

June 24, 2024

News and notes

Before going on to discuss the geology and geopolitics of [El Salvador](#), here are some news items I thought were interesting.

Geopolitics

- [Niger revokes French nuclear group's licence at major uranium mine.](#)
- Related to [last week's post: Amnesty International condemns Egypt for deportations of Sudanese refugees](#); they don't want refugees in Egypt.
- I missed this issue a [couple of weeks ago: Ecuador Suspends China Visa Deal Amid Flood Of US-Bound Migrants.](#)
- Flight to gold: [More central banks to increase gold reserves within 12 months, WGC survey finds.](#)
- I mentioned this issue in [last week's posting: "Why Africa's Largest \\$5B Nile Dam is So Controversial | WSJ Breaking Ground" on YouTube.](#)

Research and News

- Coastal geology: [Evaluating coastal lagoon sustainability through the driver-pressure-state-impact-response approach: a study of Khenifiss Lagoon, southern Morocco.](#)
- Geochemistry: [Biotite dissolution kinetics at pH 4 and 6.5 under anaerobic conditions and the release of dissolved Fe\(II\).](#)
- Petrology: [Generation of mantle-derived basaltic andesites in volcanic arcs.](#)
- More petrology: [Stress-induced changes in magnetite: insights from a numerical analysis of the Verwey transition.](#)
- Carbon cycle research: [Global patterns of organic carbon transfer and accumulation across the land-ocean continuum constrained by radiocarbon data.](#)
- Modelling an earth shattering kaboom: [Modeling airbursts by comets, asteroids, and nuclear detonations: shock metamorphism, meltglass, and microspherules.](#)
- [Disputed tectonic setting for the late Silurian-early Carboniferous development of the northern New England Orogen: detrital zircon ages suggest a continental margin arc association.](#)
- [Cryptic geological histories accessed through entombed and matrix geochronometers in dykes; Phys.org summary \[here.\]\(#\)](#)
- Sedimentology: [Evolving fill-and-spill patterns across linked early post-rift depocentres control lobe characteristics: Los Molles Formation, Argentina.](#)

- [The ‘Ultimate Honor’: Why a Colorful Mineral Honors the Smithsonian’s Namesake.](#)

Paleontology

- [\(Ceratopsidae: Centrosaurinae\) from the Campanian Judith River Formation of Montana reveals rapid regional radiations and extreme endemism within centrosaurine dinosaurs](#); Phys.org summary [here](#).
- Evolution: [Evolution and extinction in a supercontinental world: did the breakup of Rodinia provide metazoans with evolutionary salvation?](#)
- Opinion: [Why museums should repatriate fossils.](#)
- [Diuqin lechiguanae gen. et sp. nov., a new unenlagiine \(Theropoda: Paraves\) from the Bajo de la Carpa Formation \(Neuquén Group, Upper Cretaceous\) of Neuquén Province, Patagonia, Argentina](#); SciNews summary [here](#).
- [Oldest southern sauropterygian reveals early marine reptile globalization](#); Phys.org summary [here](#).
- [Micro-CT data reveal new information on the craniomandibular and neuroanatomy of the dicynodont *Gordonia* \(Therapsida: Anomodontia\) from the late Permian of Scotland](#); Phys.org summary [here](#).
- [The relationships and paleoecology of *Pachystropheus rhaeticus*, an enigmatic latest Triassic marine reptile \(Diapsida: Thalattosauria\)](#); SciTechDaily summary [here](#).
- [The Wasps \(Hymenoptera\) from Lower Cretaceous Lebanese and Spanish Ambers.](#)

Mineral Deposit Geology

- [The Spatial and Temporal Evolution of the Sadisdorf Li-Sn-\(W-Cu\) Magmatic-Hydrothermal Greisen and Vein System, Eastern Erzgebirge, Germany .](#)
- [Zircon Petrochronology of Au-Rich Porphyry and Epithermal Deposits in the Golden Quadrilateral \(Apuseni Mountains, Romania\).](#)

