: an update. *from:* James, K.H., Lorente, M.A. & Pindell, J.L. (eds) The Origin and Evolution of the Caribbean Plate. Geological Society, London, Special Publications, v. 328, pp. 1–55
Pistolesi, M., Rosi, M., Cioni, R., Cashman, K.V., Rossotti, A., and Aguilera, E., 2011, Physical volcanology of the post–twelfth-century activity at Cotopaxi volcano, Ecuador: Behavior of an andesitic central volcano. Geological Society of America Bulletin, v. 123, no. 5-6, pp. 1193-1215.
Robin, C., Samaniego, P., LePennec, J.-L., Fornari, M., Mothes, P., and van der Plicht, J., 2010, New radiometric and petrological constraints on the evolution of the Pichincha volcanic complex (Ecuador). Bulletin of Volcanology, v. 72, no. 9, pp. 1109-1129.
Robin, C., Samaniego, P., LePennec, J.-L., Mothes, P., and van der Plicht, J., 2008, Late Holocene phases of dome growth and Plinian activity at Guagua Pichincha volcano (Ecuador). Journal of Volcanology and Geothermal Research, v. 176, no. 1, pp. 7-15.
Ruiz, M.C., Lees, J.M., and Johnson, J.B., 2006, Source constraints of Tungurahua Volcano Explosion Events. Bulletin of Volcanology, v. 68, no. 5, pp. 480-490.
Samaniego, P., Barba, D., Robin, C., Fornari, M., and Bernard, B., 2012, Eruptive history of Chimborazo volcano (Ecuador): A large, ice-capped and hazardous compound volcano in the Northern Andes. Journal of Volcanology and Geothermal Research, v. 221-222, pp. 33-51.
Samaniego, P., LePennec, J.-L., Robin, C., and Hidalgo, S., 2011, Petrological analysis of the pre-eruptive magmatic process prior to the 2006 explosive eruptions at Tungurahua volcano (Ecuador). Journal of Volcanology and Geothermal Research, v. 199, no. 1, pp. 69-84.
Samaniego, P., Robin, C., Monzier, M., Mothes, P., Beate, B., and Garcia, A., 2005, Guagua Pichincha Volcano: Holocene and Late Pleistocene Activity. Fourth Conference Cities on Volcanoes International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) – Quito, Ecuador, Excursion A4, 16 pgs.
Stern, C.R., 2004, Active Andean Volcanism: its geologic and tectonic setting. REvista Geologica de Chile, vol. 31, no. 2, pp. 161-206.
The Fact File, 2018, *Ecuador Facts – 44 Important Facts about Ecuador.* Last updated on August 14th, 2018, accessed December 2018, http://thefactfile.org/ecuador-facts/
Vera, R. 2016, Geology of Ecuador. Graficas Iberia, Quito, Ecuador, 153 pgs.
Vezzoli, L., Apuani, T., Corazzato, C., and Uttini, A., 2017, Geological and geotechnical characterization of the debris avalanche and pyroclastic deposits of Cotopaxi Volcano (Ecuador). A contribute to instability-related hazard studies. Journal of Volcanology and Geothermal Research, v. 332, pp. 51-70.
Weather Spark, 2018, *Average Weather in March in Quito Ecuador*. Accessed December 2018, https://weatherspark.com/m/20030/3/Average-Weather-in-March-in-Quito-Ecuador
Winter, J.D., 2009, Principles of Igneous and Metamorphic Petrology (2nd Edition): Pearson, New York, NY, 720 pgs.
Wright, H.M.N., Cashman, K., Mothes, P., Hall, M.L., Ruiz, A.G., and LePennec, J.-L., 2012, Estimating rates of decompression from textures of erupted ash particles produced by 1999–2006 eruptions of Tungurahua volcano, Ecuador. Geology, v. 40, no. 7, pp. 619-622.
Yepes, H., Audin, L., Alvarado, A., Beauval, C., Aguilar, J., Font, Y., and Cotton, F., 2016, A new view for the geodynamics of Ecuador: implication in seismogenic sources definition and seismic hazard assessment. Tectonics, v. 35, no. 5, pp. 1249-1279.

