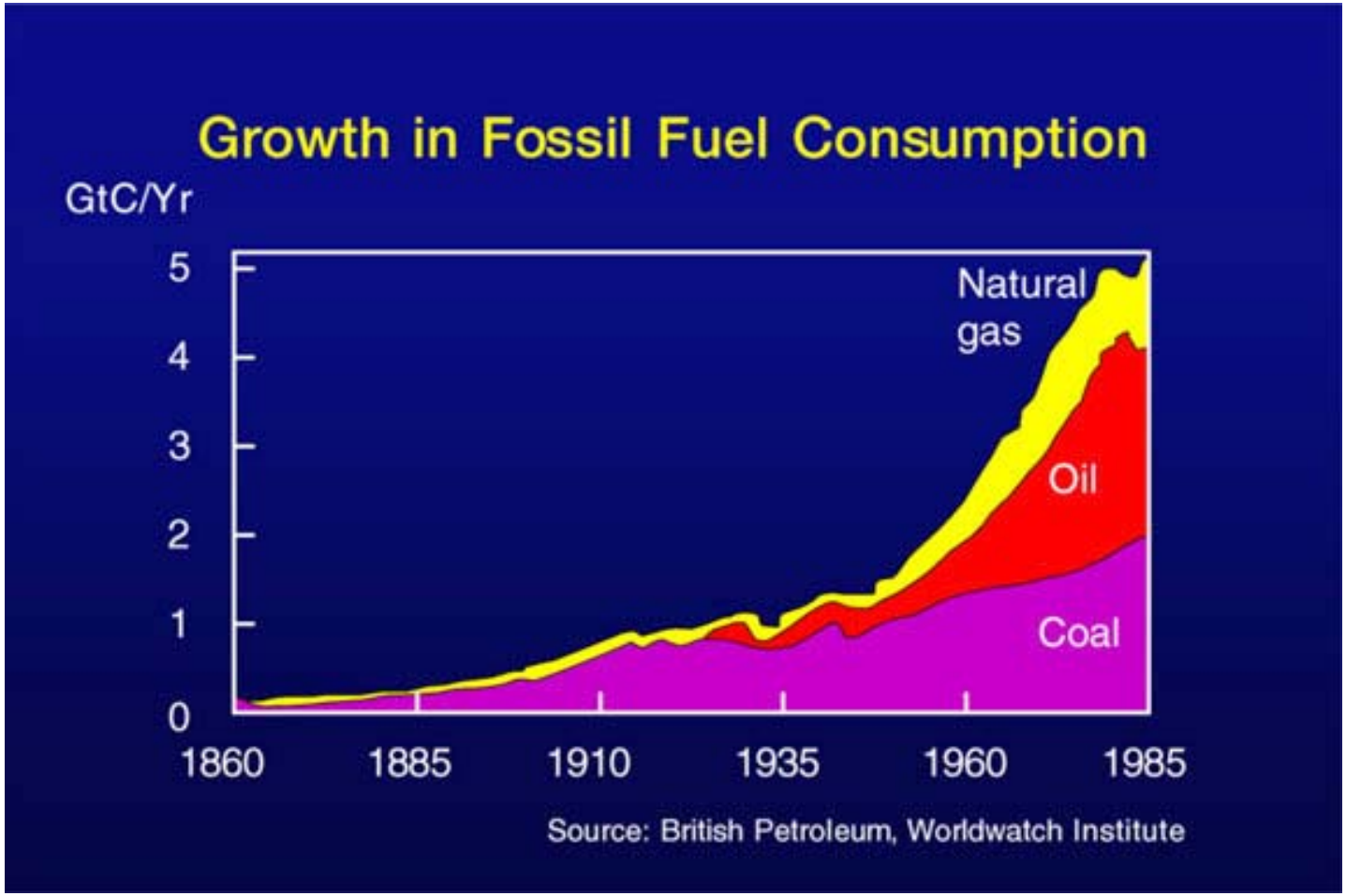
Geothermal Energy in Latin America

Energy and Development

- Latin American economies require energy to power industry
- Most electrical energy comes from burning of fossil fuels

Most Energy is Produced by Burning Fossil Fuels



GtC/Yr = Giga tons of Carbon per year

http://geothermal.marin.org/GEOpresentation/sld117.htm

Problems with Burning Fossil Fuels

- Expensive - many countries must import
- Contributes to local pollution and global warming
- Nonrenewable

Renewable energy can be obtained from wind, solar, hydro-, and geothermal energy sources. For the parts of Latin America that have volcanoes, the most important of these is geothermal.

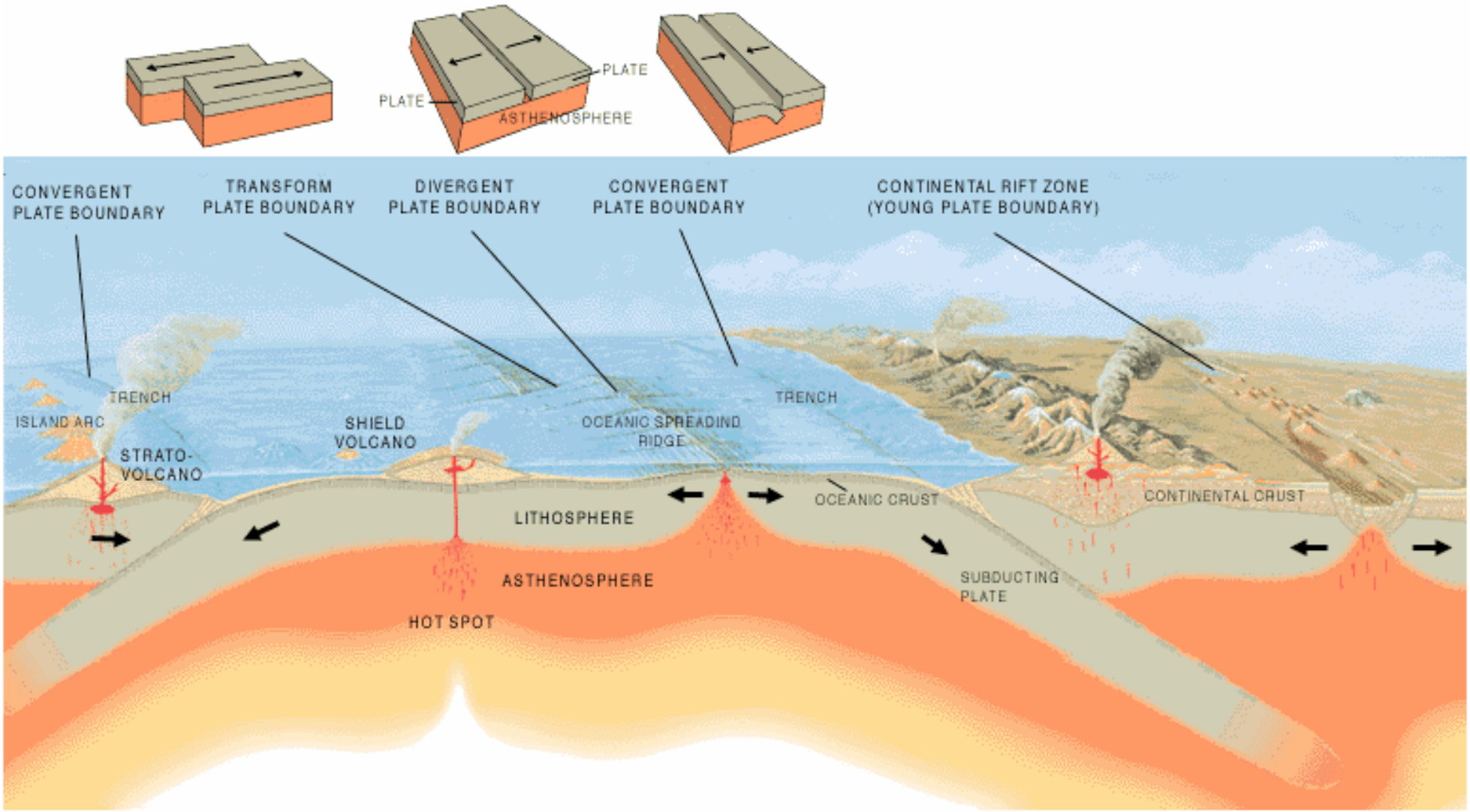
http://geothermal.marin.org/GEOpresentation/sld121.htm

What is Geothermal Energy?

- Geothermal Energy is heat (thermal) derived from the earth (geo). It is the thermal energy contained in the rock and fluid in the earth's crust.
- Geothermal energy is abundant around volcanic regions, especially where water can sink deep into the ground and be heated.
- These resources can be classified as low temperature (less than 90°C or 194°F), moderate temperature (90°C - 150°C or 194 - 302°F), and high temperature (greater than 150°C or 302°F).
- The highest temperature resources are needed for electric power generation.
- Uses for low and moderate temperature resources can be divided into two categories: direct use and ground-source heat pumps.
- Direct use uses the heat in the water for heating of buildings, greenhouses, aquaculture, and resorts.

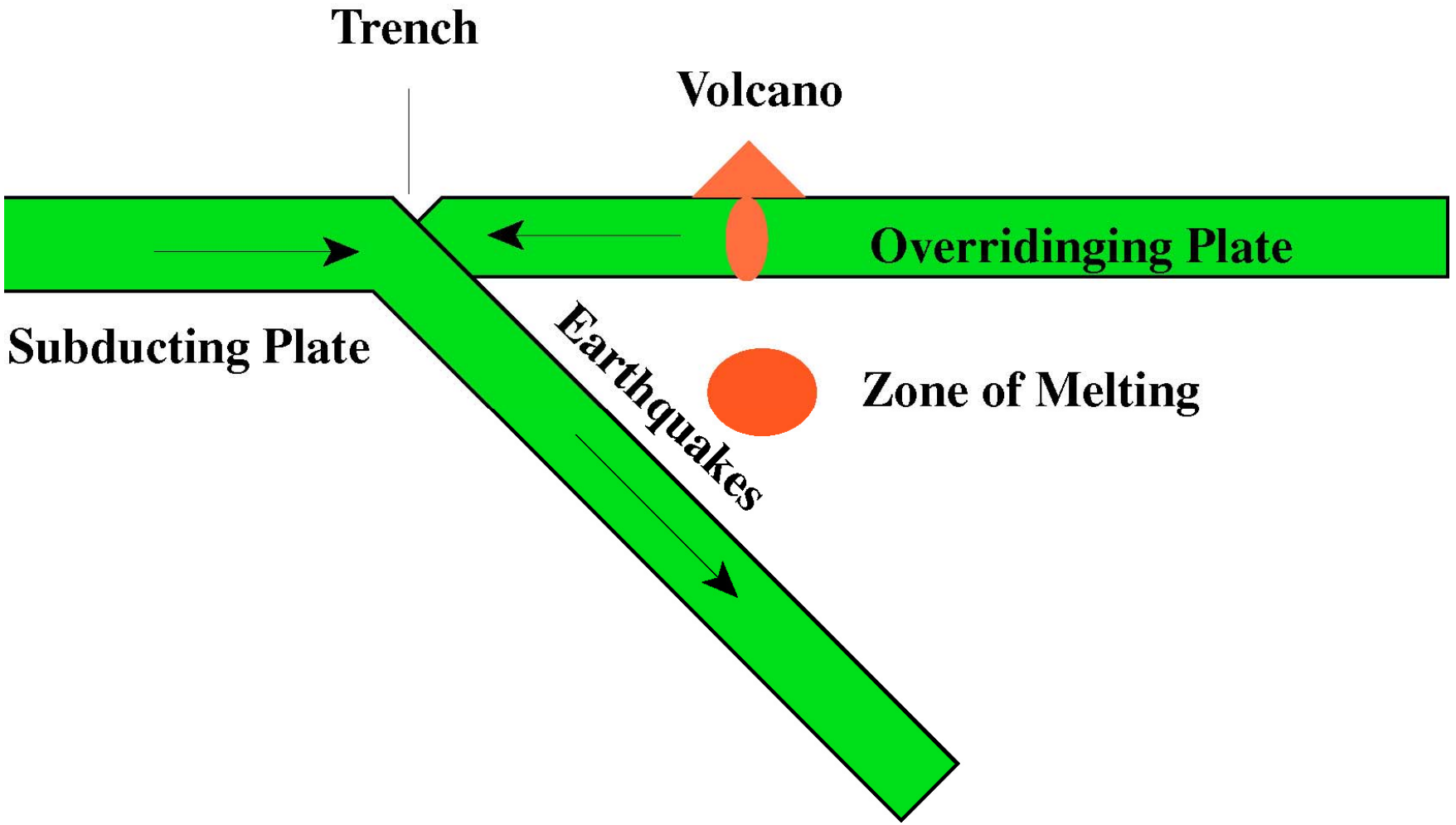
http://geoheat.oit.edu/whatgeo.htm

Plate Tectonics review

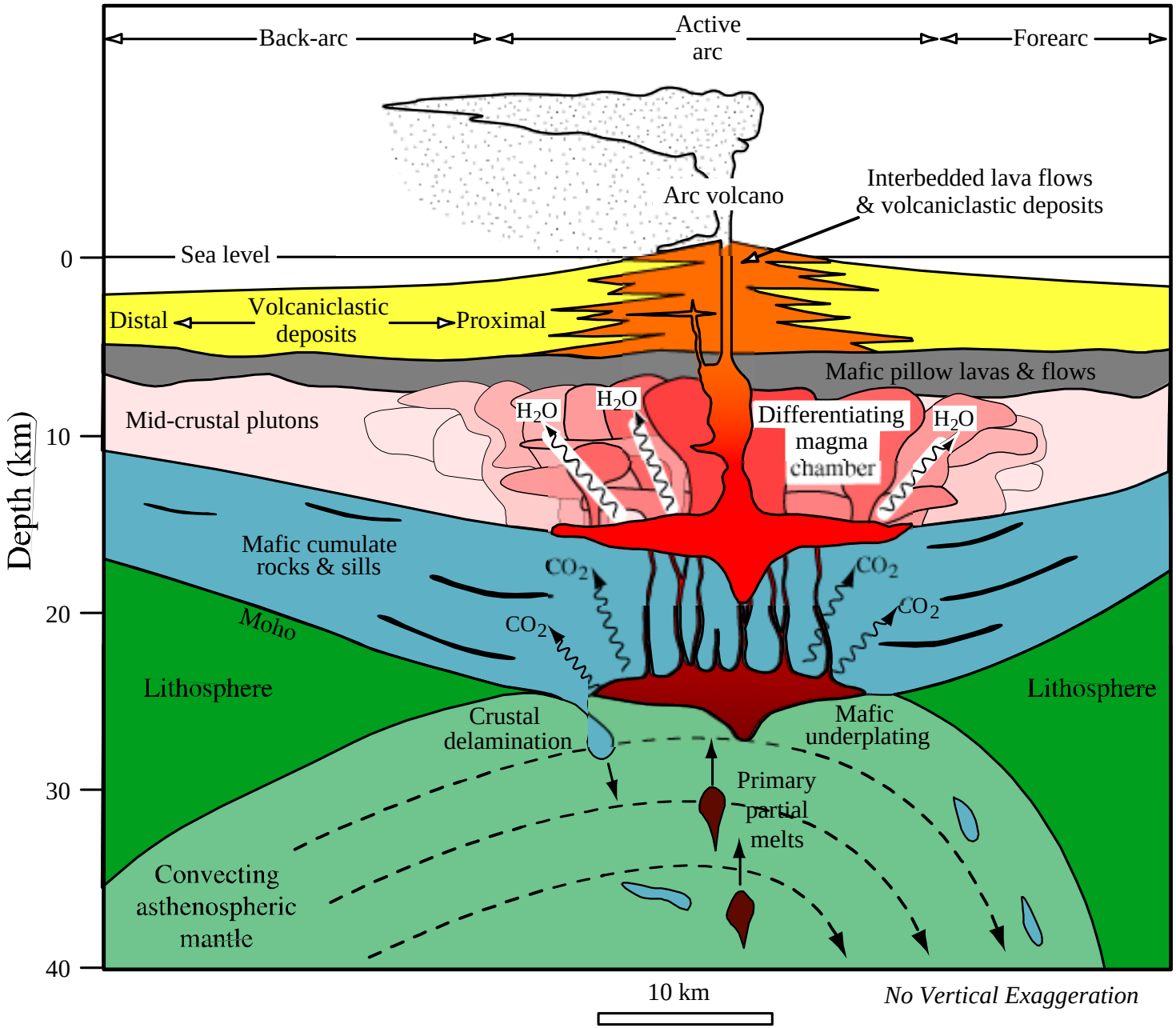


"This Dynamic Earth" http://pubs.usgs.gov/publications/text/Vigil.html

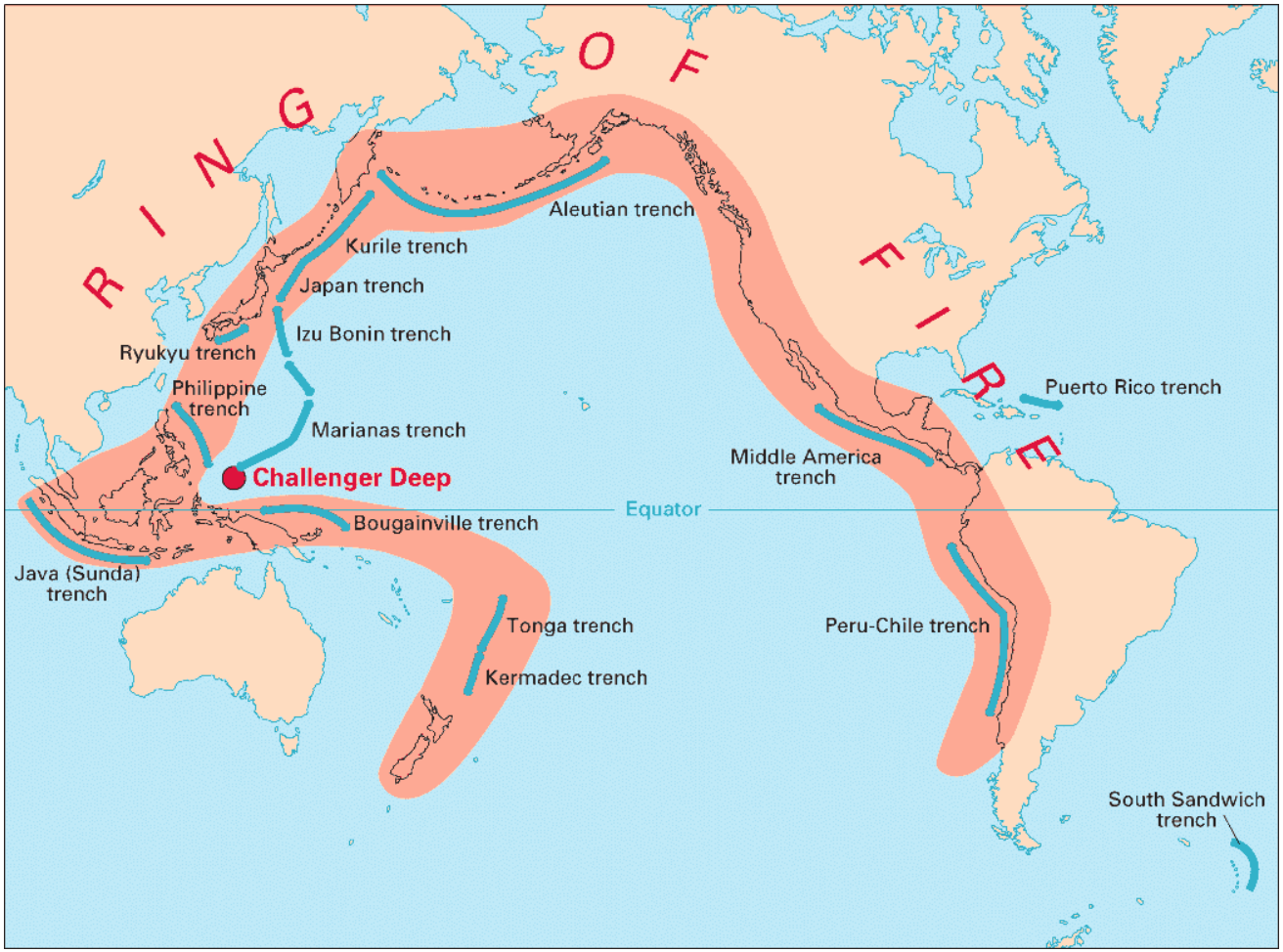
Convergent Margins, Subduction Zones: Trenches, Earthquakes, and Volcanoes



Arc volcanoes & intrusions provide heat for geothermal systems



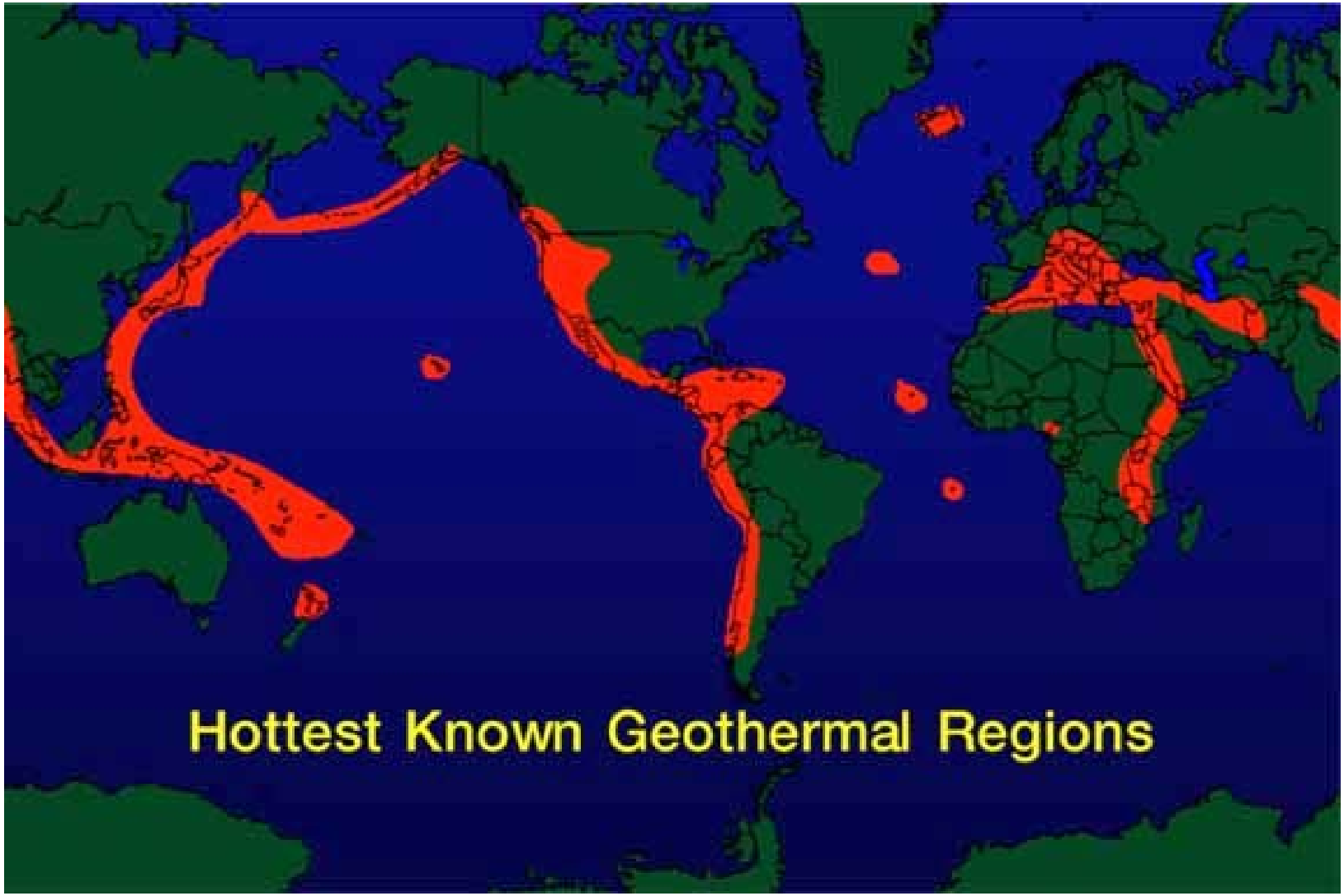
Circum-Pacific “Ring of Fire”



*Volcanic arcs and oceanic trenches partly encircling the Pacific Basin form the so-called **Ring of Fire**, a zone of frequent earthquakes and volcanic eruptions. The trenches are shown as blue lines. The volcanic arcs, although not labelled, are parallel to, and always landward of, the trenches. For example, the Andes volcanic arc is associated with the Peru-Chile Trench.*

“This Dynamic Earth” http://pubs.usgs.gov/publications/text/fire.html

Geothermal Regions correspond to Volcanic Regions



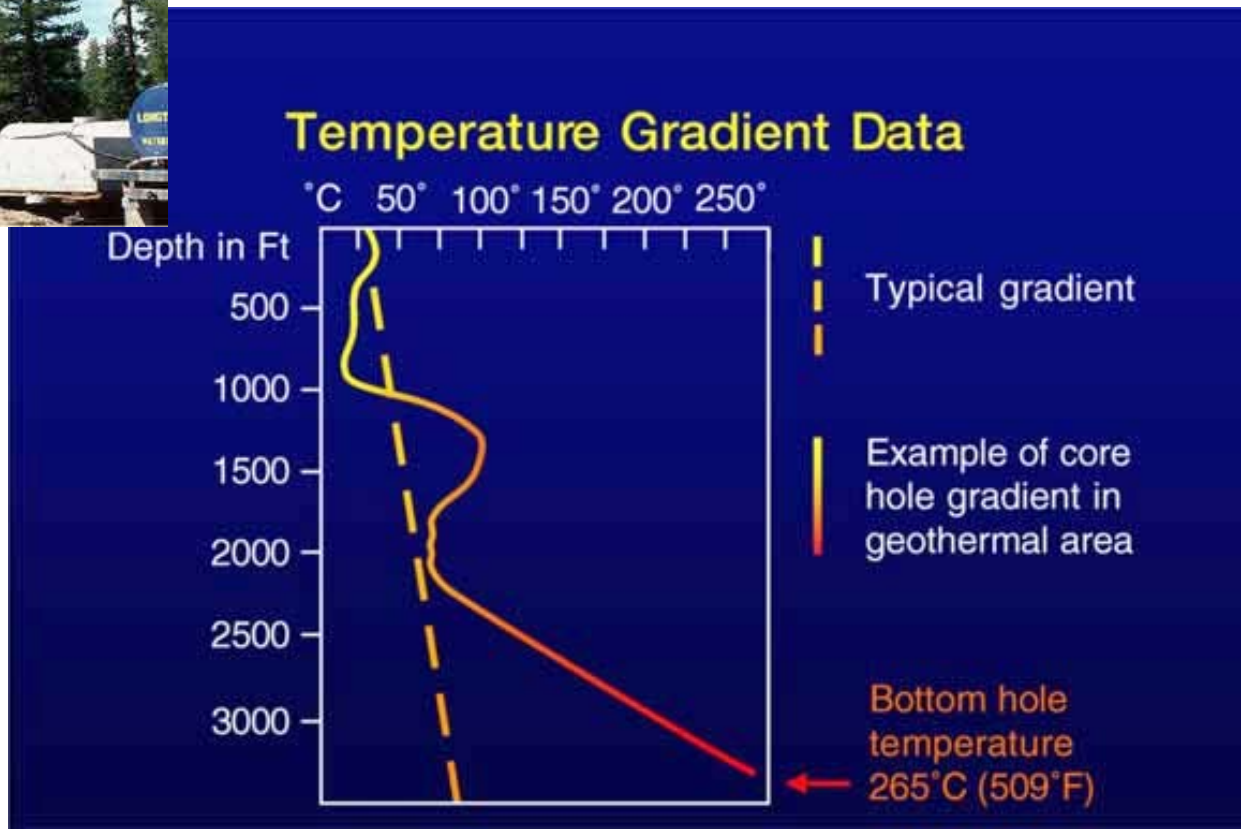
http://geothermal.marin.org/GEOpresentation/sld015.htm

Active Volcanoes of Latin America

114 Volcanoes with Historical Eruptions

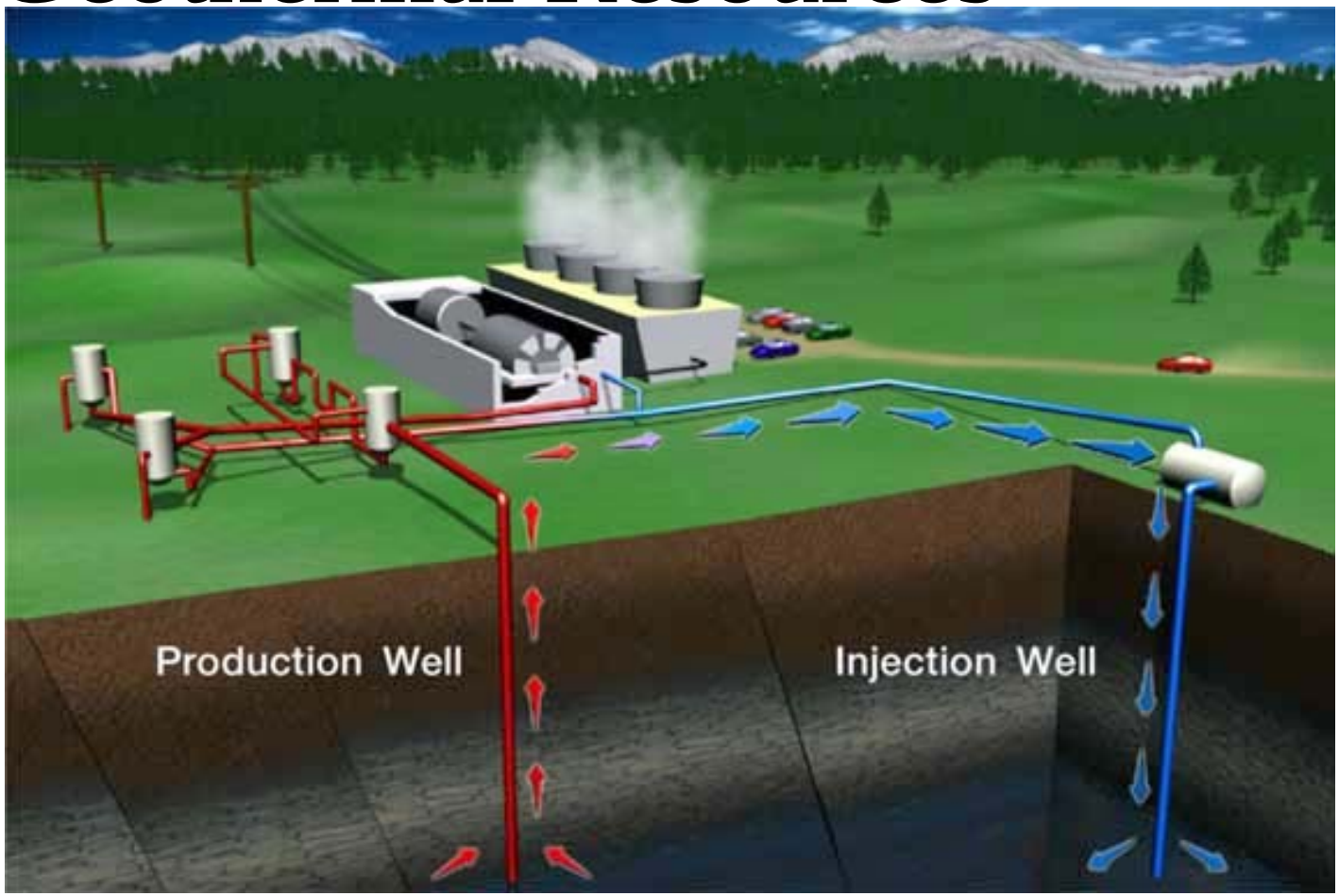
Finding Geothermal Resources

Must find hot areas with abundant circulating water and drill down to find the hottest regions



http://geothermal.marin.org/GEOpresentation/sld030.htm

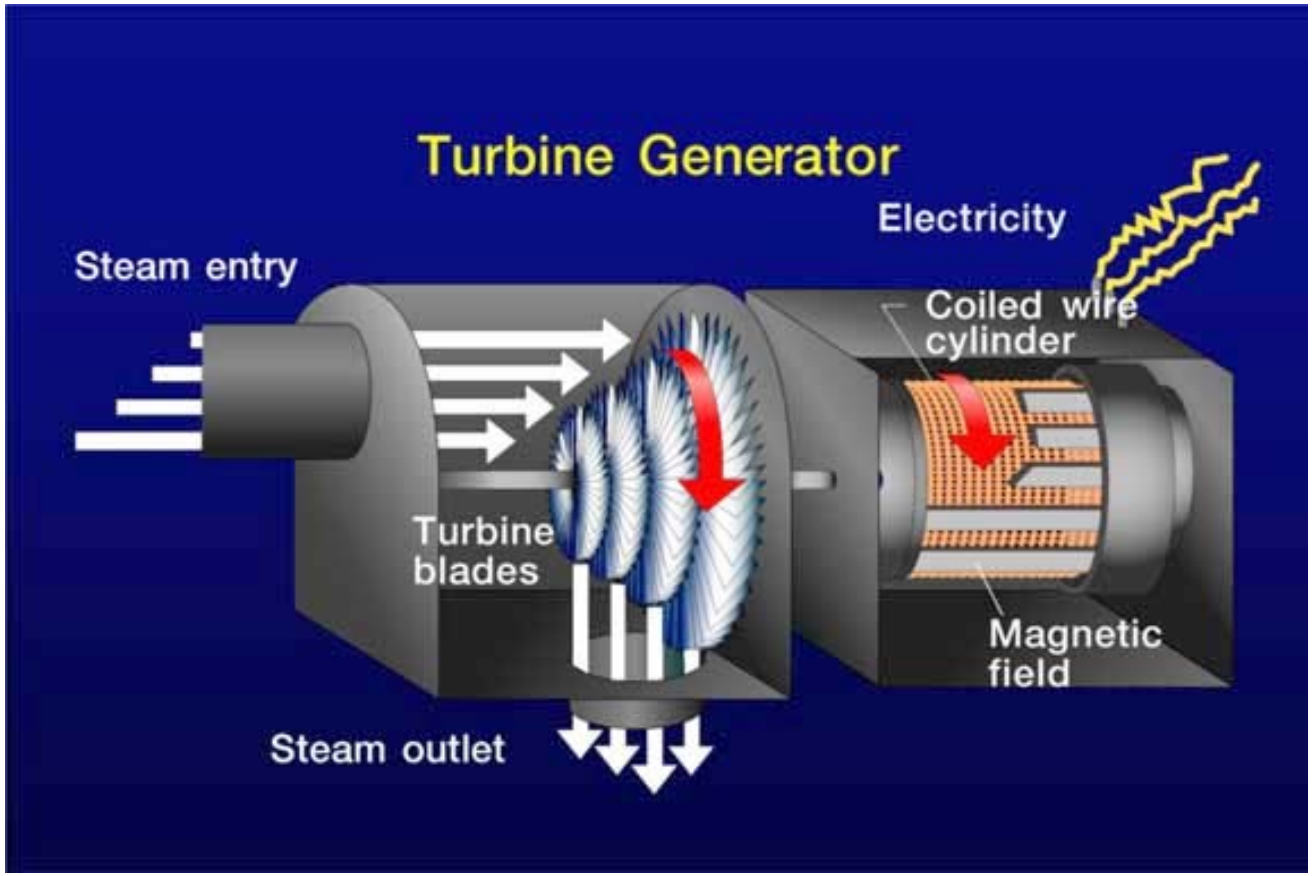
Producing Electricity from High-T Geothermal Resources



- **Natural steam from the production wells power the turbine generator. The steam is condensed by evaporation in the cooling tower and pumped down an injection well to sustain production.**

http://geothermal.marin.org/GEOpresentation/sld037.htm

Turbine Generator



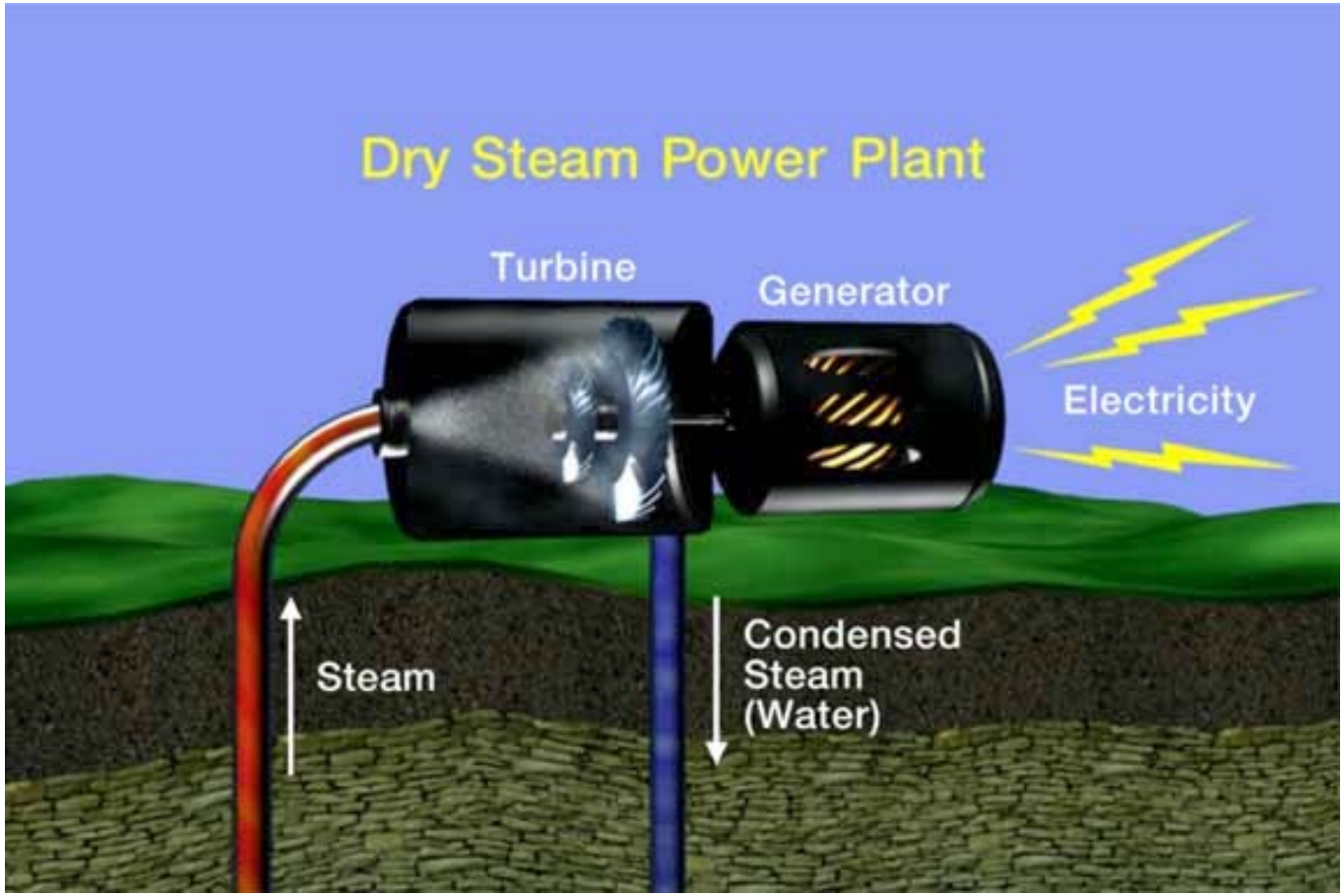
- **Like all steam turbine generators, the force of steam is used to spin the turbine blades which powers the generator, producing electricity. The same general principal is used with hydrocarbon-fueled electrical generators. But with geothermal energy, no fuel is burned.**

http://geothermal.marin.org/GEOpresentation/sld038.htm

Technologies for Producing Electricity from Geothermal Energy

- Dry Steam
- Flash Steam
- Binary Cycle

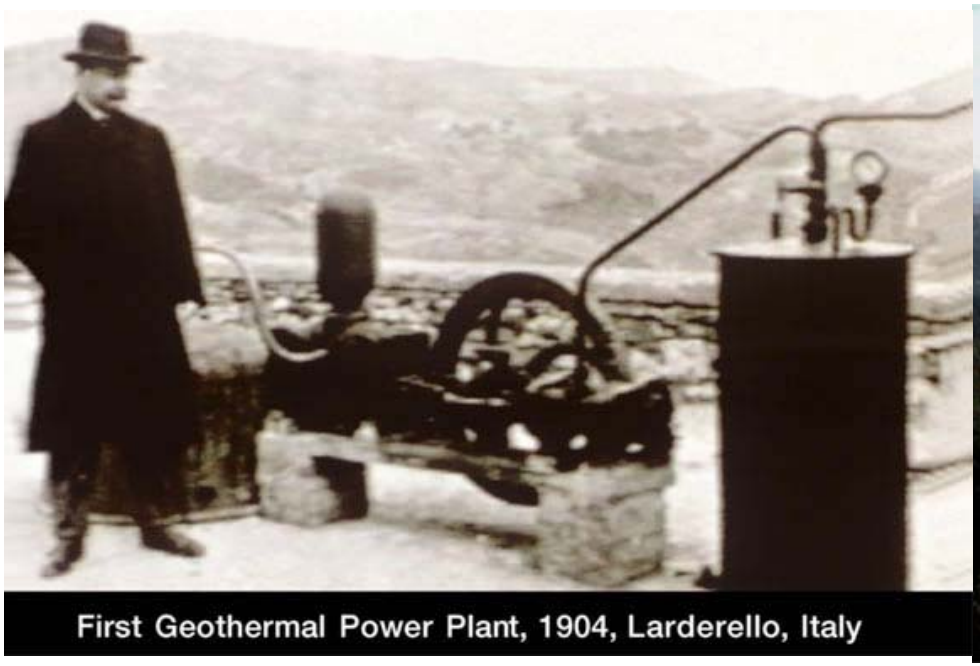
Dry Steam Generators



- **In dry steam power plants, the steam (and no water) shoots up the wells and is passed through a rock catcher (not shown) and then directly into the turbine. Dry steam fields are rare.**

http://geothermal.marin.org/GEOpresentation/sld049.htm

Dry Steam Generators

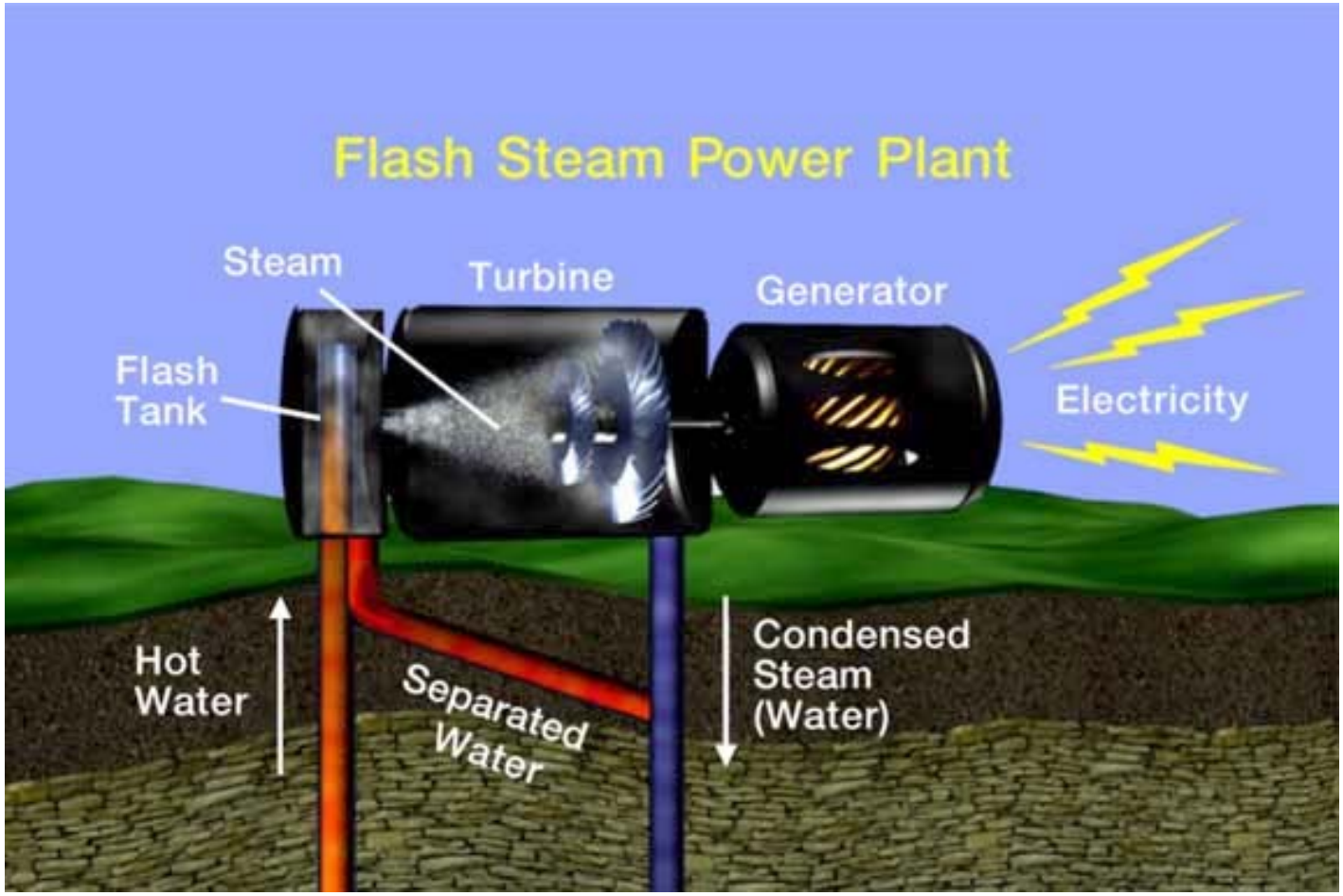


First Geothermal Power Plant, 1904, Larderello, Italy

- **Prince Piero Ginori Conti invented the first geothermal power plant in 1904, at the Larderello dry steam field in Italy**
- **The first geothermal power plants in the U.S. were built in 1962 at The Geysers dry steam field, in northern California. It is still the largest producing geothermal field in the world.**

http://geothermal.marin.org/GEOpresentation/sld050.htm

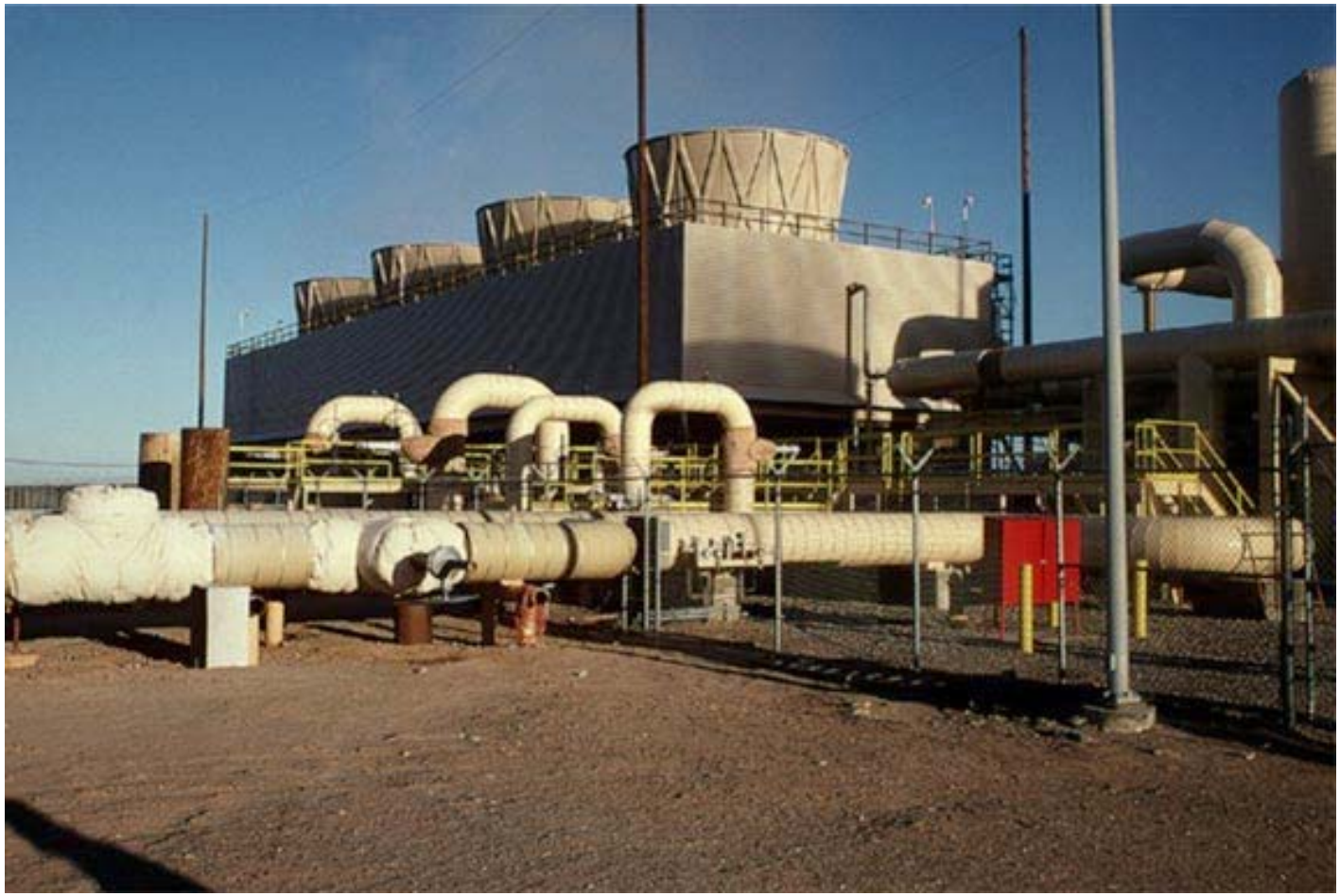
Flash Steam Generators



- **Flash steam power plants use hot water reservoirs. In flash plants, as hot water is released from the pressure of the deep reservoir in a flash tank, some of it 'flashes' or boils to steam.**

http://geothermal.marin.org/GEOpresentation/sld054.htm

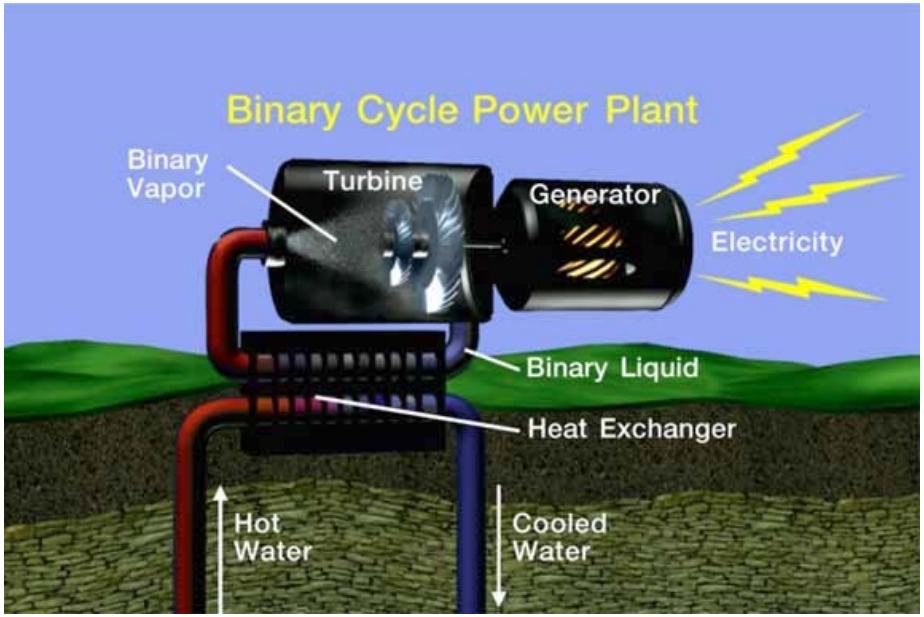
Flash Steam Plants

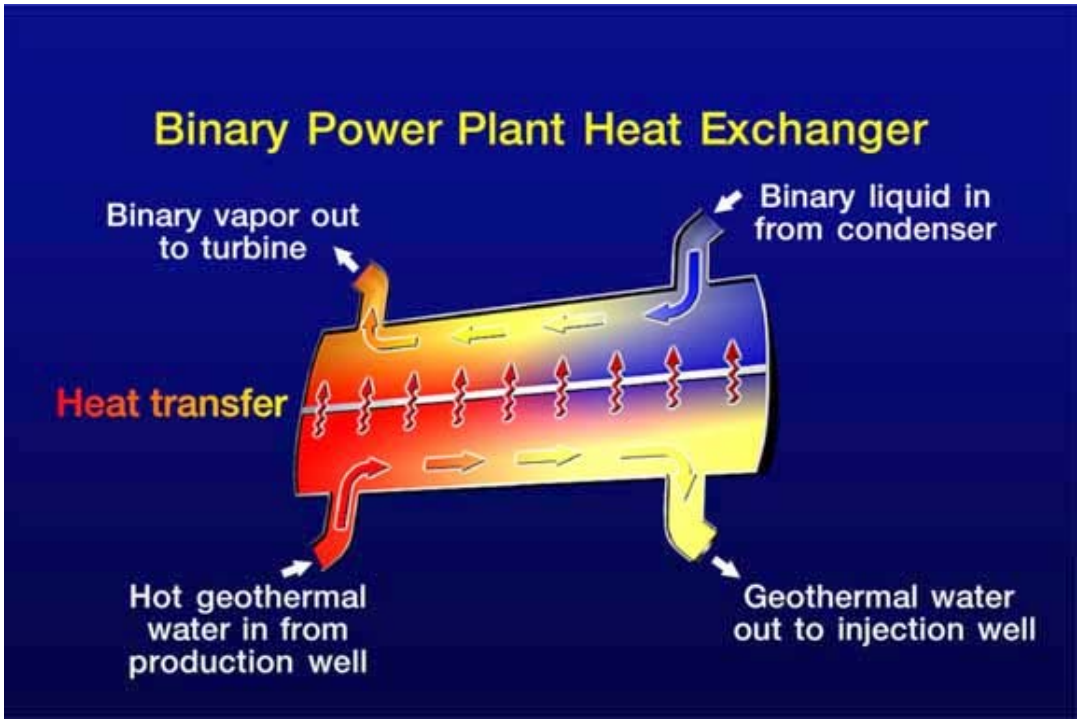


- **Flash technology was invented in New Zealand. Flash steam plants are the most common, since most geothermal reservoirs are hot water reservoirs. This flash steam plant is in East Mesa, California.**

http://geothermal.marin.org/GEOpresentation/sld055.htm

Binary Cycle Generators





- In a binary cycle power plant, the heat from geothermal water is used to vaporize a fluid that has a lower boiling point than water in separate adjacent pipes. The vapor, like steam, powers the turbine generator.
- In the heat exchanger, heat is transferred from the geothermal water to a second liquid. The geothermal water is never exposed to the air and is injected back into the periphery of the reservoir.

http://geothermal.marin.org/GEOpresentation/sld059.htm

Binary Cycle Generators

- **This power plant provides about 25% of the electricity used on the Big Island of Hawaii. It is a hybrid binary and flash plant.**

http://geothermal.marin.org/GEOpresentation/sld062.htm

Benefits of Geothermal Power

- Provides clean and safe energy using little land
- Is renewable and sustainable
- Generates continuous, reliable "baseload" power
- Conserves fossil fuels and contributes to diversity in energy sources
- Avoids importing and benefits local economies
- Offers modular, incremental development and village power to remote sites

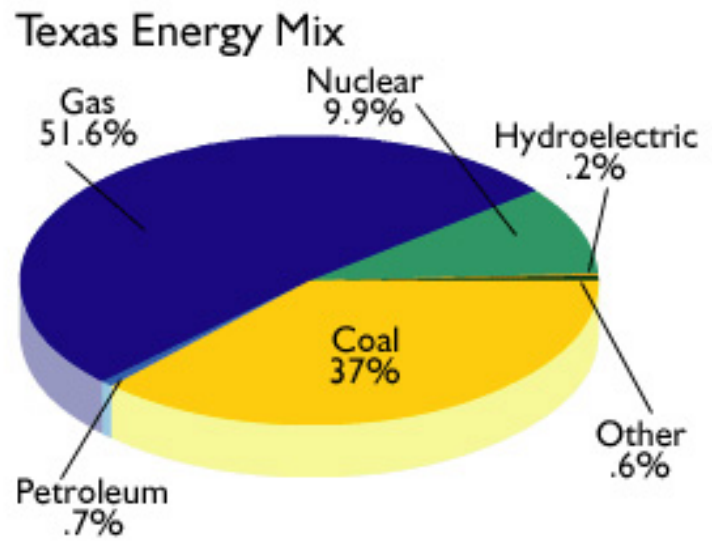
http://geothermal.marin.org/GEOpresentation/sld065.htm

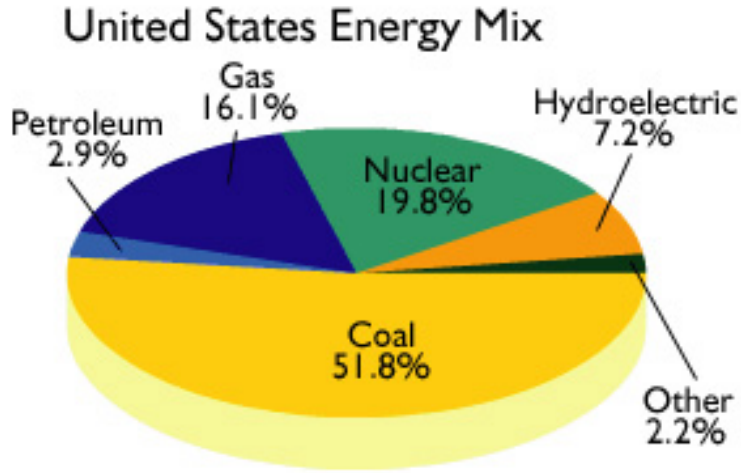
Production of Electricity

- The standard unit of power is the watt (after James Watt). A watt is equal to 1 joule per second. One watt is the amount of power that is delivered to a component of an electric circuit when a current of 1 ampere flows through the component and a voltage of 1 volt exists across it.
- Generation of electricity is usually reported in millions of watts, or megawatts (MW).
- A good example is the Comanche Peak nuclear power plant, located about 80 miles southwest of downtown Dallas. It is one of the largest electricity generating plants in Texas and has an operating capacity of 2,300 MW (two 1,150 MW units).

Production of Electricity in US, 2001 (cont'd.)

- *Coal-fired plants generated >50% of U.S. electricity.*
- *Nuclear Power = 20%*
- *Natural gas = 16 %*
- *Hydroelectric = 7%*
- *Oil burning = 3%*
- *Other (including geothermal) = 2%*





http://www.balancedenergy.org/state/tx.asp

Consumption of Electricity

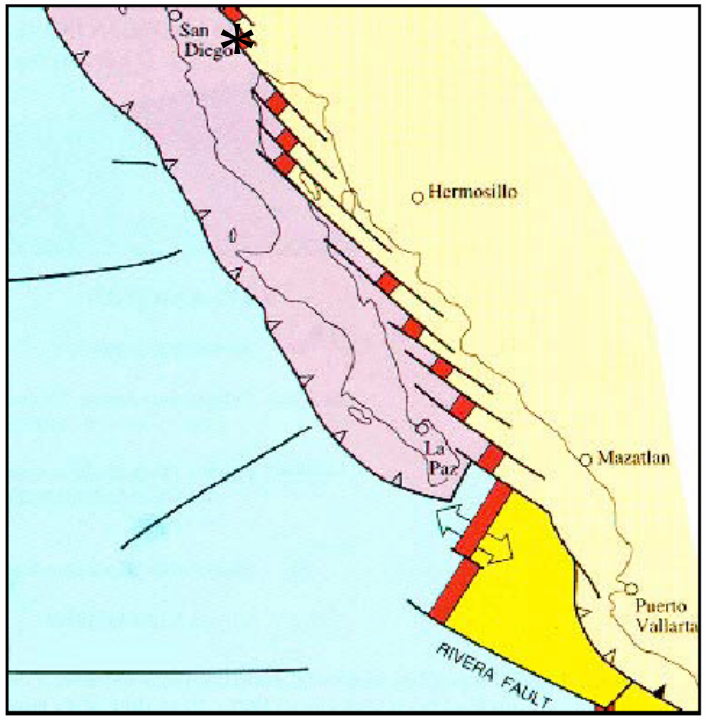
- Measured by Kilowatt-hours (kWh)
- Kilowatt-hours are determined by multiplying the number of kW's required by the number of hours of use. For example, if you use a 40-watt light bulb 5 hours a day, you have used 200 watts of power, or 0.2 kilowatt-hours of electrical energy.
- US annual consumption per capita: 11,236 kWh (1993)

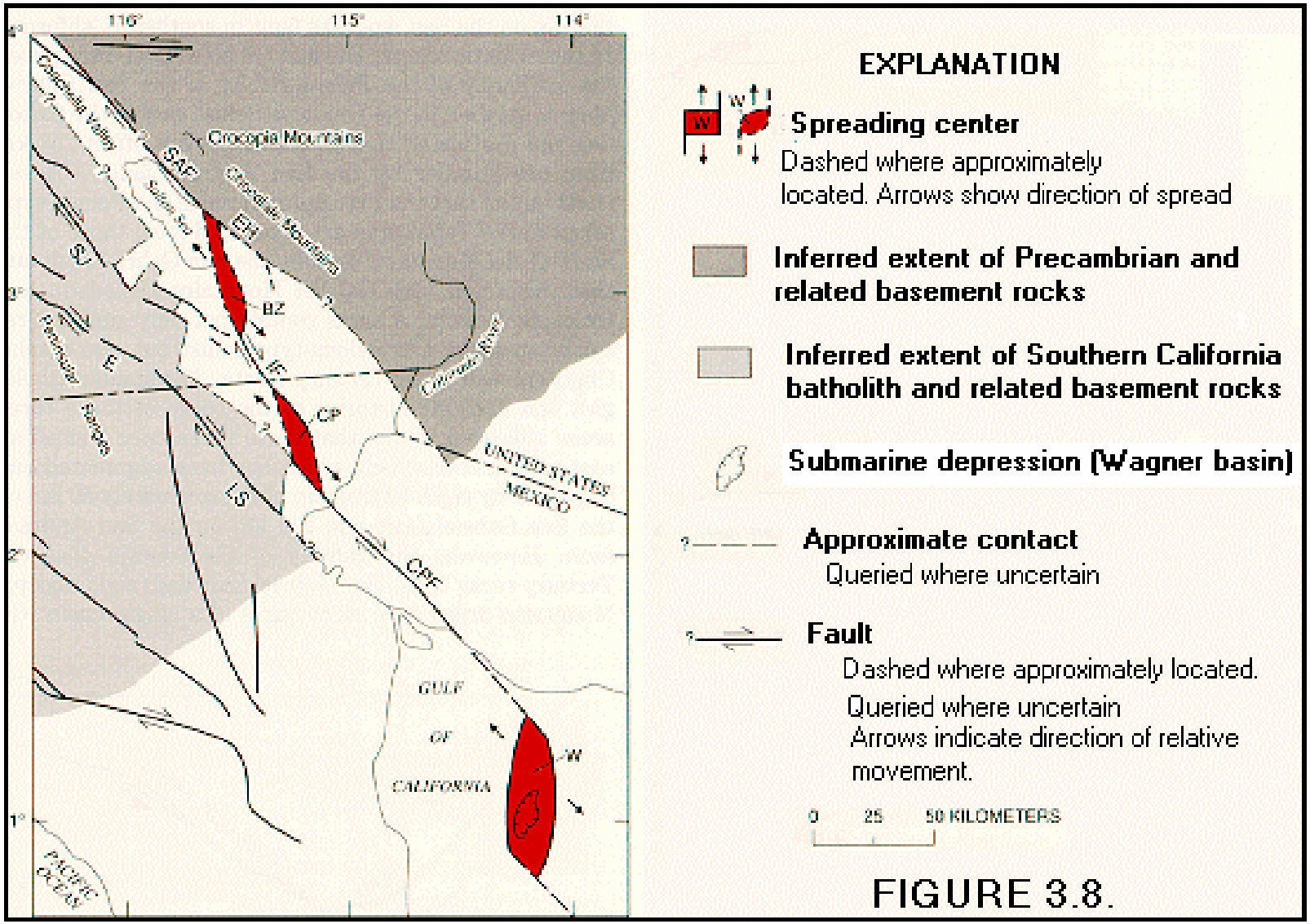
Production of Electricity using Geothermal Energy

- The geothermal field that generates the most electricity in the world is The Geysers (California) with with a peak capability of nearly 1,100 MW -- enough electricity to supply a city of over a million inhabitants.
- The largest field that generates the most electricity in Latin America is Cerro Prieto, Baja California, Mexico (720 MW).
  - Other Mexican geothermal field that power electrical generating plants are Los Azufres (93 MW) and Los Humeros (42 MW)

Mexican Geothermal Electricity

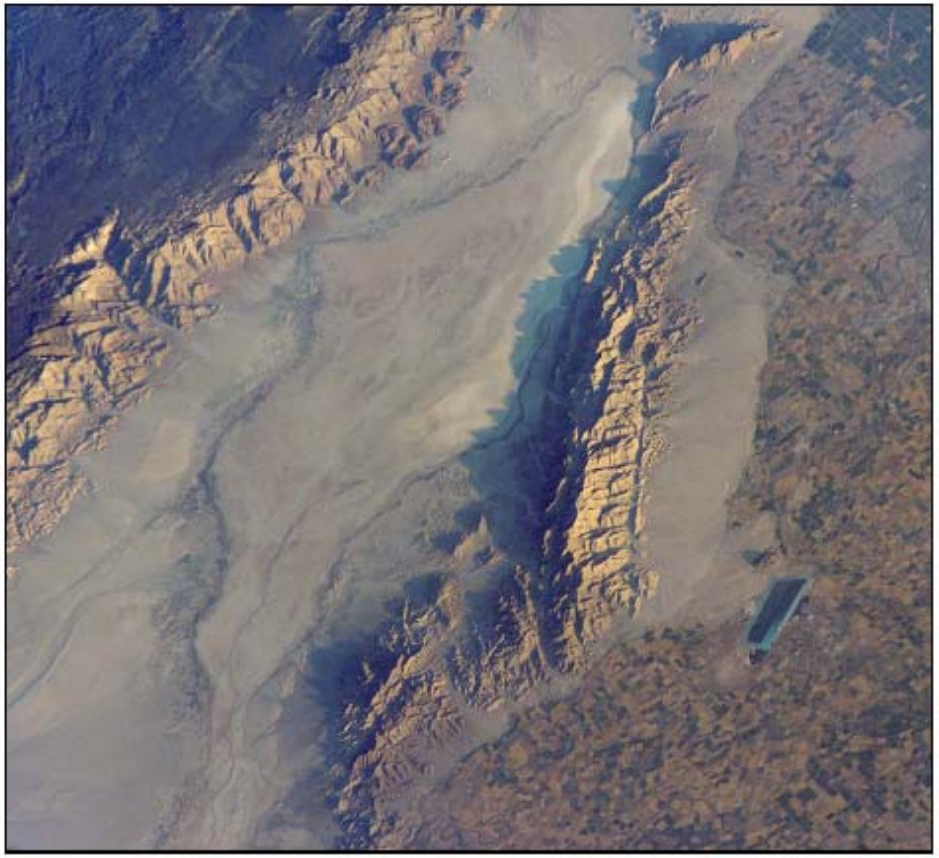
Cerro Prieto Geothermal Field, Mexico





The Salton Trough, showing major spreading centers and termination of the San Andreas fault. Spreading centers: BZ, Brawley seismic zone; CP, Cerro Prieto geothermal area; W, Wagner Basin. Major transform faults: CPF, Cerro Prieto; IF, Imperial; SAF, San Andreas. Other major faults: E, Elsinore; EH, East Highland Canal seismicity lineament; LS, Laguna Salada; SJ, San Jacinto.

- A huge hot-water (280-360° C) geothermal system occurs at Cerro Prieto along an offshore segment of the East Pacific Rise which bounds the North American and Pacific plates. This field now produces 720 MW of electricity from geothermal reservoirs as deep as 4000 m.



- Above: The Sierra de los Cucapah and Sierra de Mayor mountains trend north south just right of center. The Laguna Salada basin is on the west side of the mountains and the Cerro Prieto Volcano, Lake, and geothermal area (lower right) are on the east side. The basin of the Laguna Salada is a graben formed by the Laguna Salada fault on the east side and the Sierra Juarez fault on the west.(May 23, 2002, ISS photograph).

Right: Cerro Prieto Volcano is the round dark area top left of center. The jade green wastewater surface ponds (Lake Cerro Prieto) of the Cerro Prieto geothermal field are center left. The three thermal generating plants are below and to the right of the ponds (Feb 12, 2001 ISS photograph).

Other Geothermal Energy in Mexico

- In the Central Mexican Volcanic Belt, Los Azufres produces 88 MWe and Los Humeros, 35 MWe. 65 MWe more geothermal power is planned.
- Mexico has over 1,500 hot springs: one Mexican state is named Aguascalientes (hot waters).
- Direct uses of geothermal heat in Mexico include industrial laundries, refrigeration, district and greenhouse heating, and fruit and wood drying.

http://geothermal.marin.org/map/mexico.html

Popocatepetl, Mexico

The Caribbean

- The Lesser Antilles islands in the eastern Caribbean have some active volcanoes and fumarole fields.
- Exploration on Guadeloupe began in 1969, and drilling of shallow high temperature wells has resulted in a 4.2 MW double flash plant (on line since 1984).
- Exploration has also been encouraging on Dominica, Monserrat and St. Lucia, but electricity is not yet being produced.

http://geothermal.marin.org/map/caribbean.html

Andes Geothermal Energy

- There is lots of potential for production of electricity using geothermal energy in South America. Andes volcanoes provide lots of heat. Several high-temperature geothermal systems occur in these sparsely populated areas.
- There is a 0.67 MW electric power plant at Copahue, Argentina, but remarkably little use of geothermal potential in South America!

http://geothermal.marin.org/map/andean.html

Geothermal Energy in Central America

- CENTRAL AMERICAN VOLCANIC BELT - Central American volcanoes extend along a subducting plate boundary through Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and into Panama. This area has many active active volcanoes and is an area of high rainfall and abundant lakes. Not surprisingly, Central America has many geothermal systems, most still undrilled.
- Development is most advanced in El Salvador, with a total of 105 MWe at Ahuachapan and Berlin. At one time Ahuachapan provided almost half of EI Salvador's electrical power.
- Nicaragua has 70 MWe at its Momotombo field. Miravalles, Costa Rica, generates 70 MWe and will add 55 MWe more by December 1997.
- A 24 MWe plant is under construction at Zunil, Guatemala, and several other areas in Central America are being considered for development.

http://geothermal.marin.org/map/cenam.html


Yucatan,
Mexico
Belize
Guatemala
Honduras
Nicaragua
El Salvador
Costa Rica
Panama
SRTM image of topography
~1700 km across

Central America Volcanoes

Arenal, Costa Rica

http://www.volcano.si.edu

Seven Countries in Central America (Four with significant Geothermal Electricity Generation in 2000)

Guatemala 33.4 MW

El Salvador 161 MW

Nicaragua 70 MW

Costa Rica 142.5 MW

Huttrer 2001

National Ranking by % of national energy produced by Geothermal in 2000

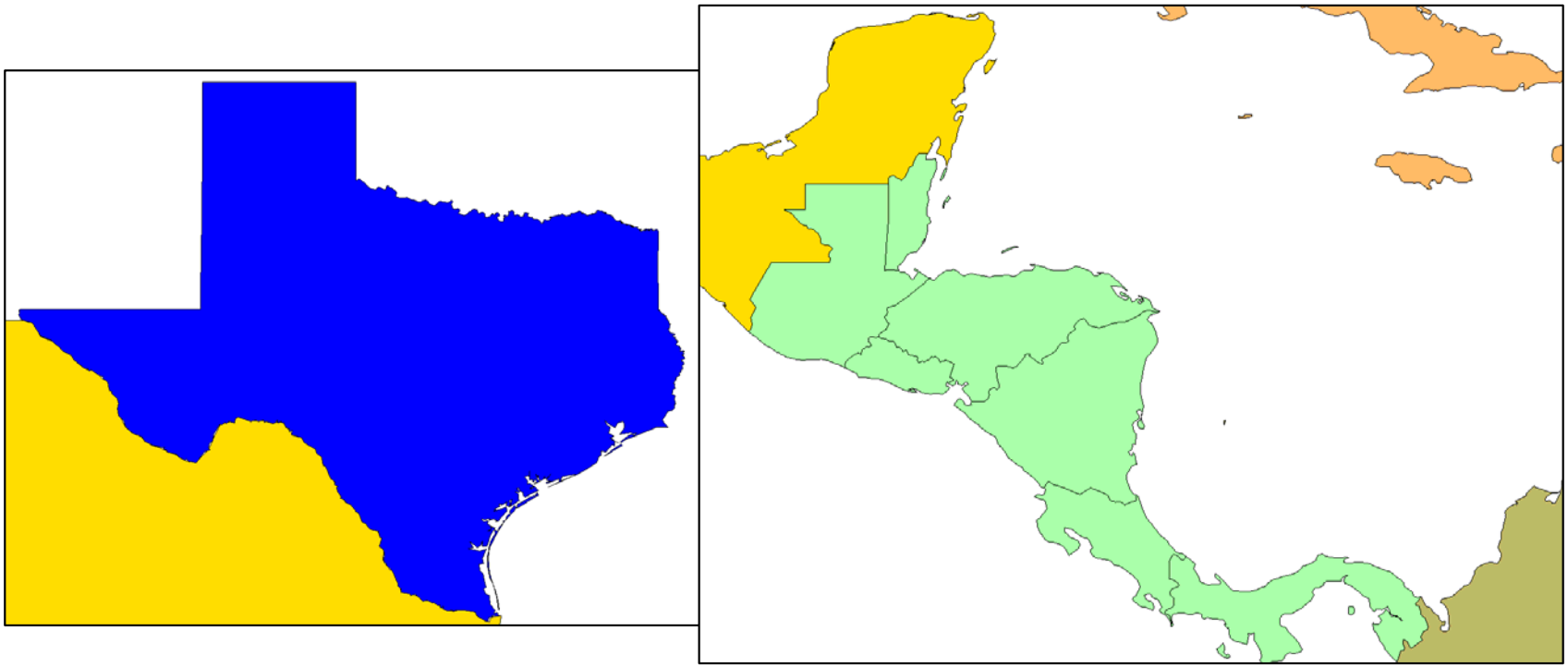
1.	Philippines	21.5%
2.	*El Salvador*	20%
3.	*Nicaragua*	17.2%
4.	Iceland	14.7%
5.	*Costa Rica*	10.2%
6.	Kenya	8.4%
7.	New Zealand	6.1%
8.	Indonesia	5.1%
9.	*Guatemala*	3.7%
10.	*Mexico*	*3.2%*

Huttrer 2001

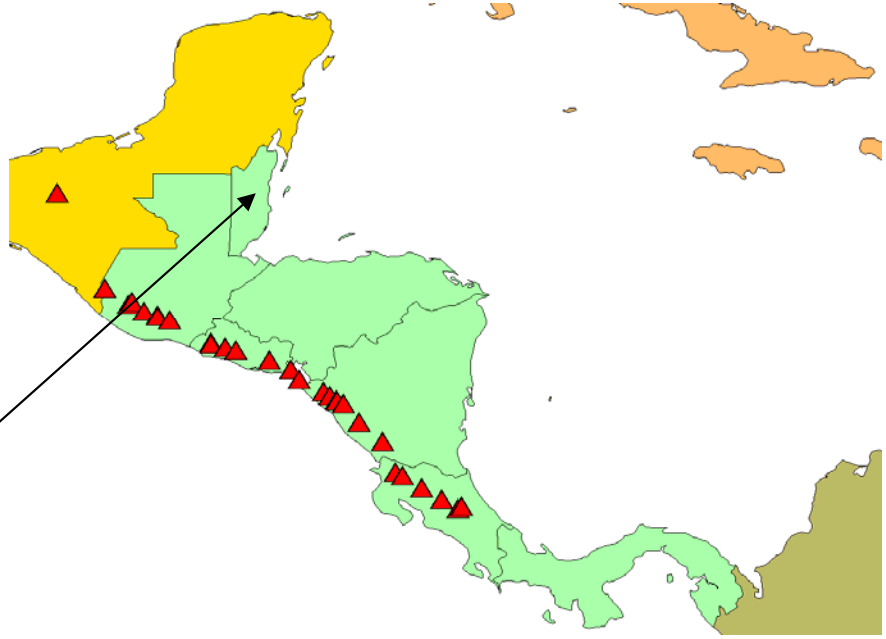
5 of the top 10 producers are in Latin America

Seven Nations of Central America

- Area ~ 75% the size of Texas
- 38 million inhabitants (~175% Texas population



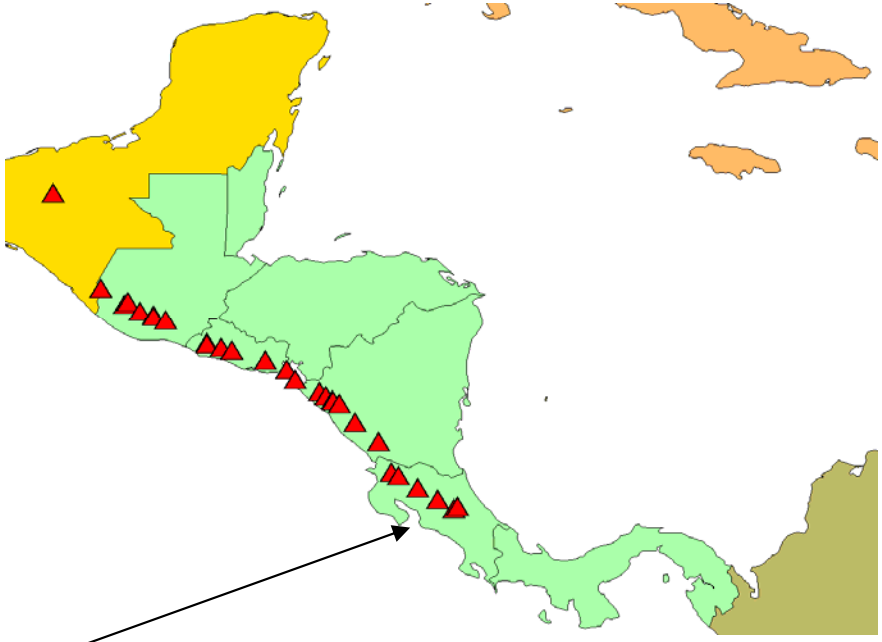
Belize



23,000 km^2
(~3% the size of Texas)
270,000 people
$3250 per capita GDP
No active volcanoes
No geothermal electricity

http://www.odci.gov/cia/publications/factbook/

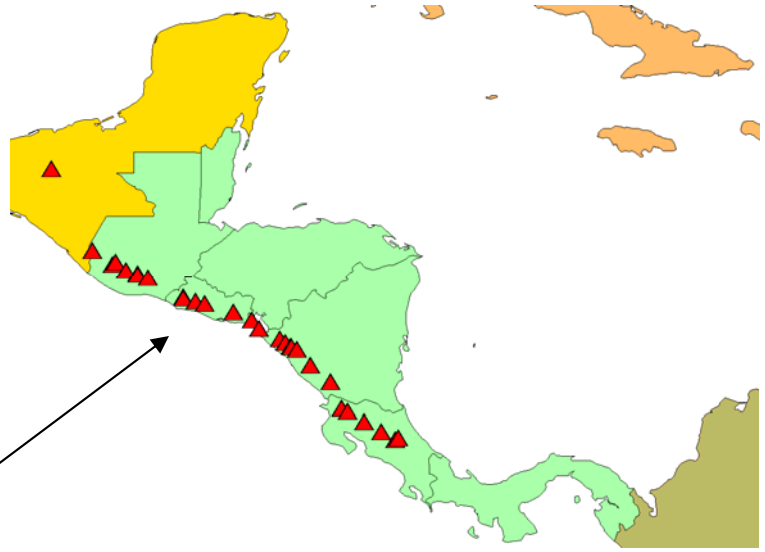
Costa Rica



51,000 km^2
(~7% the size of Texas)
3,800,000 people
$8500 per capita GDP
Several active volcanoes
10% of electricity generated by geothermal

http://www.odci.gov/cia/publications/factbook/

El Salvador



21,400 km^2
(~3% the size of Texas)
6,400,000 people
$4600 per capita GDP
Several active volcanoes
20% of electricity generated from geothermal