Mining and Energy

- Seabed mining: [Over 200 million metric tons of rare metals found near remote Tokyo island.](#)
- [Vale unveils \\$3.3 billion plan to boost copper and nickel output.](#)
- [Five reasons why we are entering the next copper super cycle.](#)
- [SaskPower, Cameco and Westinghouse sign MOU on future nuclear development.](#)
- [Oil exploration boom in Namibia.](#)
- Batteries: [Urgent needs for second life using and recycling design of wasted electric vehicles \(EVs\) lithium-ion battery: a scientometric analysis.](#)

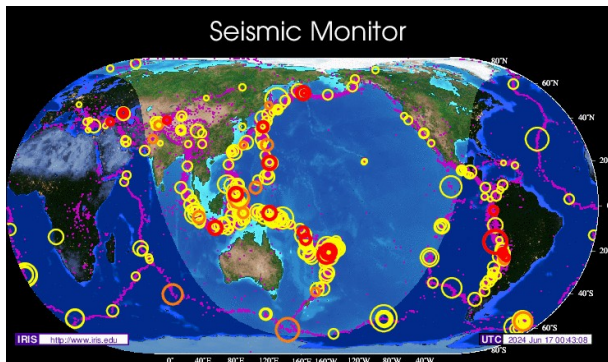
Environmental Geology and Hydrogeology

- [B.C. launches lawsuit against makers of 'forever chemicals'](#).
- [How the Recycling Symbol Duped People into Buying More Plastic](#).
- [One in Four US Households Likely Exceed New Soil Lead Guidance Levels](#); Phys.org summary [here](#).
- Soil remediation research: [Macrophyte assisted phytoremediation and toxicological profiling of metal\(loid\)s polluted water is influenced by hydraulic retention time](#).
- This affects soil remediation: [Conceptualizing soil fauna effects on labile and stabilized soil organic matter](#); Phys.org summary [here](#).
- [British Columbia coal miner fined for repeatedly violating environmental protection regulations](#).
- Groundwater research: [Joint inversion of induced polarization and hydraulic tomography data for hydraulic conductivity imaging](#).

Glaciers and Climate Change

- [A 12-year climate record of wintertime wave-affected marginal ice zones in the Atlantic Arctic based on CryoSat-2](#).
- Climate engineering, what could go wrong? [Diminished efficacy of regional marine cloud brightening in a warmer world](#); Guardian summary [here](#).
- Climate change records: [Holocene solar activity inferred from global and hemispherical cosmic-ray proxy records](#).

Volcanoes, Earthquakes and Geohazards



[Seismic Monitor](#)



[Active Volcano Map](#)

- United States Geological Survey (USGS) Volcano Watch: [Petrologists gather to discuss challenges and goals in understanding Kilauea chemistry](#).

- USGS Yellowstone Volcano Observatory(YVO): [The YVO 2023 Annual Report](#).
- [Smithsonian / USGS Weekly Volcanic Activity Report](#).



Mt. Fuji, Fine Wind, Clear Weather (Gaifū kaisei)
Credit: [Katsushika Hokusai](#) (1760-1849), [public domain](#)

- [Changes in the magmatic plumbing system associated with the Gotemba sector collapse at Mount Fuji, Japan](#).
- [Hokkaido University researcher awarded the Ben Cullen Prize 2024](#) for paper “[Disaster, survival and recovery: the resettlement of Tanegashima Island following the Kikai-Akahoya ‘super-eruption’](#)”.
- [Euro-Mediterranean Seismological Centre](#); celebrating their 50th Anniversary, guestbook [here](#).
- [Earthquakes Monitoring Live Worldwide](#).
- [M4.3 earthquake on Maacama Fault rattles Northern California](#); USGS summary [here](#).
- [M6 earthquake beneath northern Venezuela was felt up to 700 km away](#); USGS summary [here](#).
- Earthquake research: [Mapping bedrock topography and detecting blind faults using the fundamental resonance of microtremor: a case study of the Pohang Basin, southeastern Korea](#).
- More earthquake research: [Directional amplification across the San Jacinto fault zone, CA](#).

Upcoming Events

- If you are in Calgary for the Stampede: [Bootleggin’ Breakfast 2024](#), Calgary, AB, July 9 & 11, 2024, plus [Stampede After Parties Announced!](#)
- [Goldschmidt 2024, August 18-24, Chicago IL](#), organized by the Geochemical Society and the European Association of Geochemistry.
- [Groundwater Week 2024](#), December 10-12 in Las Vegas, Nevada.

June 24, 2024

Geology and the Fate of Societies – El Salvador



Figure 1a – El Salvador

Credit: [CIA World Factbook](#), public domain



Figure 1b – Location Map

Credit: [CIA World Factbook](#), public domain

The [Republic of El Salvador](#) is a country in [Central America](#). To the northeast of the country is [Honduras](#); to the northwest is [Guatemala](#); and to the south is the [Pacific Ocean](#). According to the [Central Intelligence Agency](#) (CIA) [World Factbook on El Salvador](#), the total area of El Salvador is 21,041 square kilometres (km²). Of the total area, 20,721 km² is land and 320 km² is water.

The government of El Salvador is a unitary [presidential republic](#). The President is [Nayib Bukele](#) and the Vice President is [Félix Ulloa](#). The legislature consists of a single house, the [Legislative Assembly](#). The Capital City and largest city in the country is [San Salvador](#), population 2,177,432 in the metropolitan area. Also according to the CIA World Factbook, 6,628,702 people live in El Salvador, about 75.4% of total population live in urban areas. The overall population density is 318.6 people per km².

Of the approximately 6.63 million people in El Salvador, 86.3% of the population are [Mestizo](#); 12.7% consider themselves [White](#); 0.2% are [Indigenous](#) (includes [Lenca](#), [Kakawira](#), and [Nahua-Pipil](#)), 0.1% consider themselves [Black](#); and the remaining 0.6% are something other. [Spanish](#) is the official language of El Salvador although Indigenous languages such as [Nawat](#) are also spoken. A plurality of [Salvadorans](#), 43.9%, are [Roman Catholic](#). Of the remainder, 39.6% are members of various [Protestant Christian](#) Churches including [Methodists](#) and [Baptists](#). 16.3% of Salvadorans say they have no religion and 0.2% are something other. In terms of education, 89.1% of the population 15 years old and older can read and write; typical schooling lasts 12 years.

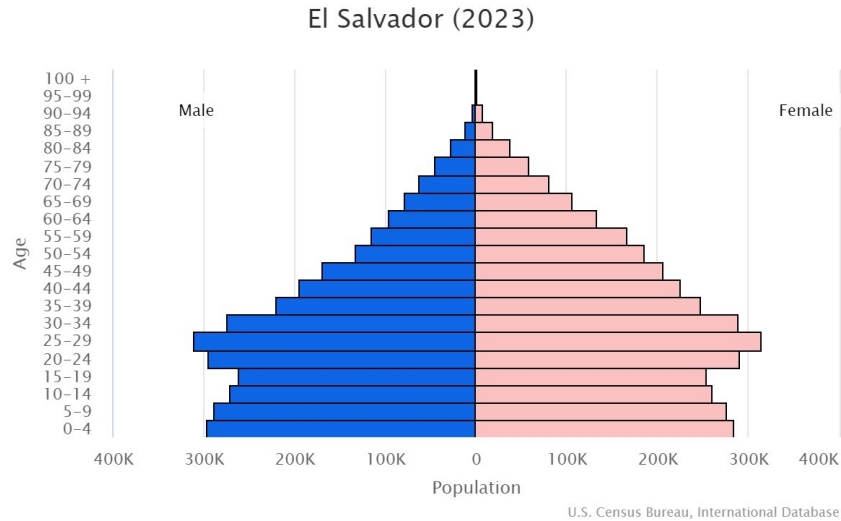


Figure 2 - Demographic Profile of El Salvador
Credit: U.S. Census Bureau, International Database, public domain

The [demographic profile of El Salvador](#) shows a fairly stable population where the median age is 29.7 years for both sexes. However, many Salvadorans fled during the [1979 to 1992 civil war](#) mainly to the [United States](#) but also to [Canada](#), [Mexico](#), Guatemala, Honduras, [Nicaragua](#), and [Costa Rica](#). Approximately 20% of all Salvadorans live abroad. Among those remaining, the life expectancy for both sexes is 75.6 years. The total fertility rate is 2.04 births per woman and the annual growth rate is 0.5%.

Geology

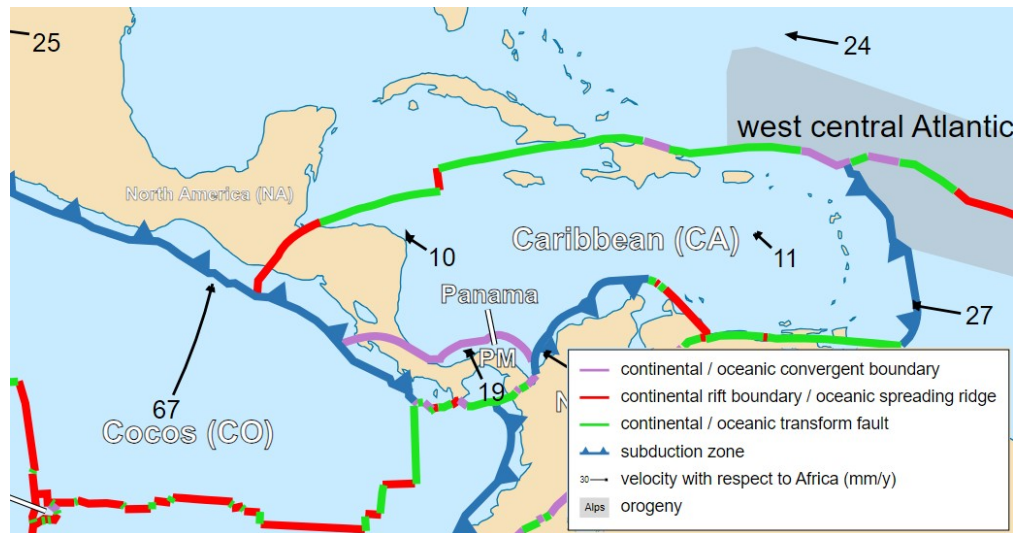


Figure 3 – Extract of Detailed Tectonic Plate Boundaries
Credit: Eric Gaba (Sting), Creative Commons Attribution-Share Alike 2.5 Generic license

Figure 3 shows the tectonic setting for the [geology of El Salvador](#). El Salvador sits on the [Caribbean Plate](#). To the west, is a [subduction zone](#) where the [Cocos Plate](#) slides under the Caribbean Plate resulting in a chain of volcanoes known as the [Central America Volcanic Arc](#). To the northwest, just across the border in Honduras, the Caribbean Plate meets the [North American Plate](#) in a [divergent boundary](#). To the

south is a convergent boundary in Costa Rica and [Panama](#) with the [Panama Plate](#). These tectonic interactions all give El Salvador a very active geology. In 2023, El Salvador [had 4,072 earthquakes](#) of magnitudes up to 6.5. [Seven volcanoes are considered active](#) in El Salvador.

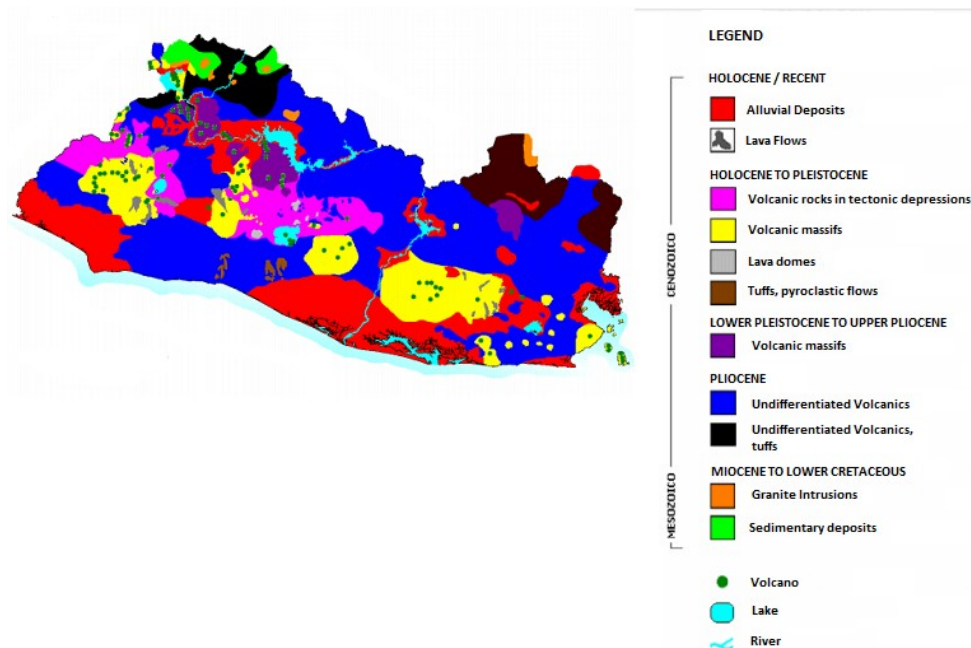


Figure 4 – Geology of El Salvador
Credit: ©Map of El Salvador

The stratigraphic sequence in El Salvador is as follows, from youngest to oldest:

- **Alluvial Deposits**, ([Holocene/Recent](#)): gravels, sands and clays along rivers and in local depressions. Deposits of this material are found on a large scale in the coastal plains to the SW and SE of the country.
- The **San Salvador Formation** (Holocene to [Pleistocene](#)) is found in the young volcanic chain that runs through the southern part of the country and made up of extrusive products from individual volcanoes, including [lava](#) flows, [lava domes](#), [pyroclastic deposits](#), [tuffs](#), [pumice](#), [volcanic breccia](#), and [volcanic ash](#); occasionally there are interbedded [lacustrine](#) sediments. The thickness of the strata and succession varies from volcano to volcano. Brown and black [paleosols](#) (fossil soils) are also found. Some of these rocks are in [volcano-tectonic depressions](#) ([caldera](#)) and volcanic [massifs](#).
- The **Cuscatlán Formation** ([Lower Pleistocene](#) to [Upper Pliocene](#)) is found in a chain of old volcanic that runs through the northern part of the country and forms a massif; it is composed of extrusive products from individual volcanoes such as lava flows, tuffs, [agglomerates](#), volcanic breccia and hardened volcanic ashes and pyroclastic deposits with interbedded lacustrine and fluvial sediments. The thickness of the strata and their succession varies from volcano to volcano. Shallow red paleosols (up to 4 meters) are also found.

- The **Balsamo Mountain Range** ([Pliocene](#)) is composed of volcanic products in which agglomerates abound with intercalations of hardened volcanic tuffs and [basaltic-andesitic](#) lava flows with an approximate thickness of 500 m. There are also very deep paleosols (up to 20 m). In addition, extrusive rocks are found with few intercalations of volcanic tuffs and agglomerates; The lower part is andesitic in character and the upper part is basaltic. There are some more acidic outcrops (even [rhyolitic](#)) especially in the east of the country. The approximate thickness of the latter is greater than 1000 m.
- The **Chalatenango Formation** ([Upper Miocene](#)) consists of acidic volcanic rocks of rhyolitic-[dacitic](#) character; very hardened tuffs of light colours prevail; The thickness of this series is greater than 500 m.
- The **Morazán Formation** ([Miocene](#)), composed of extrusive volcanics ranging from [intermediate/basic](#) volcanic rocks to [acidic](#) rocks such as pyroclastic deposits, rhyolite and [volcaniclastic](#) rocks.
- The **Metapán Formation** ([Early Miocene](#) to [Early Cretaceous](#)) is made up of thin violet-red Early Miocene [sandstones](#) with [quartzite conglomerates](#); underneath are there are red [limestone](#) conglomerates with layers of sandstone; this series represents the erosion products of the lowermost layers; it has a thickness of greater than 400 m. The [Albian](#) aged rocks are violet andesitic volcanic tuffs approximately 100 m thickness. The Early Cretaceous deposits are fine-grained red sandstones, with clay cement and fine stratifications; deeper down there are quartz conglomerates that are generally [silicified](#) and [metamorphosed](#) with a thickness greater than 350 m.
- **Granitic Intrusions**, [batholiths](#), in the Northern mountains are also of [Cretaceous](#) age.

Resources

Agriculture



Figure 5 – Corn Field in El Salvador

Credit: [randreu](#), [Creative Commons Attribution 3.0 Unported](#) license

The CIA World Factbook indicates that 74.7% of the land in El Salvador is used for agriculture (33.1% [arable land](#), 10.9% [permanent crops](#), and 30.7% [permanent pasture](#)). Of the remainder, 13.6% is forest and the final 11.7% has other, or no, use – this includes urban areas.

[Coffee](#) (by far the largest cash crop, [30653 tonnes in 2022](#)), [cotton](#), corn ([maize](#)), and [sugarcane](#) are the most important agricultural products in El Salvador. Other food production includes [bananas](#), [coconuts](#), [tamarind](#), [melons](#), [mango](#), [jalapeño peppers](#), [okra](#), and [pineapple](#). Flowers, especially [marigolds](#), have become an export item. For livestock, [cattle](#), [hogs](#), and [poultry](#) are raised. Statistics on agricultural production from the [United Nations Food and Agriculture Organization](#) (FAO) can be found [here](#). Information on the current crop year, also from the FAO, can be found [here](#).



Figure 6 – Fishing Wharf at Puerto El Triunfo
Credit: Larry Osman, [public domain](#)

[Fishing](#), both [artisanal](#) and [commercial](#) are also important sources of food in El Salvador. Species caught include [shrimp](#), [lobster](#), [mullet](#), [snappers](#), [jacks](#), [groupers](#), [sharks](#), and [anchovies](#).

In recent years, Salvadorans have begun raising fish in [aquaculture](#). Species raised include [tilapia](#) (*Oreochromis spp*), whiteleg shrimp (*Penaeus vannamei*) and giant river prawns (*Macrobrachium rosenbergii*). Since much of the aquaculture produce is exported, look for it in your fish market. [Sport fishing](#) is another popular fishing activity among adventurous tourists.

Overall, El Salvador is a food importer since much of the country’s agricultural production in the country consists of commercial cash crops for export. [Food imports in El Salvador are worth 36% more than food exports](#). Recent political disorder, such as the [1979 to 1992 civil war](#) didn’t do much to help the farmers an encourage production. The [FAO](#) indicates that in the period 2020 – 2022, 48.4% (almost half!) of the population suffered from severe or moderate food insecurity.

Forestry



Figure 7 – Forest near Laguna de Alegría

Credit: [Viktor Pinchuk](#), [Creative Commons Attribution-Share Alike 4.0 International](#) license

As noted above, the CIA World Factbook, 13.6% of the land in El Salvador is forest. Natural [forest cover](#) in El Salvador has been greatly reduced by the needs of agriculture. Highland areas of the country were [deciduous oak and pine forests](#). Among the native trees in El Salvador is the [balsa](#) (*Ochroma pyramidale*). Well known forest areas include the [Bosque Conchagua](#), [Bosque La Joya](#) and the [Bosque San Diego La Barra](#). Statistics on forest production from the FAO are shown [here](#). You can also look at an interactive map of deforestation in El Salvador [here](#).

Mineral Resources



Figure 8 – Pozzolana Quarry near Ciudad Arce

Credit: [Daniel Chavez Castro](#), [Creative Commons Attribution 3.0 Unported](#) license

Köppen-Geiger climate classification map for El Salvador (1980-2016)



Figure 10 – Köppen-Geiger Climate Classification for El Salvador

Credit: [Beck et al, 2018](#), [Creative Commons Attribution-Share Alike 4.0 International](#) license

As a tourist destination, El Salvador has not been a favourite in the past, despite its fine climate. Travel advisories [here](#) and [here](#) make it clear why you might want to stay away. If you still want to go, check out [Climates to Travel](#) and [Lonely Planet](#). As a geologist, the volcanoes certainly are an attraction to me.

History and Geopolitics

A Violent History



Figure 11 – Mayan Ruins of Tazumal in Santa Ana, El Salvador

Credit: [Paralogical](#) at [en.wikipedia](#), [Creative Commons Attribution 3.0 Unported](#) license

It seems to be a sad fact that some of the most beautiful places in the world have some of the saddest histories. The [history of El Salvador](#) seems to fit this observation. I won't go into great detail, rather I'll

provide you with a few links and you can follow up on what interests you. Briefly, the main points of Salvadoran history are as follows:

- The [history prior](#) to the arrival of the Spaniards, intertribal wars and human sacrifice;
- The [Spanish conquest](#) 1524 to 1525, conquest might be too polite a word;
- The [colonial period](#) 1525 to 1821, subjugation/enslavement of the native population and elite competition between [Criollos](#) and [Peninsulares](#).
- The [struggle for independence](#) 1821 to 1841, kicking out the Peninsulares;
- The rise of a [native oligarchy](#) connected to the export of cash crops, 1841 to 1931, i.e. powerful families running the country like a business;
- The rule of [military dictatorships](#) 1931 to 1979, resolving the differences between the oligarchs;
- [Civil war 1979 to 1992](#), lots of bloodshed over who gets to run the country, and lots of people fleeing the violence;
- The post-war period 1992–2019; the habits of the civil war period continued with [organized crime](#) in the form of “[maras](#)”, the most notorious of which is [MS-13](#) ([accused of human sacrifice](#));
- The current regime that has [declared war on the criminal gangs](#) and reduced the country’s homicide rate by 70% – you can hear President Bukele describe the struggle in his own words [here](#), it’s about an hour long.



Figure 12 – Honduran Chance-Vought F4U-5N Corsair Used in 1969 Football War
Credit: [Bidgee](#), [Creative Commons Attribution-Share Alike 3.0 Australia](#) license

As if their internal troubles were not enough, El Salvador periodically gets into [wars](#) for various reasons. Some of these were dust-ups with its neighbours over boundaries and resources; some were part of much larger disputes such as [World War II](#); and some appear purely [Ruritanian](#) frivolity such as the [Football War of 1969](#). Frivolous or not, real people suffered and died.

For another view on the politics and history of El Salvador, check out this video [here](#).

Geopolitics – A Dangerous Part of the World



Figure 13 – Puente El Jobo, the Border between Guatemala and El Salvador
Credit: MomoSV, [Creative Commons Attribution-Share Alike 4.0 International](#) license

The current president of El Salvador has hit upon a pathway to restore order in his troubled country after decades of civil war and criminal activity. We can only wish the people of El Salvador well and hope that they succeed in building a peaceful polity. [It won't be easy](#), but at least they seem to be on the right path, despite the [protests](#) of those who don't have to live with crime and disorder.

El Salvador still has problems with its neighbours Guatemala and Honduras. Maybe they always will as a geopolitical reality. The current big issue for all three countries is that [people are still seeking to leave](#) these and other countries, [often to escape disorder](#). The United States is often their preferred future destination. However it works out, mass migrations are potent sources of disorder in their own right and will challenge El Salvador's people and government for years to come.

This brings in the United States, a Great [Power and hegemon](#) with a strong interest in what happens in El Salvador. Simply stated, the USA cannot forever take in unlimited numbers of migrants. The disorder such migrations bring can disturb the peace of any polity, even large countries like the USA and even when most of the migrants are poor, but peaceful people. With an upcoming election, [where immigration will be a major issue](#), expect changes in how the USA deals with immigrants. This will affect El Salvador, [remember that about 1/4 of the country's Gross Domestic Product](#) is made up of remittances from expatriate Salvadorans to their families back home. An attack on immigrants could dry up this source of income. Keep an eye on this issue.

Another concern for the Americans with regard to El Salvador is the influence of other [Great Powers such as China](#). China is seeking to expand its influence in Central America and has proposed [building a deep water port off the coast of El Salvador](#). China is seeking trade opportunities and political influence. Also, by acting in America's backyard, China can divert American interest away from other Chinese projects, such a potential war to conquer Taiwan. It is a serious game and El Salvador could get caught up in much larger disputes between the USA and China.

That kind of wraps things up for now. I probably missed some things about El Salvador, but I think that we got to look at the essentials. I expect to be on holiday for the next couple of weeks, so I'll just show news and research links in my weekly posts.

Standard Caveat

The purpose of my weblog postings is to spark people's curiosity in geology. Don't entirely believe me until you've done your own research and checked the evidence. If I have sparked your curiosity in the subject of this posting, follow up with some of the links provided here. If you want to, go out into the field and examine some rocks on your own with the help of a good field guide. Follow the evidence and make up your own mind.

In science, the only authority is the evidence.