BUDGET INFORMATION

(as of 01/01/19)

Cost of plane flights ($701.86 x 11)…………………………………………**$7,720.50**

All-inclusive tour with Expats Journeys……………………………………..**$7,425.00**
(*the charge was $825 per student and professors go for free, I just distributed the cost of the 9 students to all 11 people attending*

Total Expenditures so far…………………………………………………...**<u>$15,145.50</u>**

Funds Remaining…………………………………………………………....**$254.50**
(this money will be applied to group meals)

Total Cost of the Trip: ……………………………………………………**$15,400**

Cost per person for the trip ……………………………………………..…**$1,400**

BOOKING RECEIPTS

AIRFARE

Your Trip to Quito, Ecuador (UIO)

JustFly Booking Number: **125-888-562**
Copa Airlines Confirmation Number : **EUM4OP**
Booking Status: **Confirmed**

Pack your bags, you're all set to travel! Check in for your flight will be available only 24 hours before departure. When it's time, go to the Copa Airlines website, where you can use your Airline Confirmation Number to get your mobile or printable boarding pass.

ITINERARY

Departure

/ Airline confirmation: **EUM4OP**

Washington, DC (IAD) to Quito, Ecuador (UIO)
1 Stop

Copa Airlines Flight 357 Economy	**9:08am** **2:10pm**	Sat Mar 9 Sat Mar 9	**Washington, DC (IAD)** **Panama City, Panama (PTY)**	Duration: **5h 2m**
	Layover: 1h 23m			
Copa Airlines Flight 159 Economy	**3:33pm** **5:31pm**	Sat Mar 9 Sat Mar 9	**Panama City, Panama (PTY)** **Quito, Ecuador (UIO)**	Duration: **1h 58m**

Total Trip Time: **8h 23m**

Return

/ Airline confirmation: **EUM4OP**

Quito, Ecuador (UIO) to Washington, DC (IAD)
1 Stop

Copa Airlines Flight 210 Economy	**6:12am** **8:14am**	Sun Mar 17 Sun Mar 17	**Quito, Ecuador (UIO)** **Panama City, Panama (PTY)**	Duration: **2h 2m**
	Layover: 1h 1m			
Copa Airlines Flight 304 Economy	**9:15am** **3:05pm**	Sun Mar 17 Sun Mar 17	**Panama City, Panama (PTY)** **Washington, DC (IAD)**	Duration: **4h 50m**

Total Trip Time: **7h 53m**

Traveler 1	Ryan Kerrigan
First Name:	Ryan
Middle Name:	
Last Name:	Kerrigan
Gender:	Male
Date of Birth:	1977-09-06

Frequent Flyer # (Airline):
None

TSA / Known Traveler ID:	None
Meal Preferences:	None
Special Services:	None

Traveler 2	Tyler Newell
First Name:	Tyler
Middle Name:	
Last Name:	Newell
Gender:	Male
Date of Birth:	1999-01-29

Frequent Flyer # (Airline):
None

TSA / Known Traveler ID:	None
Meal Preferences:	None
Special Services:	None

Traveler 3	Alex Hockensmith
First Name:	Alex
Middle Name:	
Last Name:	Hockensmith