http://www.odci.gov/
cia/publications/factbook/

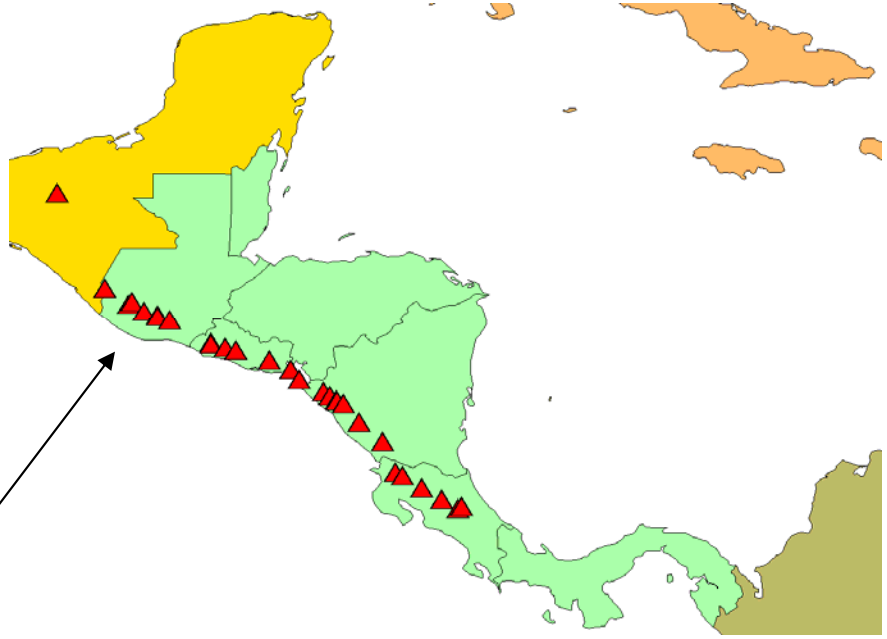
Ahuacupan, El Salvador

Berlin

95 MW Flash Plants at Ahuachapan

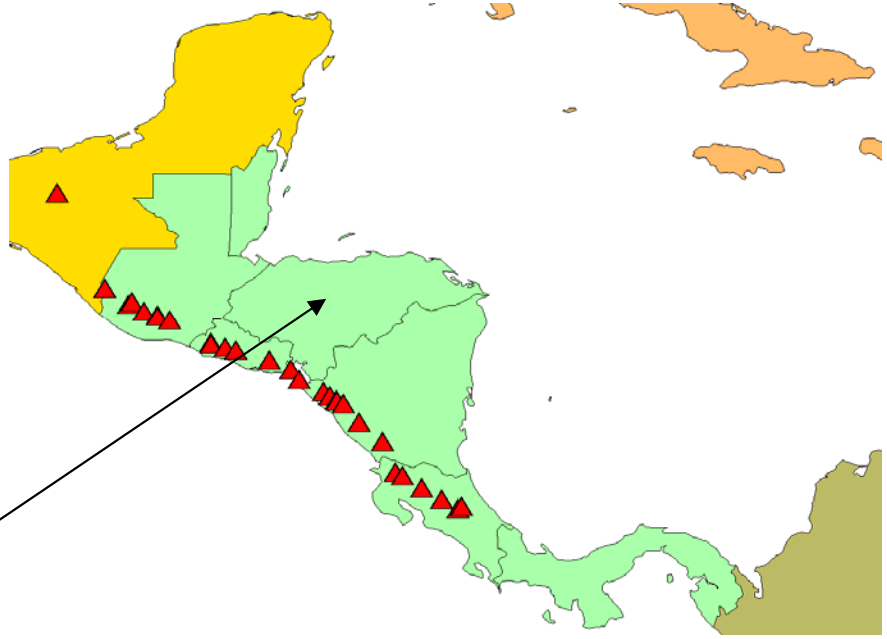
56 MW plant at Berlin

Guatemala



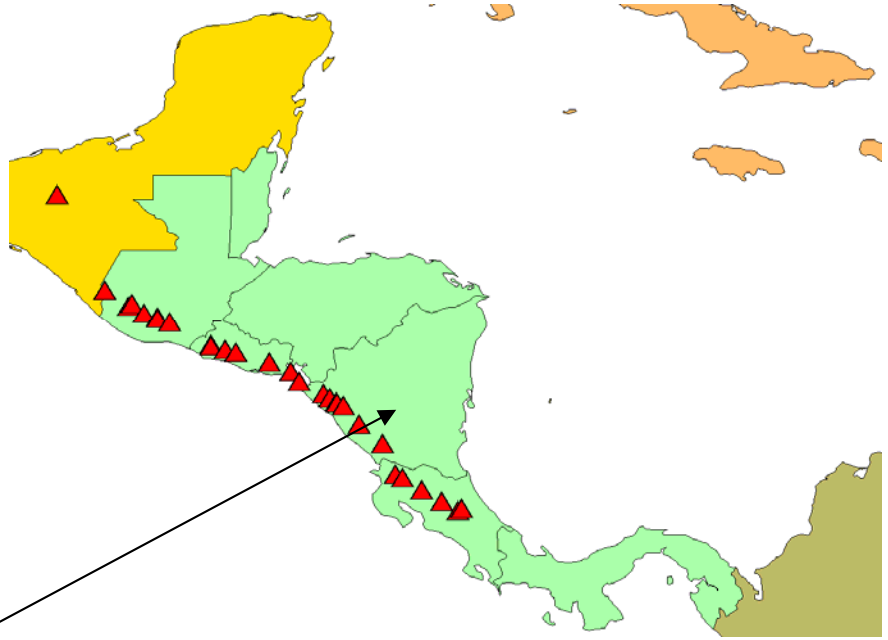
109,000 km^2
(~16% the size of Texas)
13,300,000 people
$3700 per capita GDP
Several active volcanoes
3.7% of electricity generated from geothermal

Honduras



113,000 km^2
(~16% the size of Texas)
6,600,000 people
$2600 per capita GDP
No active volcanoes
No electricity generated from geothermal

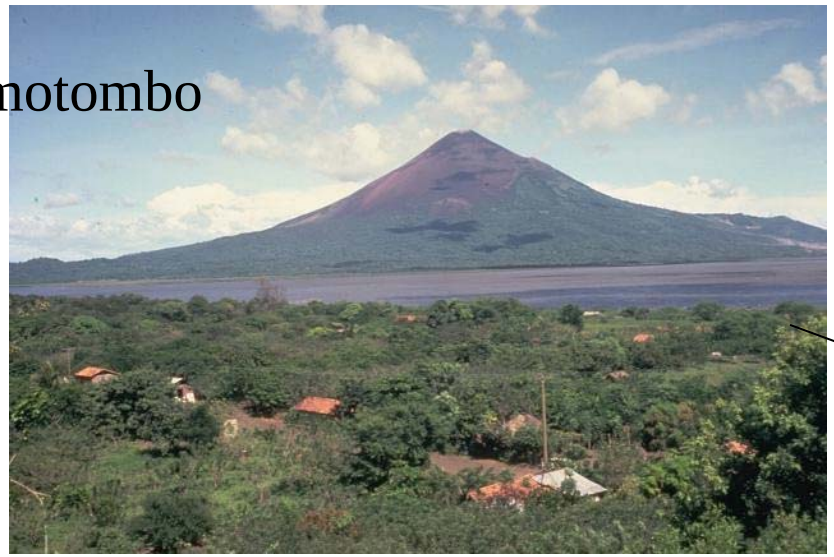
Nicaragua



129,500 km^2
(~19% the size of Texas)
5,000,000 people
$2500 per capita GDP
Several active volcanoes
17% of electricity generated from geothermal

Nicaragua geothermal energy

Momotombo

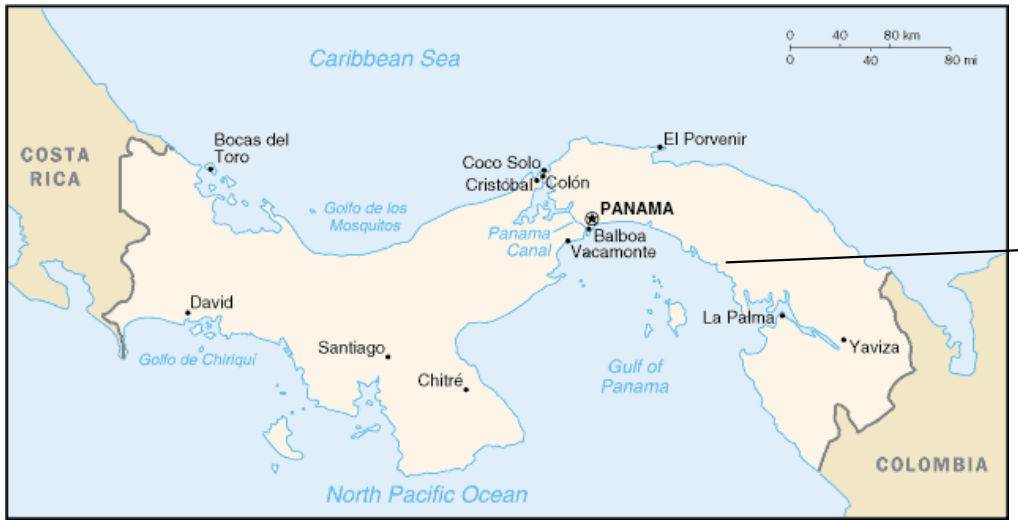


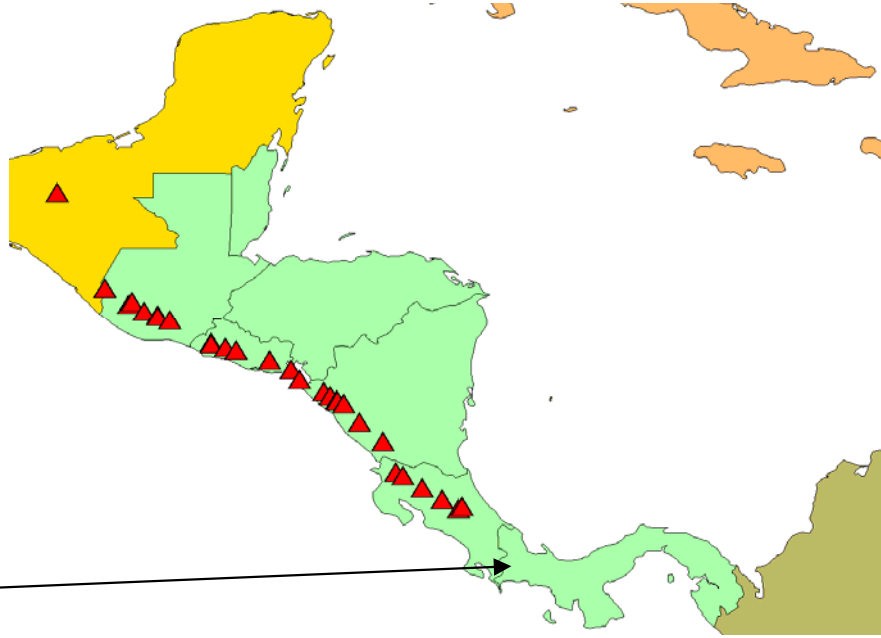
Momotombo geothermal plant: 20-70MW

STS61C-31-0051

Momotombo and Lake Managua

Panama





78,200 km^2
(~11% the size of Texas)
2,900,000 people
$5900 per capita GDP
No active volcanoes
No electricity generated from geothermal

Puzzle: Why has Central America lots of Geothermal Energy but South America does not?

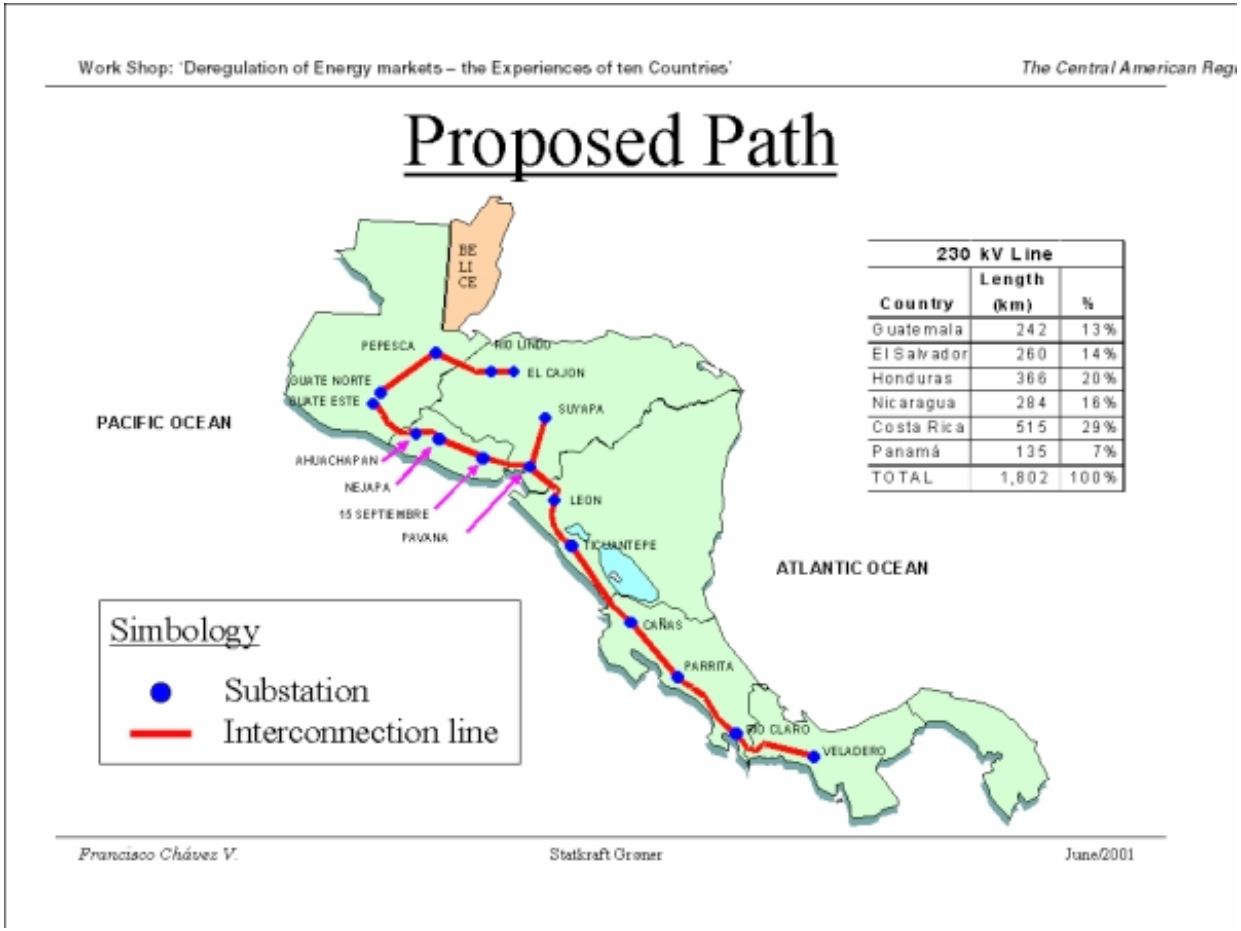
South American nations with geothermal potential have other options:

- Hydrocarbons (Argentina, Colombia, Ecuador, Peru)
- Hydro power (Argentina,Colombia, Ecuador, Peru, Chile, Bolivia)

Argentina sells Chile natural gas cheaply, to produce electricity @ $0.05/kWh.

Geothermal costs $0.05-0.08/kWh

The SIEPAC Project: Sistema de interconexión Electrica de los Países de América Central



- Create a regional high-voltage (230 kV) power line and electricity market for region.
- July 2003 construction begins on the 1880 km line.
- The Inter-American Development Bank (IDB) has approved a $ 320 mm loan for SIEPAC.

Competition to Geothermal in Central America

- Natural Gas pipeline is being planned, either from Mexico or from Colombia, or both.