Gender:	Male
Date of Birth:	1995-11-21

Frequent Flyer # (Airline):
None

TSA / Known Traveler ID:	None
Meal Preferences:	None
Special Services:	None

Traveler 4 Kim Waltermire

First Name:	Kim
Middle Name:	
Last Name:	Waltermire

Gender:	Female
Date of Birth:	1986-10-06

Frequent Flyer # (Airline):
None

TSA / Known Traveler ID:	None
Meal Preferences:	None
Special Services:	None

Traveler 5 Jacob Marsh

First Name:	Jacob
Middle Name:	
Last Name:	Marsh

Gender:	Male
Date of Birth:	1997-03-07

Frequent Flyer # (Airline):
None

TSA / Known Traveler ID: None

Meal Preferences: None

Special Services: None

Traveler 6 ✈ Abigal Wess

First Name: Abigal
Middle Name:
Last Name: Wess

Gender: Female
Date of Birth: 1989-09-12

Frequent Flyer # (Airline):
None

TSA / Known Traveler ID: None

Meal Preferences: None

Special Services: None

E-TICKETS

	Traveler	E-Ticket
1	Ryan Kerrigan	#230-7271720726
2	Tyler Newell	#230-7271720732
3	Alex Hockensmith	#230-7271720737
4	Kim Waltermire	#230-7271720741
5	Jacob Marsh	#230-7271720743
6	Abigal Wess	#230-7271720744

RECEIPTS

	Date	Receipt #	Amount
1	Nov 29, 2018	115102842	$3873.00 USD

ORBITZ

Quito

Mar 9, 2019 - Mar 17, 2019 | Itinerary # 7395317504929

Important Information

- All passengers traveling to the US must provide valid travel documents and details of their full US destination address for US Immigration.
- Proof of citizenship is required for international travel. Be sure to bring all necessary documentation (e.g. passport, visa, transit permit). To learn more, visit our Visa and Passport page .

Washington (IAD) → Quito (UIO)

Mar 9, 2019 - Mar 17, 2019 , 5 round trip tickets

CONFIRMED
Orbitz.com Booking ID QVL79F

Your reservation is booked and confirmed. There is no need to call us to reconfirm this reservation.

Traveler Information

Jessica Miller Adult	No frequent flyer details provided
Susan Ma Adult	No frequent flyer details provided
Jennifer Hlivko Adult	No frequent flyer details provided
Kyle Sarver Adult	No frequent flyer details provided
Kyle Molnar Adult	No frequent flyer details provided

* Seat assignments, special meals, frequent flyer point awards and special assistance requests should be confirmed directly with the airline.

Mar 9, 2019 - Departure 1 stop Total travel time: 8 h 23 m

Washington IAD 9:08am → Panama City PTY 2:10pm — 5 h 2 m
Copa 357
Economy / Coach (V) | Confirm seats with the airline*

Layover: 1 h 23 m

Panama City → Quito — 1 h 58 m

Price Summary

Traveler 1: Adult	$769.50
Flight	$630.00
Taxes & Fees	$139.50
Traveler 2: Adult	$769.50
Flight	$630.00
Taxes & Fees	$139.50
Traveler 3: Adult	$769.50
Flight	$630.00
Taxes & Fees	$139.50
Traveler 4: Adult	$769.50
Flight	$630.00
Taxes & Fees	$139.50
Traveler 5: Adult	$769.50
Flight	$630.00
Taxes & Fees	$139.50
Total:	$3,847.50

All prices quoted in US dollars.

Additional Flight Services

- The airline may charge additional fees for checked baggage or other optional services.

PTY 3:33pm UIO 5:31pm
Copa 159
Economy / Coach (V) | Confirm seats with the airline*

Mar 17, 2019 - Return 1 stop **Total travel time: 7 h 53 m**

Quito Panama City 2 h 2 m
UIO 6:12am PTY 8:14am
Copa 210
Economy / Coach (U) | Confirm seats with the airline*

Layover: 1 h 1 m

Panama City Washington 4 h 50 m
PTY 9:15am IAD 3:05pm
Copa 304
Economy / Coach (U) | Confirm seats with the airline*

Airline Rules & Regulations

-
- Tickets are nonrefundable, nontransferable and name changes are not allowed.
- Please read the complete penalty rules for changes and cancellations applicable to this fare.
- Please read important information regarding airline liability limitations .

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- Call Orbitz customer care at 844-663-2266
- For faster service, mention itinerary #7395317504929

PREVIOUS SPRING BREAK GROUPS

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

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 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 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

NOTES: