MYANMAR ENGINEERING SOCIETY

GEOTHERMAL ENERGY

TECHNOLOGY & RESOURCES

(AN INTRODUCTION)

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19TH JANUARY 2008

CONTENTS

Introduction

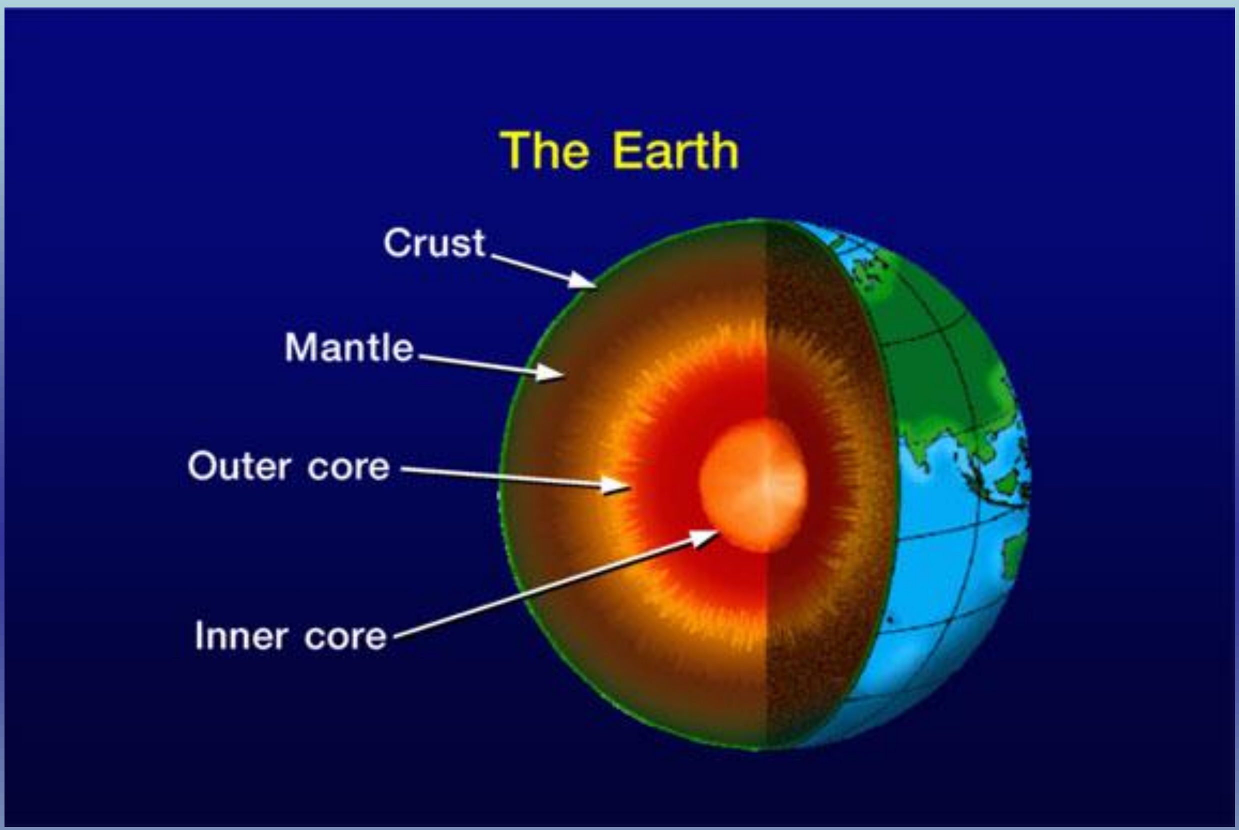
Introduction

- Geothermal energy is a renewable and sustainable power source that comes from the heat generated by the earth. “Geo” means earth and “thermal” means heat.

Geo means **Earth**

Thermal means **Heat**

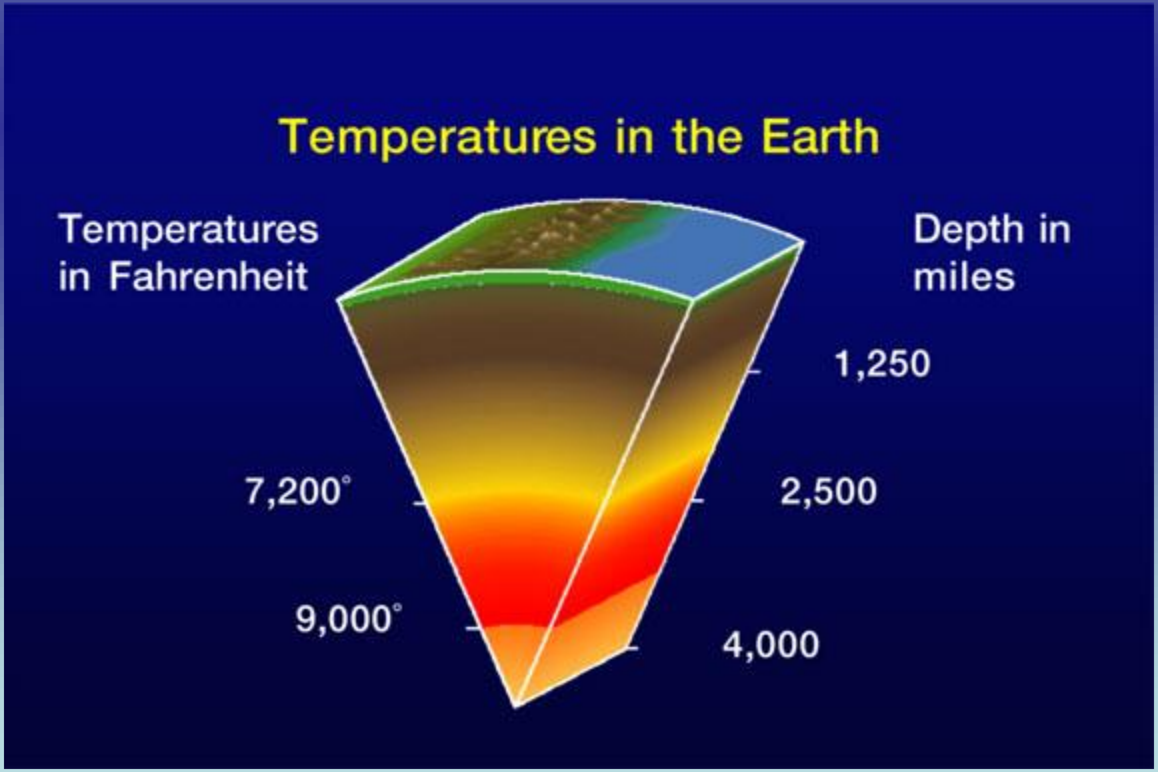
- The Earth has four main layers, as is shown in the picture below.



- Heat flows outward from Earth’s interior. The crust insulates us from Earth’s interior heat. The mantle is semi-molten, the outer core is liquid and the inner core is solid.

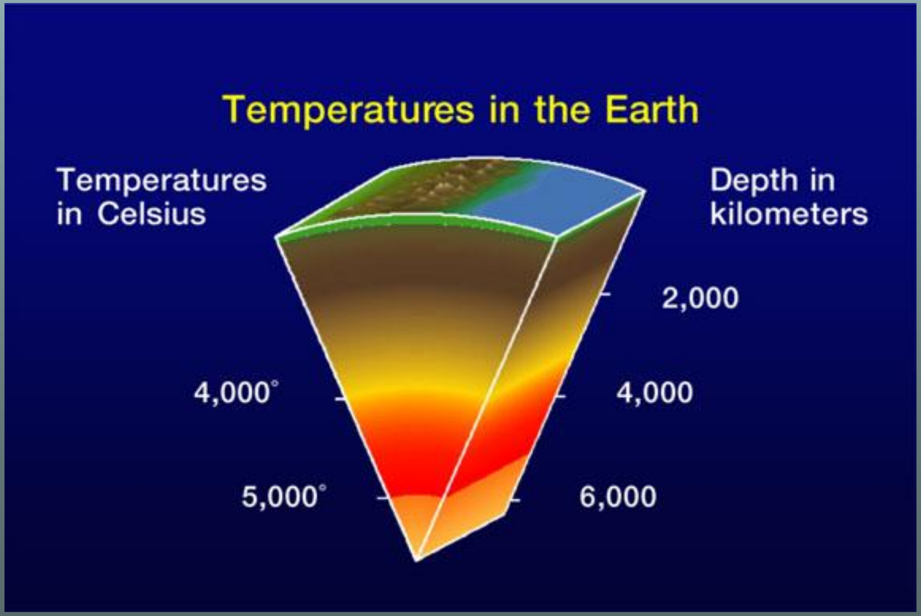
EARTH'S HEAT AND VOLCANIC REGIONS

- Each layer has different compositions, functions and temperatures, as is illustrated in the figure below.
- It is almost 6,500 kilometers (4,000 miles) from the surface to the center of the Earth, and the deeper you go, the hotter it gets. The outer layer, the crust, is three to 35 miles thick and insulates us from the hot interior.



The deeper you go, the hotter it gets (in Fahrenheit and miles).

- From the surface down through the crust the normal temperature gradient (the increase of temperature with the increase of depth) in the Earth's crust is 17 - 30°C per kilometer of depth (50-87°F per mile).
- Below the crust is the mantle, made of highly viscous, partially molten rock with temperatures between 650 and 1,250°C (1,200-2,280°F).
- At Earth's core, which consists of a liquid outer core and a solid inner core, temperatures may reach 4,000-7,000°C (7,200 to 12,600°F).



The deeper you go, the hotter it gets (in Celsius and kilometers).

- Thinned or fractured crust allows magma to rise to the surface as lava. Most magma doesn't reach the surface but heats large regions of underground rock.

- Rainwater can seep down faults and fractured rocks for miles. After being heated, it can return to the surface as steam or hot water.

This steaming ground is in the Philippines.

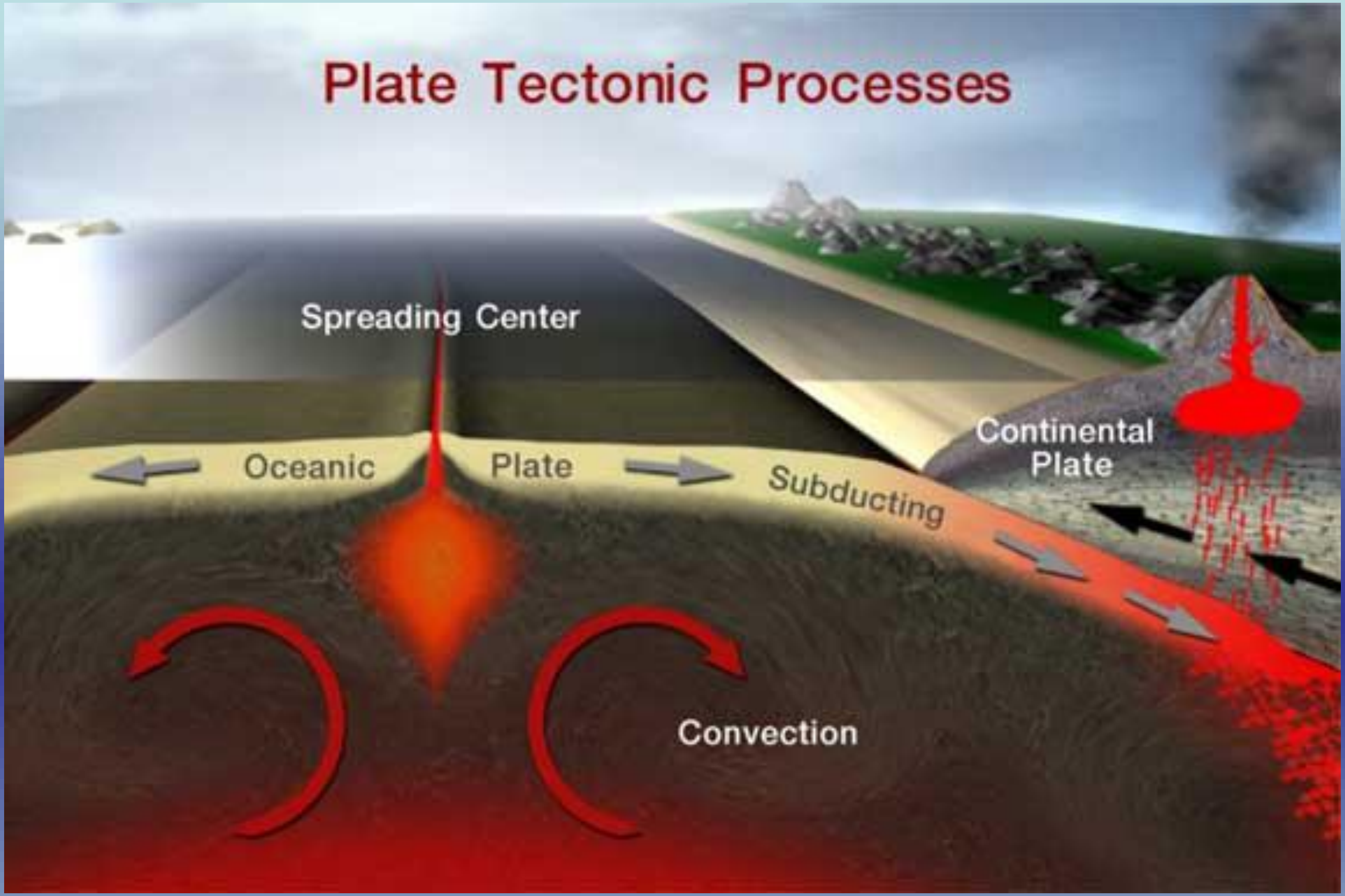
Volcanoes are obvious indications of underground heat, this volcano, Mt. Mayon in the Albay province of the Philippines erupted in 1999.

- When hot water and steam reach the surface, they can form fumaroles, hot springs, mud pots and other interesting phenomena.

Locations of Geothermal Energy Use

Locations of Geothermal Energy Use

- Geothermal energy is generally harnessed in areas of volcanic activity. The Pacific Ring is a prime spot for the harnessing of geothermal activity because it is an area where the **tectonic processes** are always taking place.
- The USGS defines tectonic processes as a series of actions and changes relating to, causing, or resulting from structural deformation of the earth's crust. [Adapted from American Heritage Dic. of the English Language, 4th ed.] This picture illustrates the term **tectonic processes**

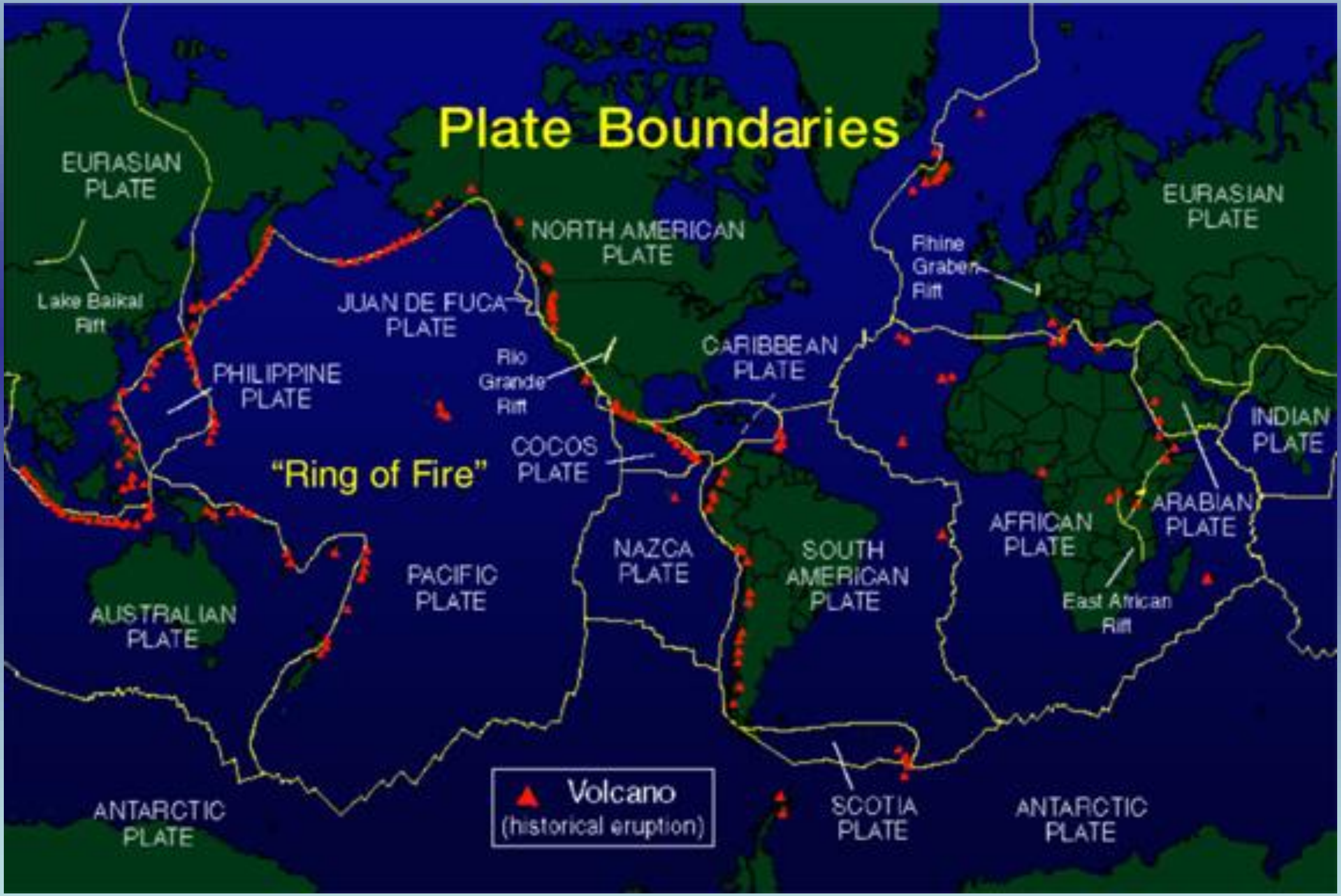


- New crust forms along mid-ocean spreading centers and continental rift zones. When plates meet, one can slide beneath another. Plumes of magma rise from the edges of sinking plates.

- Geothermal power plants are used all over the world. They are located where tectonic plates collide and generate volcanic activity.

- The map below shows where plate boundaries are located and the following map illustrates the general location of geothermal power plants being used around the world.

- Earth’s crust is broken into huge plates that move apart or push together at about the rate our fingernails grow. Convection of semi-molten rock in the upper mantle helps drive plate tectonics.

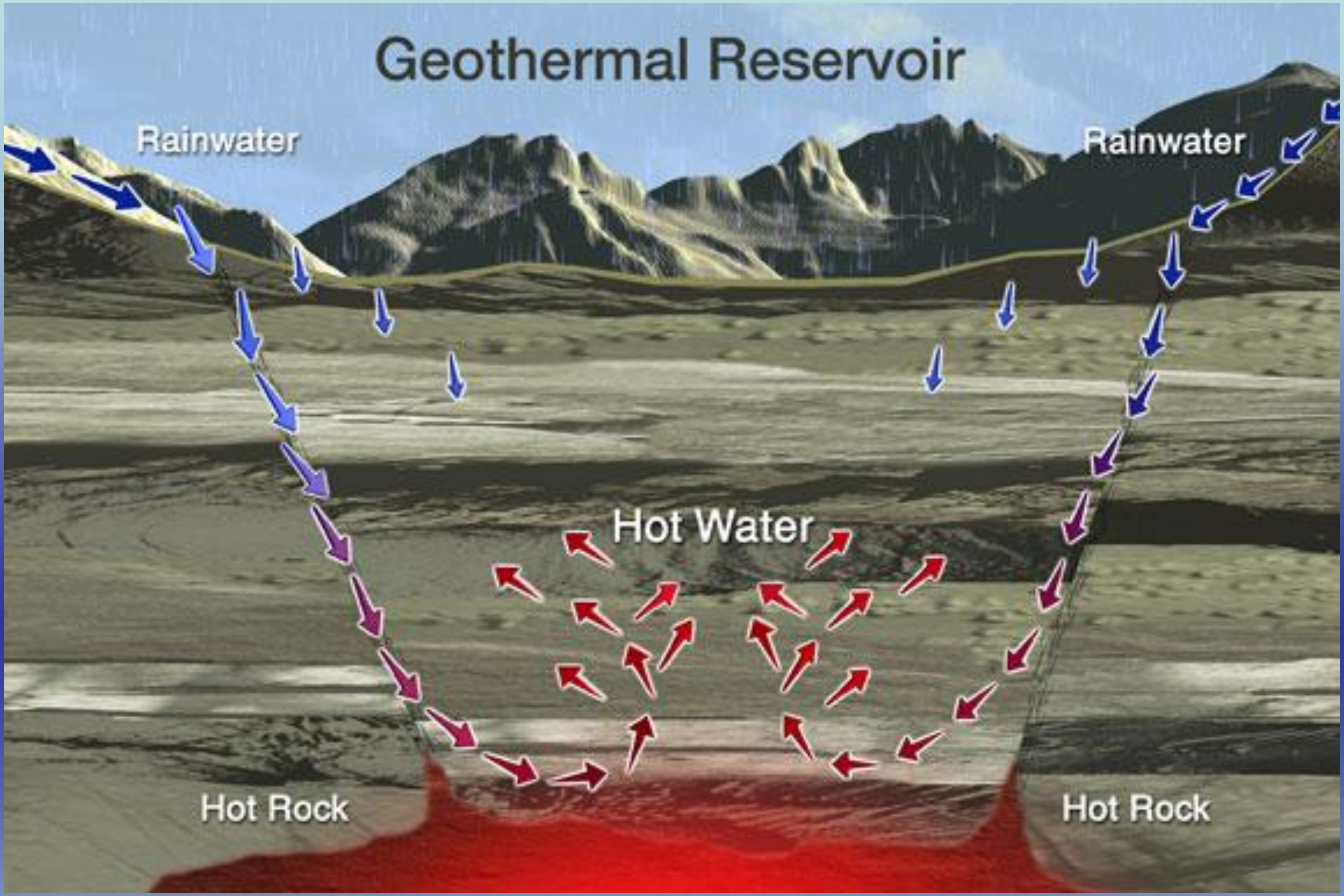


The table below shows MW of Geothermal Energy in different countries around the world. For more information on the countries below.

Producing countries in 1999	Megawatts
United States	2,850
Philippines	1,848
Italy	768.5
Mexico	743
Indonesia	589.5
Japan	530
New Zealand	345
Costa Rica	120
Iceland	140
El Salvador	105
Nicaragua	70
Kenya	45
China	32
Turkey	21
Russia	11
Portugal (Azores)	11
Guatemala	5
French West Indies (Guadeloupe)	4
Taiwan	3
Thailand	0.3
Zambia	0.2

Powerful Energy Source

- Geothermal reservoirs can reach temperatures of 700°F/370°C (more than 3 times boiling).
- A geothermal reservoir is a powerful source of energy!



- When the rising hot water and steam is trapped in permeable and porous rocks under a layer of impermeable rock, it can form a geothermal reservoir.

Geothermal Resources

Geothermal Resources

1. Hydrothermal convection systems

(a) Vapor-dominated systems- extremely rare (geysers)

(b) Liquid-dominated systems-more common (hot springs)

Exploited commercially worldwide

2. Hot Igneous resources

(a) Hot dry rock

(b) Magma systems

Extensive R & D on Hot Dry Rock

3. Conduction-dominated resources

(a) Geopressured resources

(b) Radiogenic resources

Hydrothermal Resources

(a) Vapor dominated systems

- Extremely rare (Geysers in California, USA, Laderello in Italy and Matsukawa in Japan)
- Produces high quality superheated steam (dry steam) from depths 5000-10,000 ft

(b) Liquid dominated systems

- More commonly found around the globe
- Produces hot water or wet steam
- associated with hot springs that discharges at the surface
- Conversion to useful energy requires more complex techmology than vapor-dominated due to impurities
- Contains dissolved salts and minerals (sodium, potassium, lithium, chlorides, sulfates, borates, bicarbonates and silica)
- New Zealand and Mexico have well developed liquid dominated resources

(c) Hot Dry Rock and Magma Resources

- Impermeable rock covering Magma chambers formed about 6 miles below surface due to geologic anomalies (tectonic plate movement and volcanic activity)
- Refered as Hot Dry Rock (HDR) deposits
- Require artificial aquifier to bring heat to surface
- R & D in USA using injected cold water where heated water is returned to surface by production well

(d) Geopressured Resources

- Formed about 60 million years ago with fluid located in subsurface rock formations carrying a part of overburden pressure,increasing the formation pressure.
- Water is confined in an insulating clay bed and normal heat flow from earth raise the temperature of the water and contains pockets of methane.
- Considered as promising sources of energy in future as it can provide mechanical energy as it is under high hydraulic pressure,geothermal energy and chemical energy as it contains methane and natural gas
- Geopressured basins are of interest due to existence in very large area and thickness.

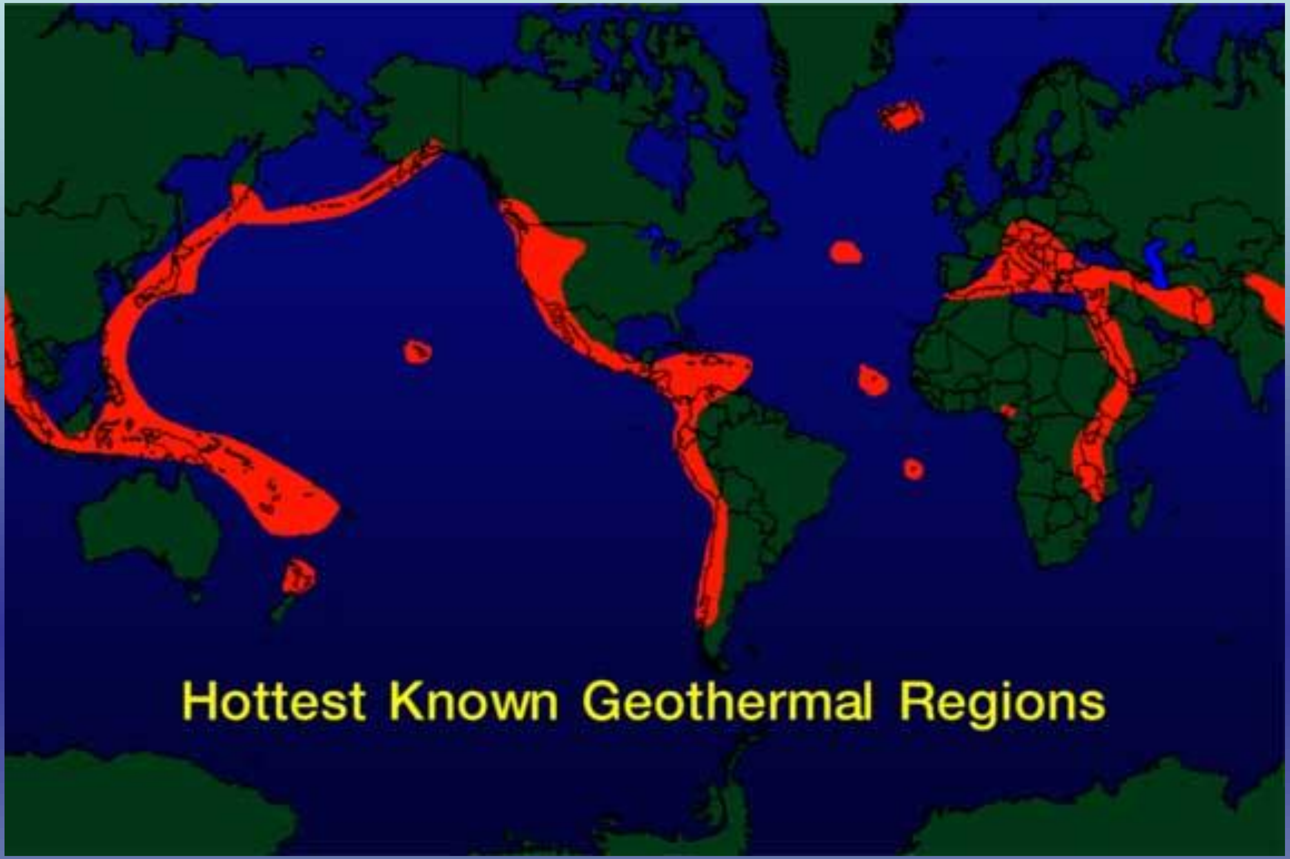
Geothermal Resource Classification

Resource Type	Temperature Characteristics	
Hydrothermal convection resources (heat carried upward from depth by convection of water or steam)		
a. Vapor dominated	- 240 C	(464 F)
b. Liquid (hot - water) dominated		
1. High temperature	150 - 350 C	(302 - 662 F)
2. Intermediate temperature	90 - 150 C	(194 - 302 F)
3. Low temperature	< 90 C	(< 194 F)
Hot igneous resources (rock intruded in molten form from depth)		
a. Molten material present - magma systems	> 659 C	(> 1218 F)
b. No molten material - hot dry rock systems	90 - 650 C	(194 - 1202 F)
Conduction - dominated resources (heat carried upward by conduction through rock)		
a. Radiogenic (heat generated by radioactive decay)	30 - 150 C	(86 - 302 F)
b. Sedimentary basins (hot fluid in sedimentary rock)	30 - 150 C	(87 - 302 F)
c. Geopressured (hot fluid under high pressure)	150 - 200 C	(302 - 392 F)

Known Geothermal Resource Area (KGRA)

- Geological estimates on all stored heat in the Earth above 15 deg C within 6 miles of the surface.
- KGRA ignores the practical *recoverability* of the resource but provides the scale, scope and location of the geothermal resource

Exploration and Drilling



- Many areas have accessible geothermal resources, especially countries along the circum-Pacific “Ring of Fire,” spreading centers, continental rift zones and other hot spots.

Geothermal Exploration Surveys

- Satellite imagery and aerial photography
- Volcanological studies
- Geologic and structural mapping
- Geochemical surveys
- Geophysical surveys
- Temperature gradient hole drilling

These and other methods are used.

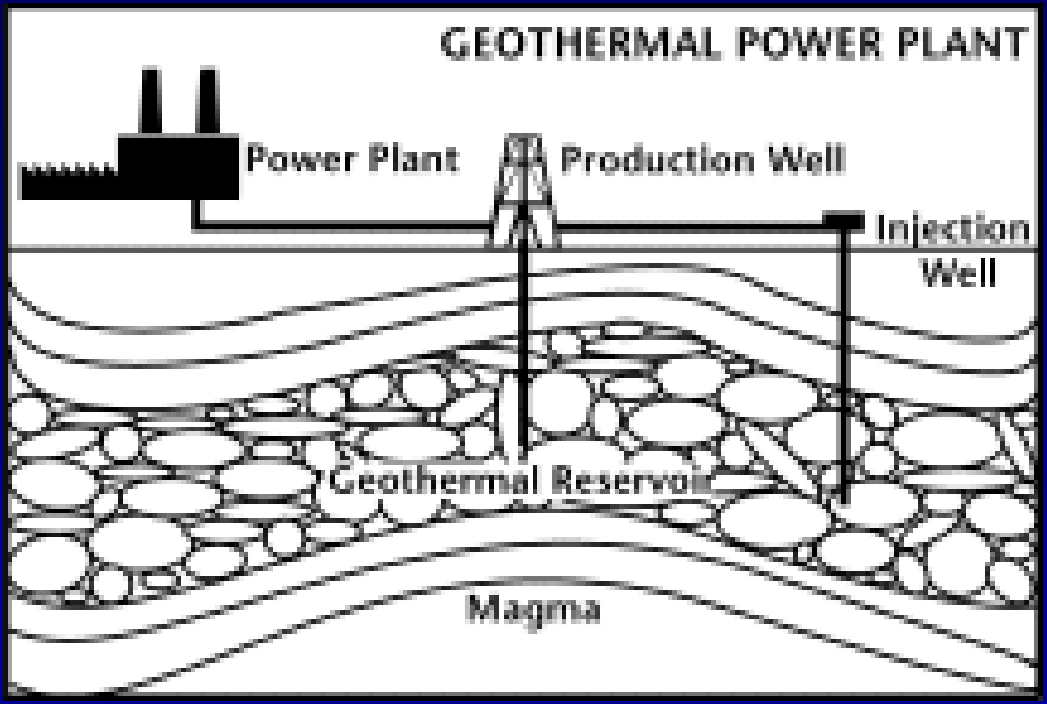
Exploration commonly begins with analysis of satellite images and aerial photographs.

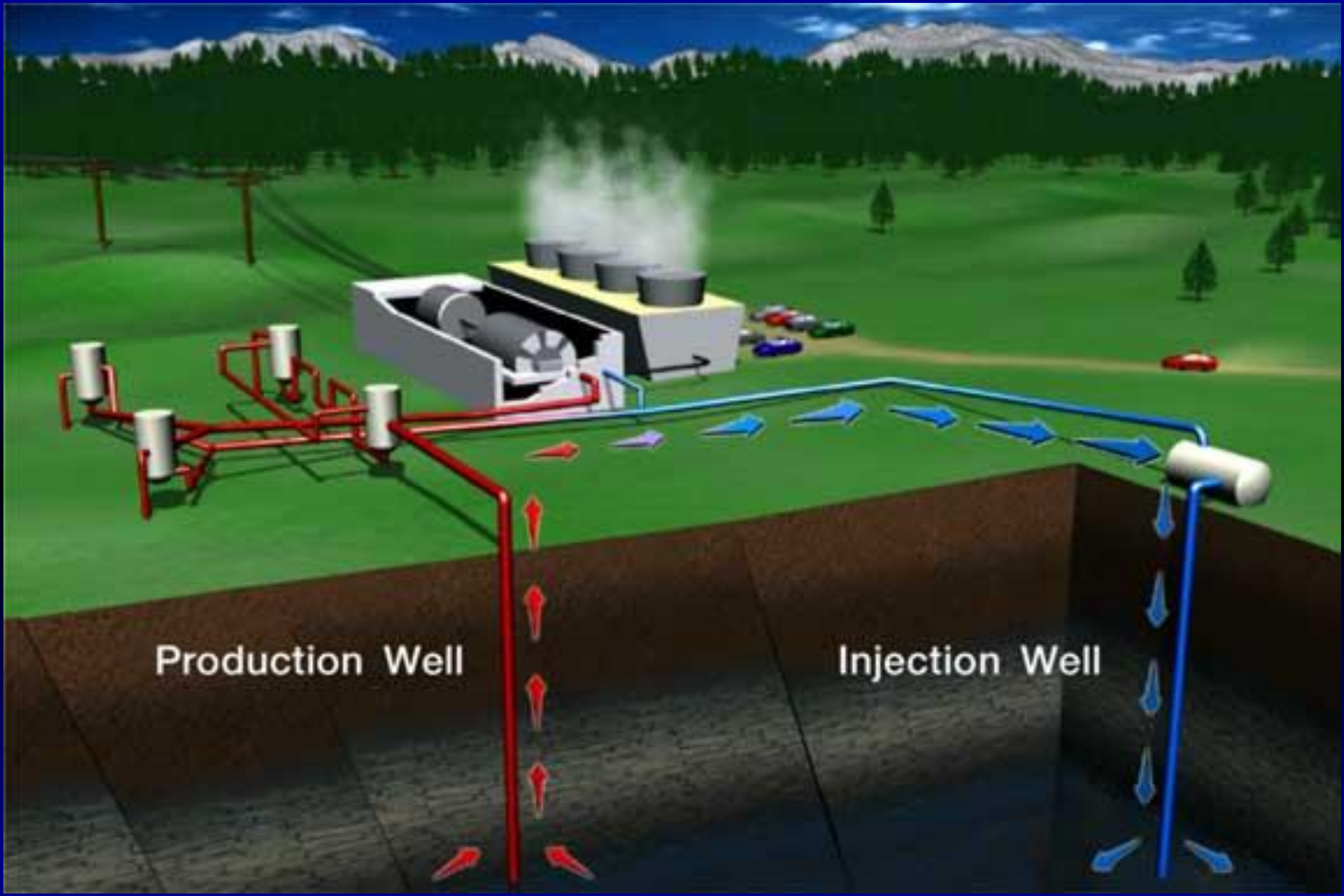
Volcanoes are obvious indications of underground heat, this volcano, Mt. Mayon in the Albay province of the Philippines erupted in 1999.

Geologic landforms and fault structures are mapped in the region. This view overlooks Basin and Range terrain East of the Sierra Nevadas.

Geologists explore volcanic regions to find the most likely areas for further study, like this steaming hillside in El Hoyo, Nicaragua.

- Geothermal energy is produced by drilling a well into the ground where thermal activity is occurring. Once a well has been identified and a well head attached, the steam is separated from the water, the water is diverted through a turbine engine which turns a generator.
- Usually the water is injected back into the ground to resupply the geothermal source.





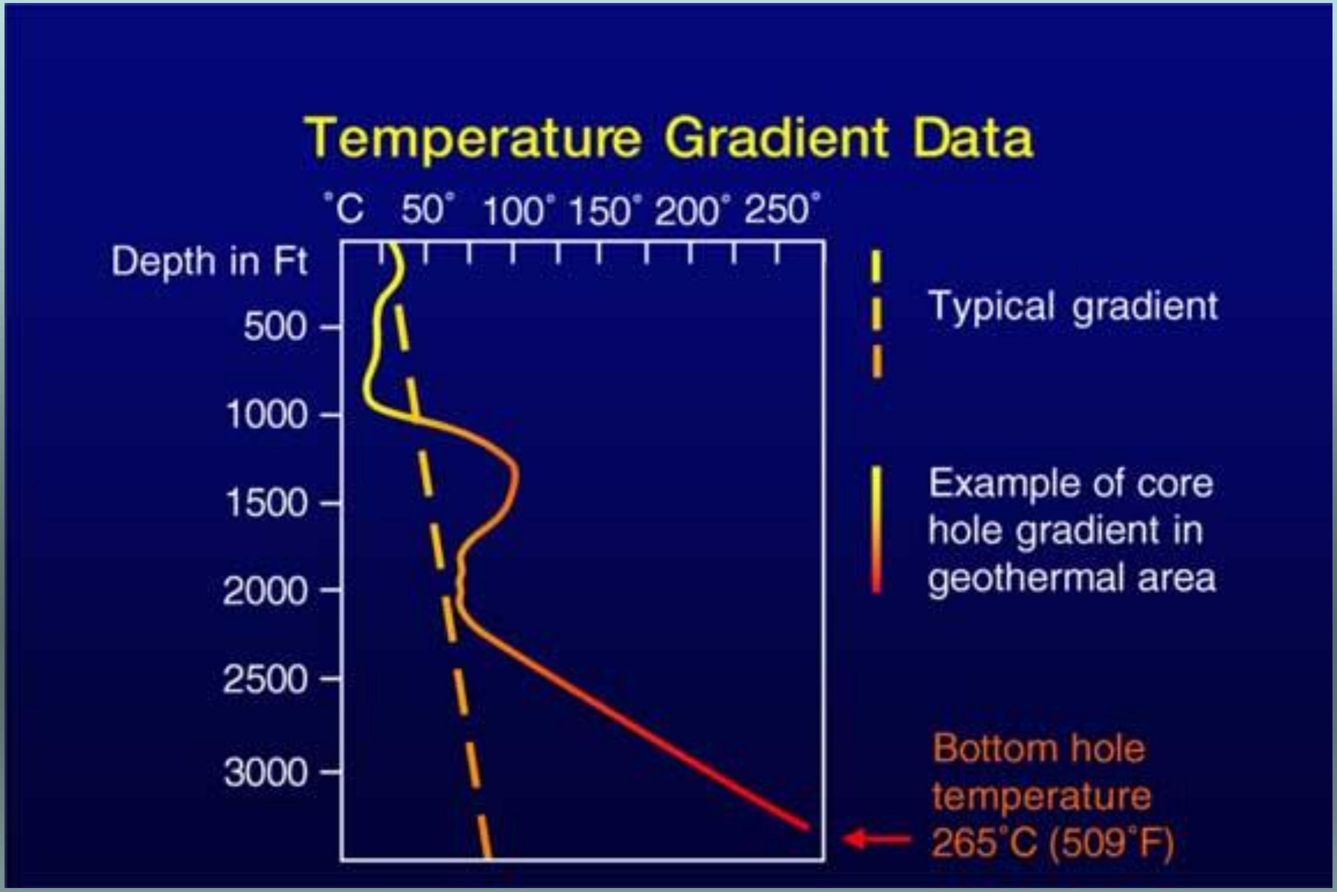
Production Well
Injection Well

First, a small- diameter "temperature gradient hole" is drilled (some only 200' deep, some over 4000 feet deep) with a truck-mounted rig to determine the temperatures and underground rock types.

Workers on a temperature gradient hole drilling project.

Either rock fragments or long cores of rock are brought up from deep down the hole and temperatures are measured at depth.

Geologists examine the cored rock (shown here marked with depth markers).



- Temperature results like this would definitely encourage the drilling of a larger, deeper well to try to find a hydrothermal reservoir.

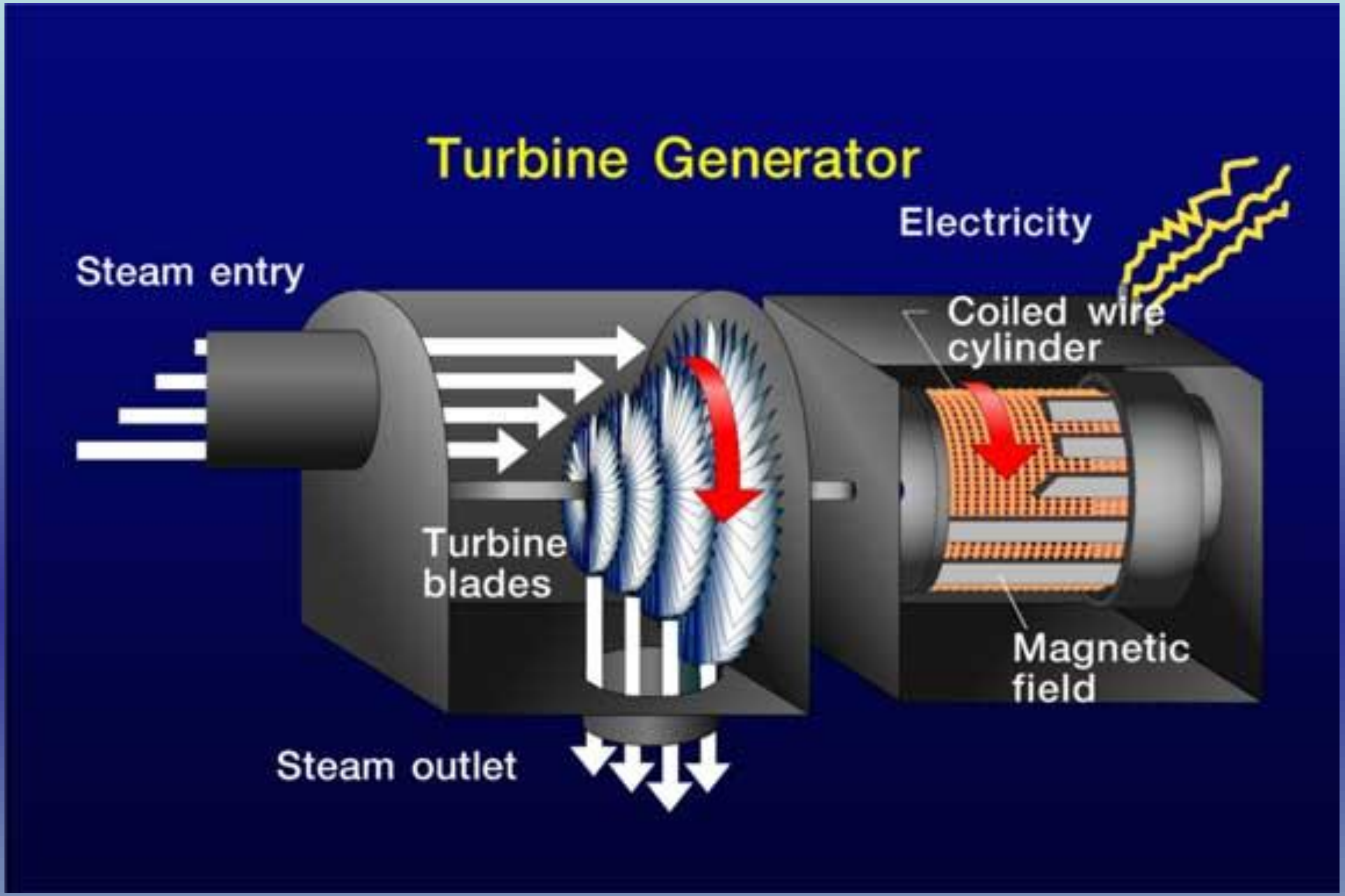
Production-sized wells require large drill rigs like these and can cost as much as a million dollars or more to drill. Geothermal wells can be drilled over two miles deep.

If a reservoir is discovered, characteristics of the well and the reservoir are tested by flowing the well.

If the well is good enough, a wellhead, with valves and control equipment, is built onto the top of the well casing.

This photograph shows a vertical geothermal well test in the Nevada Desert.

Generation of Electricity



Like all steam turbine generators, the force of steam is used to spin the turbine blades which spin the generator, producing electricity. But with geothermal energy, no fuels are burned.

Turbine blades inside a geothermal turbine generator.

Turbine generator outdoors at an Imperial Valley geothermal power plant in California.

Types of Geothermal Power Plants

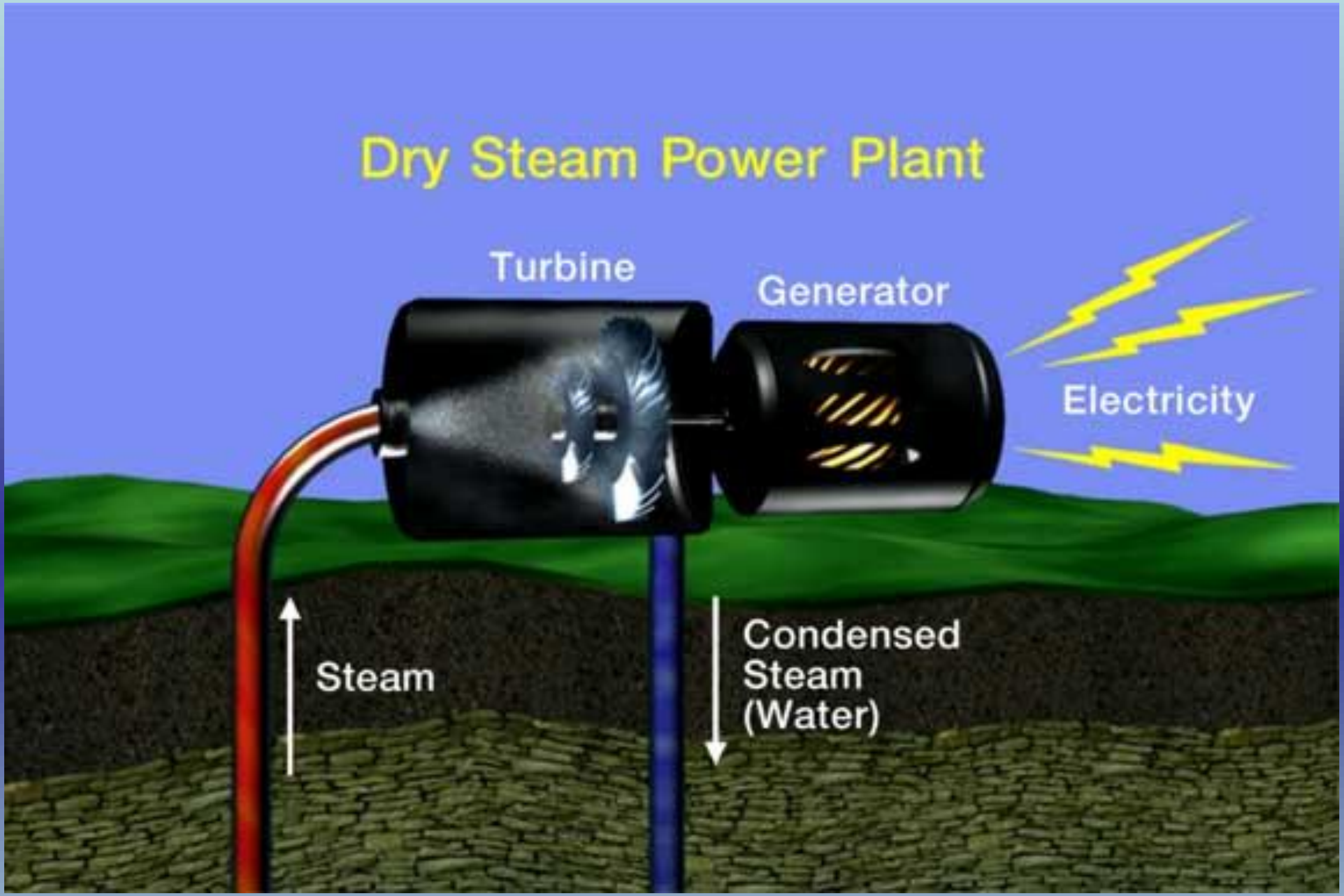
Types of Geothermal Power Plants

Power Plants

- Dry Steam
- Flash Steam
- Binary Cycle

There are different kinds of geothermal reservoirs and different kinds of power plants.

Dry Steam Power Plants or Hot Dry Rock Power Plants



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.

Dry Steam Power Plants or Hot Dry Rock Power Plants

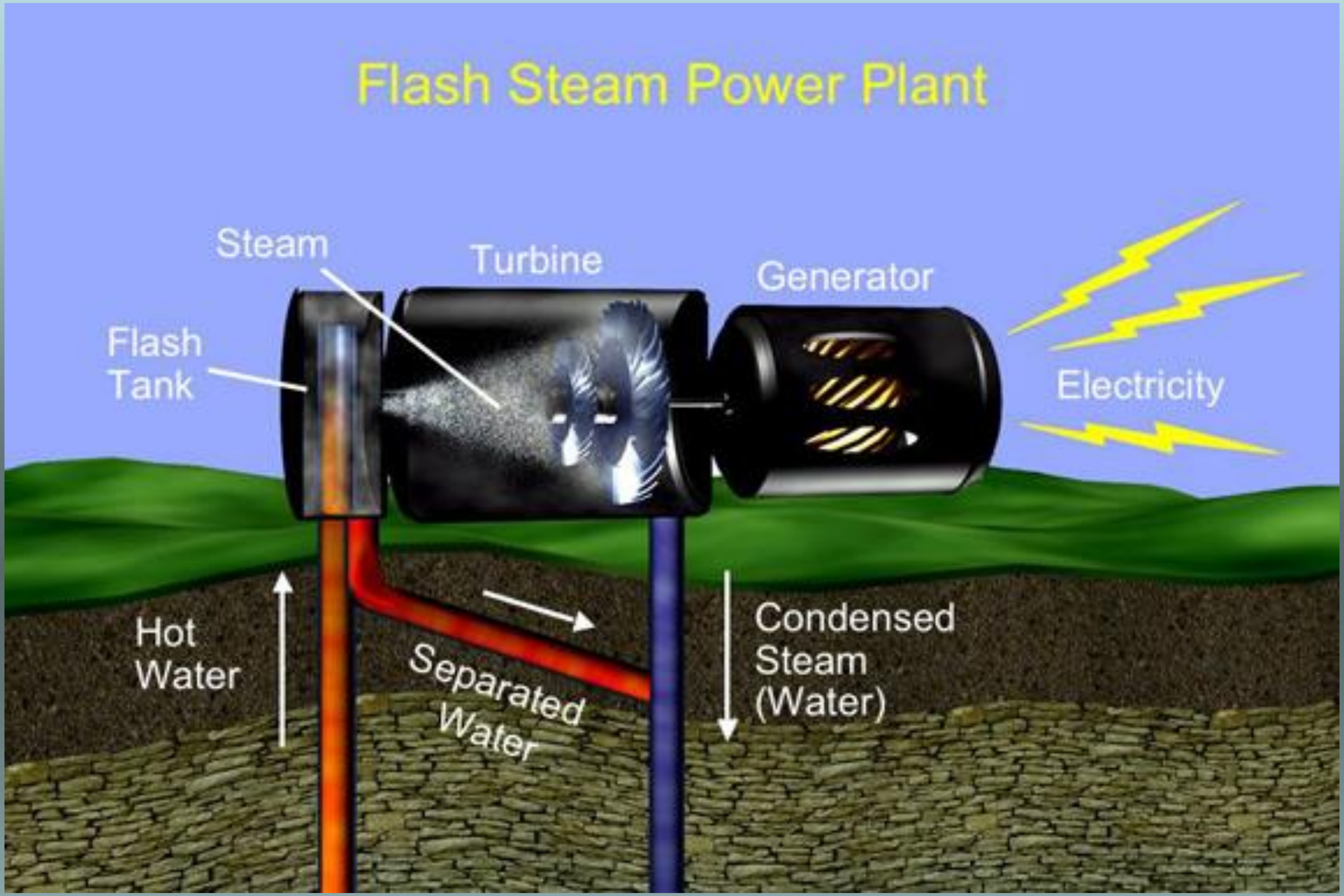
- Vapor dominated resources where steam production is not contaminated
- Steam is 1050°F - 1220° F
- Steam passes through turbine
- Steam expands
- Blades and shaft rotate and generate power
- Cooling towers generate waste heat
- Most common and most commercially attractive (Godfrey Boyle)
- Used in areas where geysers do not exist
- Need water to inject down into rock
- Well is deep
- Takes more time to inject water in well

First Geothermal Power Plant, 1904, Larderello, Italy

The first modern geothermal power plants were also built in Lardello, Italy. They were destroyed in World War II and rebuilt. Today after 90 years, the Lardello field is still producing.

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.

Flash or Steam plants



- 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 if it flashes to steam.

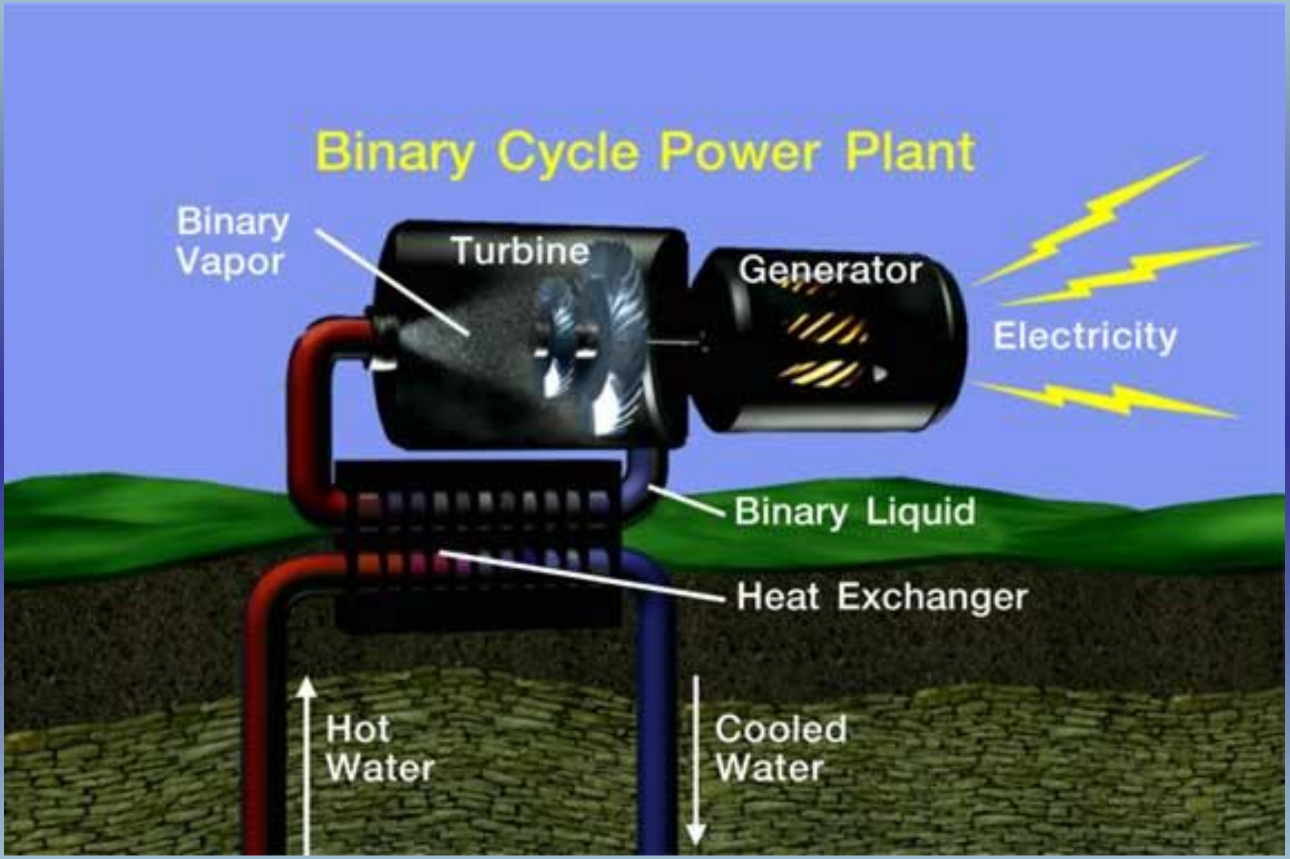
Flash or Steam plants

- Use very hot (more than 300° F) steam and hot water resources (as found at The Geysers plants in northern California)
- Steam either comes directly from the resource, or the very hot, high-pressure water is depressurized (“flashed”) to produce steam.
- Steam then turns turbines, which drive generators that generate electricity.
- Only significant emission from these plants is steam (water vapor).
- Minute amounts of carbon dioxide, nitric oxide, and sulfur are emitted, but almost 50 times less than at traditional, fossil-fuel power plants.
- Energy produced this way currently costs about 4-6 cents per kWh.

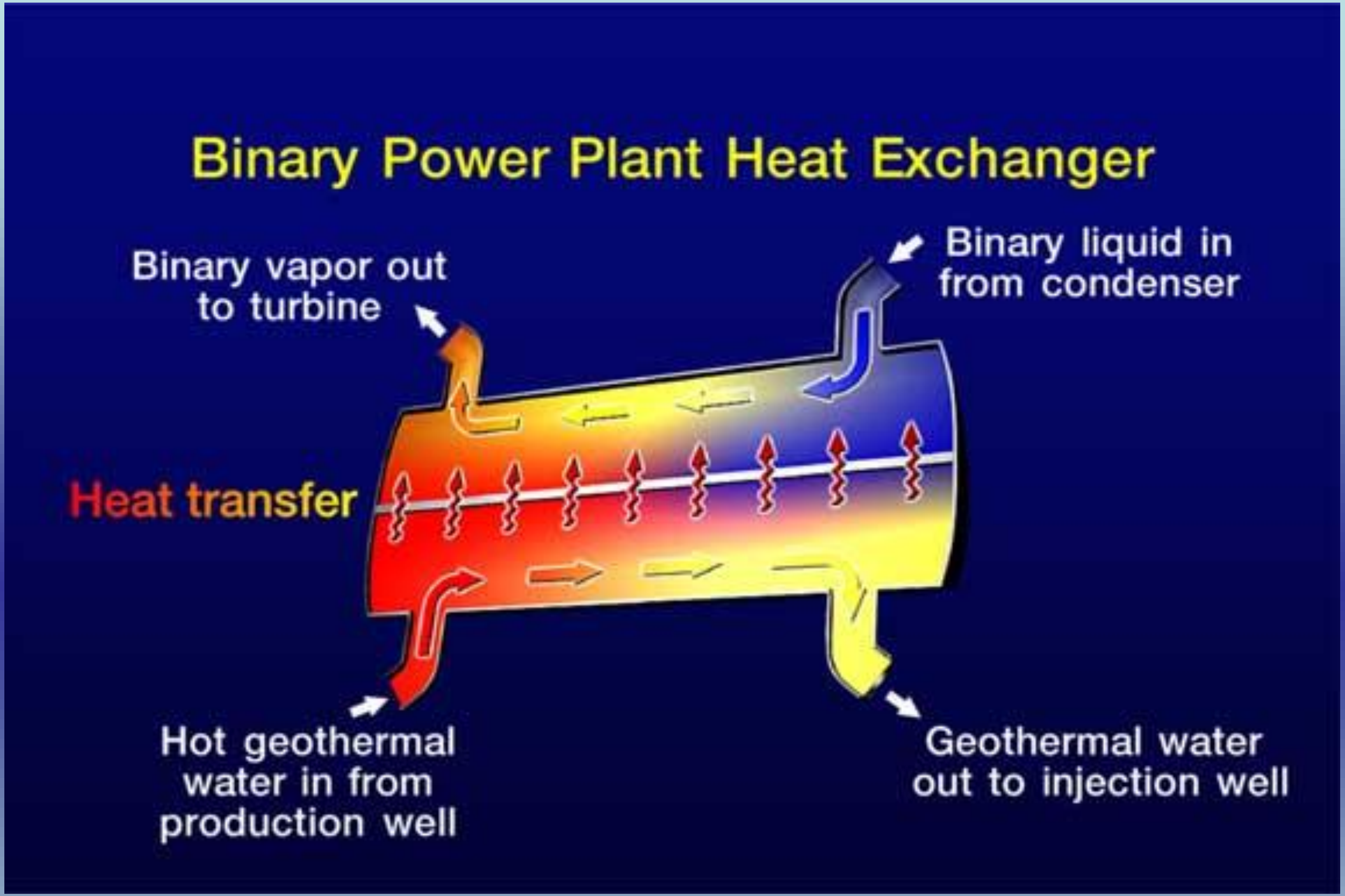
This flash plant is in Japan. In flash plants, both the unused geothermal water and condensed steam are injected back into the periphery of the reservoir to sustain the life of the reservoir.

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

- Geothermal technology has three varied ways of taking geothermal energy and turning it in to useable energy for humans to use. The most common systems are steam and binary power plants.



- **In a binary cycle power plant (binary means two), the heat from geothermal water is used to vaporize a "working fluid" 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.

Binary cycle power plant

- Uses lower-temperatures, but much more common, hot water resources (100° F – 300° F).
- Hot water is passed through a heat exchanger in conjunction with a secondary (hence, “binary plant”) fluid with a lower boiling point (usually a hydrocarbon such as isobutane or isopentane).
- Secondary fluid vaporizes, which turns the turbines, which drive the generators.
- Remaining secondary fluid is simply recycled through the heat exchanger.
- Geothermal fluid is condensed and returned to the reservoir.
- Binary plants use a self-contained cycle, nothing is emitted.
- Energy produced by binary plants currently costs about 5 to 8 cents per kWh.
- Lower-temperature reservoirs are far more common, which makes binary plants more prevalent.

Multiple Use Containerized Small Power Plant Fangs, Thailand 300 kW Geothermal Power Fang.

- Geo-Fluid flow is at temp. of 230º F, injection fluid heats spa, provides for refrigeration and crop drying. Plant availability is 94%Power Plant is water cooled by once through flow of river.

This small binary power plant is in Fang, Thailand.

Binary technology allows the use of lower temperature reservoirs, thus increasing the number of reservoirs that can be used. This binary plant is at Soda Lake, Nevada.

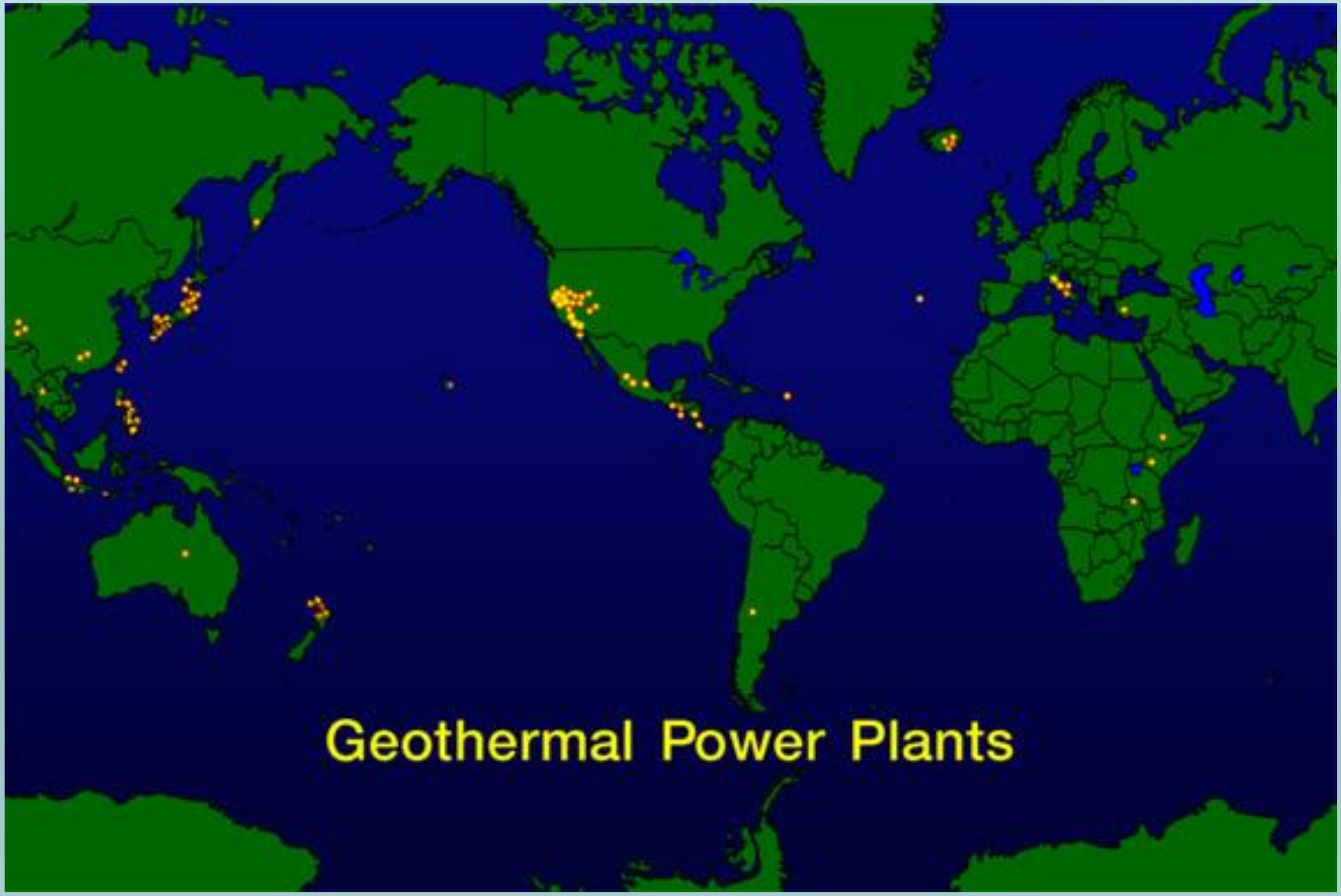
This power plant provides about 25% of the electricity used on the Big Island of Hawaii. It is a hybrid binary and flash plant.

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

Worldwide Electricity Generation

Geothermal power plants are producing over 8,200 megawatts of electricity in 21 countries, supplying about 60 million people -- mostly in developing countries.



- People who live in these areas are receiving electricity from geothermal power plants.

Countries Generating Electricity with Geothermal Resources

Australia	Indonesia	Portugal (Azores)
China	Italy	Russia (Kamchatka)
Costa Rica	Japan	Taiwan
El Salvador	Kenya	Thailand
Ethiopia	Mexico	Tibet
France (Guadeloupe)	New Zealand	Turkey
Guatemala	Nicaragua	United States
Iceland	Philippines	Zambia

...and geothermal power plants are planned in several other countries

- **Geothermal power could serve 100% of the electrical needs of 39 countries (over 620,000,000 people) in Africa, Central/ South America and the Pacific. See:** www.geotherm.org/PotentialReport.htm

Direct Uses

- **Producing electricity is a relatively new use of geothermal energy. People have used Earth's natural hot water directly since the dawn of humankind.**

Direct Uses

- Balneology (hot spring and spa bathing)
- Agriculture (greenhouse and soil warming)
- Aquaculture (fish, prawn, and alligator farming)
- Industrial Uses (product drying and warming)
- Residential and District Heating

Worldwide Geothermal Direct Use

- Direct uses of geothermal water supply over 11,000 thermal megawatts in over 40 countries.
- Another 35 countries use natural hot springs for bathing but have not yet developed their geothermal reservoirs for commercial use.

This historical drawing depicts Native Americans using hot springs at what is now Calistoga, California. Some tribes considered hot springs to be neutral territory where no wars were allowed.

Use of hot springs by Maoris of New Zealand for cooking and other purposes extends into modern times.

Modern day Beppu Japan uses geothermal water and heat in buildings and factories and has 4,000 hot springs and bathing facilities that attract 12 million tourists a year.

Bathing in hot pools like these at Hot Creek, Mammoth Lakes, California, has been practiced throughout history. Be careful — people and animals have been burned badly in unfamiliar pools.

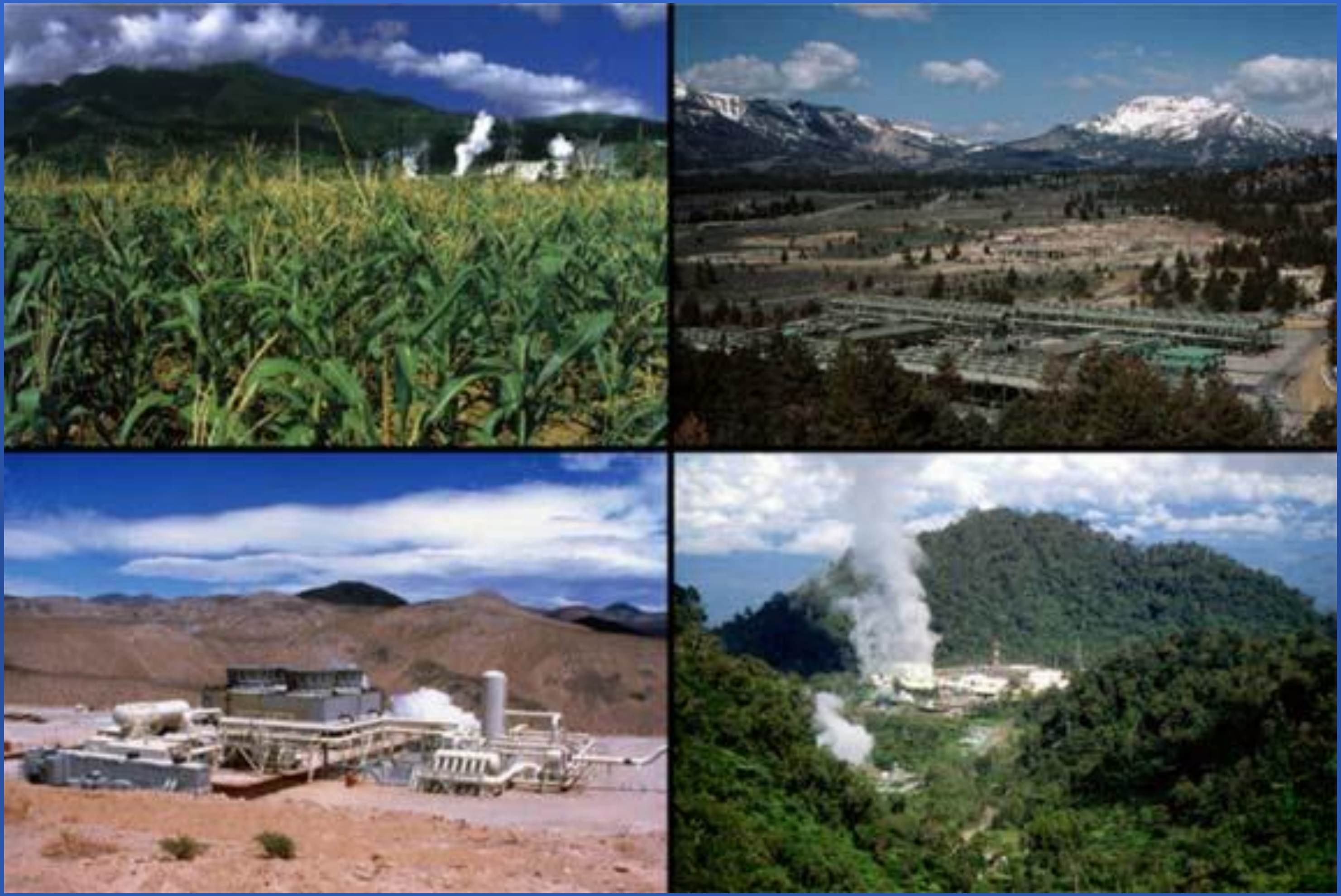
Since Roman times, we have piped the hot water into pools to better control the temperature. These are photos of outdoor and indoor pool and spa bathing in Japan, the US, and Europe.

Easy on the Environment

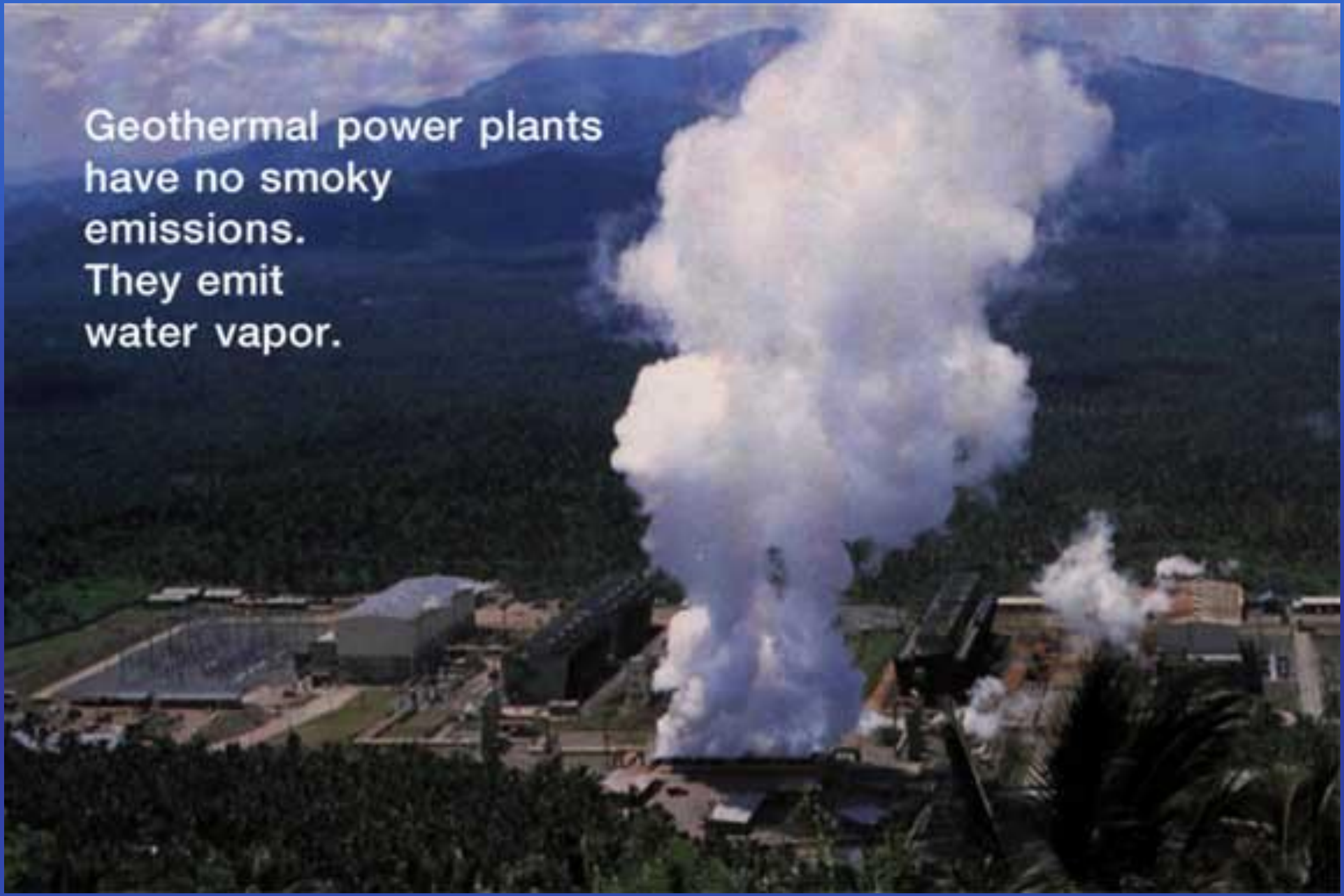
Geothermal power plants have been built:

- In the middle of crops
- In forested recreation areas
- In fragile deserts
- In tropical forests

Geothermal power plants are clean and are operating successfully in sensitive environments.



- These geothermal plants are operating successfully in a Philippine cornfield, at Mammoth Lakes, Calif., in the Mojave Desert of California, and in a tropical forest, at Mt. Apo, Philippines.



- Those white plumes you see at geothermal power plants are steam (water vapor). Geothermal plants do not burn fuel or produce smoke.

This photo of Reykjavik, Iceland, was taken in 1932, when buildings were all heated by burning of (imported) fossil fuels.

Today, about 95% of the buildings in Reykjavik are heated with geothermal water. Reykjavik is now one of the cleanest cities in the world.

This small greenhouse is heated with geothermal water. Plants grow faster and larger when they have additional heat available.

Peppers, tomatoes, and flowers are commonly grown in geothermal heated greenhouses.

- Geothermal water is also used to speed the growth of fish. These are growing in a geothermally heated hatchery at Mammoth Lakes, California.

This net full of fish was grown in geothermally heated waters in California's Imperial Valley.

Closeup of a prawn grown in a research project with geothermally heated water at the GeoHeat Center, Oregon Institute of Technology.

Closeup of individual fish from a geothermal fish farm.

Philippine's geothermic production

- Worldwide, the Philippines rank second to the United States in producing geothermic energy.
- Leyte is one of the island in the Philippines where geothermic power plants were developed. The developments here started in 1977 by the company **PNOC**.
- In the Philippines geothermal energy already provides 27% of the country's total electricity production generated in power plants. Geothermal power plants are on the islands Luzon, Negros, Mindanao and Leyte.
- The production of the electricity by geothermal plants is cheaper than the electricity produced in plants by using natural gas and coal. It is even cheaper than electricity produced by hydro power stations.
- The possibility of getting the hot steam is only in weaker parts of the crust of the earth. The Pacific Rim is such a weak belt. The Philippines is located in the Western part of the Pacific Rim. In this weak belt deep fractures occur in the earth's crust and the tens of volcanic centers are the consequences of these fractures.
- The hot molten material (magma) inside the inner earth is in this belt close enough to the earth surface to heat the water reservoirs, from which the hot steam can be generated!

Upper Mahiao, The Philippines

Power plant in Tongonan, region Ormoc City, Leyte (Picture: PNOC)

Volcanoes are obvious indications of underground heat, this volcano, Mt. Mayon in the Albay province of the Philippines erupted in 1999.

- Geothermal power plant operators in geothermal power plant control room in the Philippines.

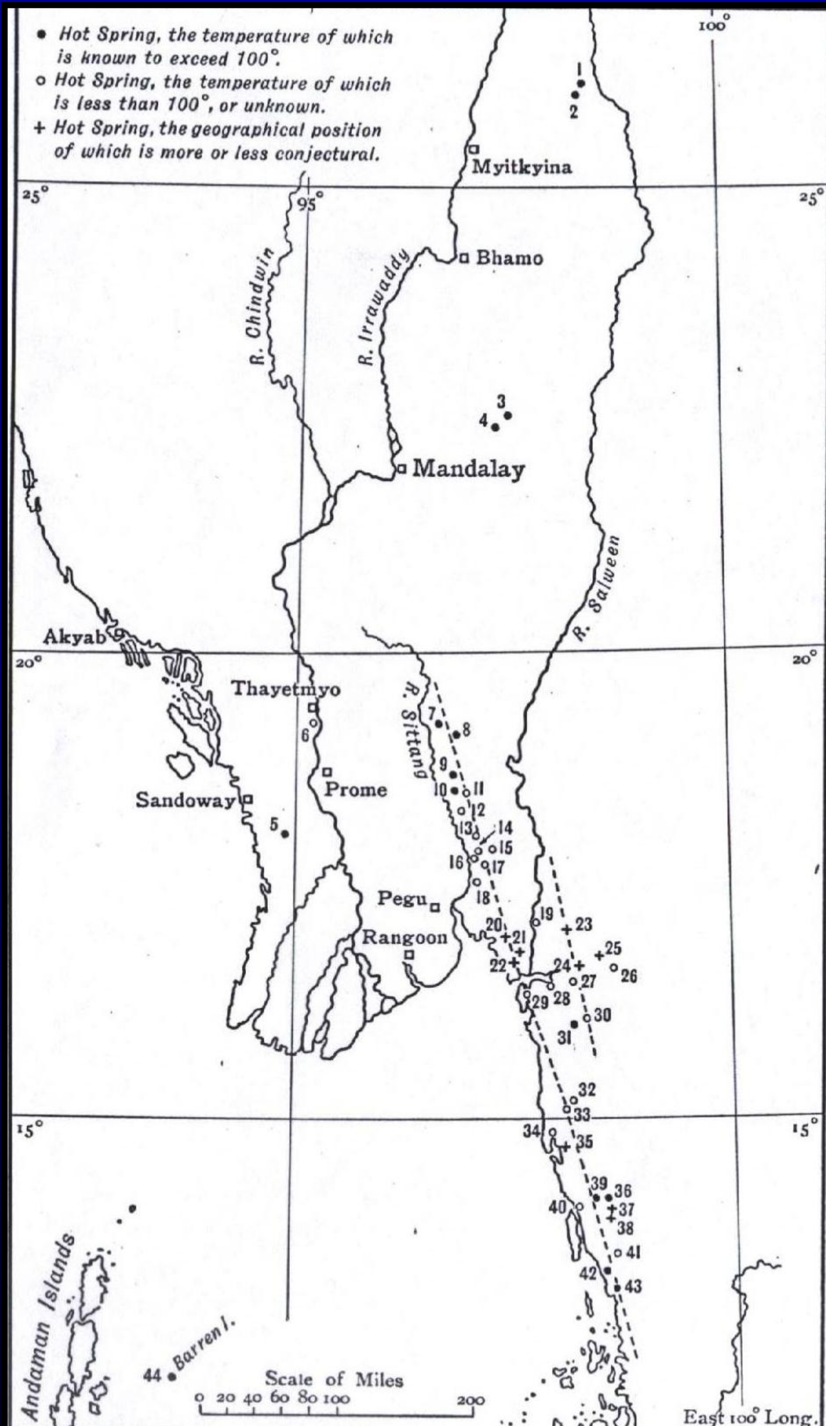
GEOTHERMAL ENERGY IN MYANMAR

Potential

- Myanmar is one of the countries with numerous geothermal resources that could be represented as an additional source of energy to fulfill its future energy requirement.
- Myanmar has five distinctive igneous alignments related to geographical features of the country, which stretches from North to South. The igneous activity appeared to be more intense during late Tertiary and Quartenary although the activity ranged from Cretaceous to as late as Recent.
- Widespread occurrences of hot springs had been known to exist not only in the younger volcanic regions but also in non-volcanic and metamorphosed areas where round water heated at depths have ascended through faults, fractures and fissues.
- Hot springs are found in Kachin State, Shan State, Kayah State, the Southern Part of Rakhine Stae in Kyaukphyu, Central Myanmar Area, Shwebo-Monywa Area and especially in Mon State and Taninthayi Division. A total of 93 hot springs have so far been recorded and identified.

Geothermal Resources of Myanmar

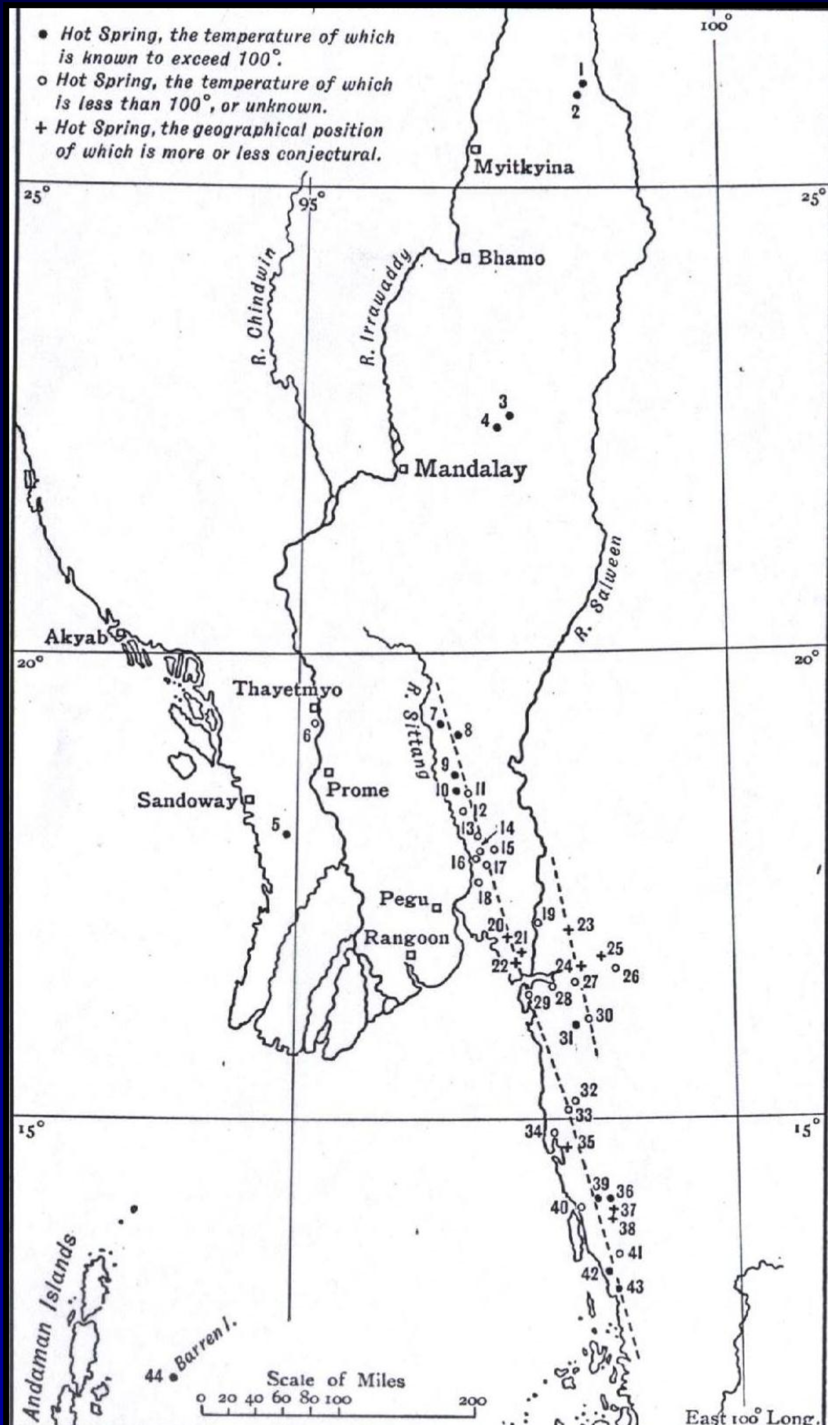
Sr. No.	State / Division	No. of Hot Springs	Average Surface Temperature Degree C	PH Number
1.	Kachin State	2	-	-
2.	Kayah State	5	-	-
3.	Kayin State	15	48.61(37.78-61.67)	-
4.	Sagaing Division	10	32.41(29.44-48.89)	7.8
5.	Taninthayi Division	19	51.46 (37.78-51.67)	-
6.	Magway Division	5	40.78 (32.22-48.89)	7.6
7.	Mandalay Division	3	36.65 (30.56-40.00)	6.5
8.	Mon State	19	51.08 (37.78-65.8)	7.7
9.	Rakhine State	1	-	-
10	Shan State	17	43.50 (27.8-61.7)	6.9



HOT SPRINGS

DISTRIBUTION OF THE HOT SPRINGS IN BURMA (MYANMAR)

1. Munglang Hka (25 58′ , 98 29′).
2. Yinchingpa (25° 56’, 98° 23’).
3. Pengwai, Northern Shan States.
4. Namon, Northern Shan States.
5. Sandoway river (18 6’, 94 54’).
6. Bule (19 16’, 95 54’)
7. Lepanbewchaung (19 16’, 96 36’).
8. Kayenchaung (19° 10’, 96° 36’).
9. Chaungna-nay (18° 44’, 96° 46’).
10. Kayloo Myoung (15° 33’, 96° 51’).
11. Bin-byai (18° 33’, 96° 55’).
12. Mai-Pouk (18° 19’, 96° 54’).
13. Sair-O-Khan (97° 4’, 18° 4’).
14. Hteepahtoh (17° 56’, 97° 3’).
15. Vadai Chaung (17° 56’, 97° 12’).
16. Koon-Pai (17° 55’, 97° 1’).
17. Maiting (17° 53’, 97° 4’).
18. Kyoung Chaung (17° 35’, 97° 2’).
19. Gyo (17° 10’, 97° 39’).
20. Nga Yai Kyoon Juin, in Martaban.



21. Seinli, in Martaban.
22. Kaline Aung, in Martaban.
23. Poung Yaboo, in the District of Salwen.
24. Noungtyne.
25. Mai-Palai.
26. Mya-waddi (16° 43’, 98° 32’).
27. Poung (16° 9’, 98° 14’).
28. Yabu (16° 34’, 98° 9’).
29. Damathat (16° 33’, 97° 52’).
30. Bonet (16° 27’, 97° 37’).
31. Ataran (17° 53’, 97° 4’).
32. Myan-Khoung (15° 13’, 98° 7’).
33. Thalan-Khoung (15° 10’, 98° 3’).
34. Nay Gyi Zin (14° 55’, 98° 0’).
35. Henzai.
36. Myitha (14° 13’, 98° 33’).
37. Paltha Kyoung.
38. Mandoo.
39. Kaukyen (14° 12’, 98° 25’).
40. Moung Mayan (14° 9’, 98° 9’).
41. Toungbyouk (13° 33’, 98° 40’).
42. Pai (13° 26’, 98° 33’).
43. Palouk (13° 13’, 98° 40’).
44. Barren Island (12° 11’, 93° 54’).

Current Status of Exploitation

- Preliminary investigations have been made on 43 hot spring during 1986 by Myanma Oil and Gas Enterprise ("MOGE"). During the investigation, surface and subsurface temperature were measured and recorded and chemical analysis performed on stream and water samples.
- Myanma Oil and Gas Enterprise ("MOGE") of the Ministry of Energy and Myanma Electric Power Enterprise ("MEPE") of Ministry of Electric Power conducted studies with Electric Power Development Co. Ltd. ("EPDC") of Japan at Bilukyun, Chaungsone Township and Thanbyuzayat Township in Mon State and also at Shwenyaung Township and at Innlay Lake in Shan State during February and March 1987. Water samples of hot springs were collected and chemical analysis and X-ray diffraction analysis were performed on these samples.
- In addition, MOGE conducted preliminary analysis of geothermal data from reconnaissance sampling of 15 hot springs in cooperation with UNOCAL of United States during 1990. Studies have also been made in collaboration with Mr. R. D. Johnston, Consultant of Geothermal Energy New Zealand Ltd. ("GENZL") and Dr. Pongpor Aganchimela of Thailand near Kyaingtone, Shan State during the same period.

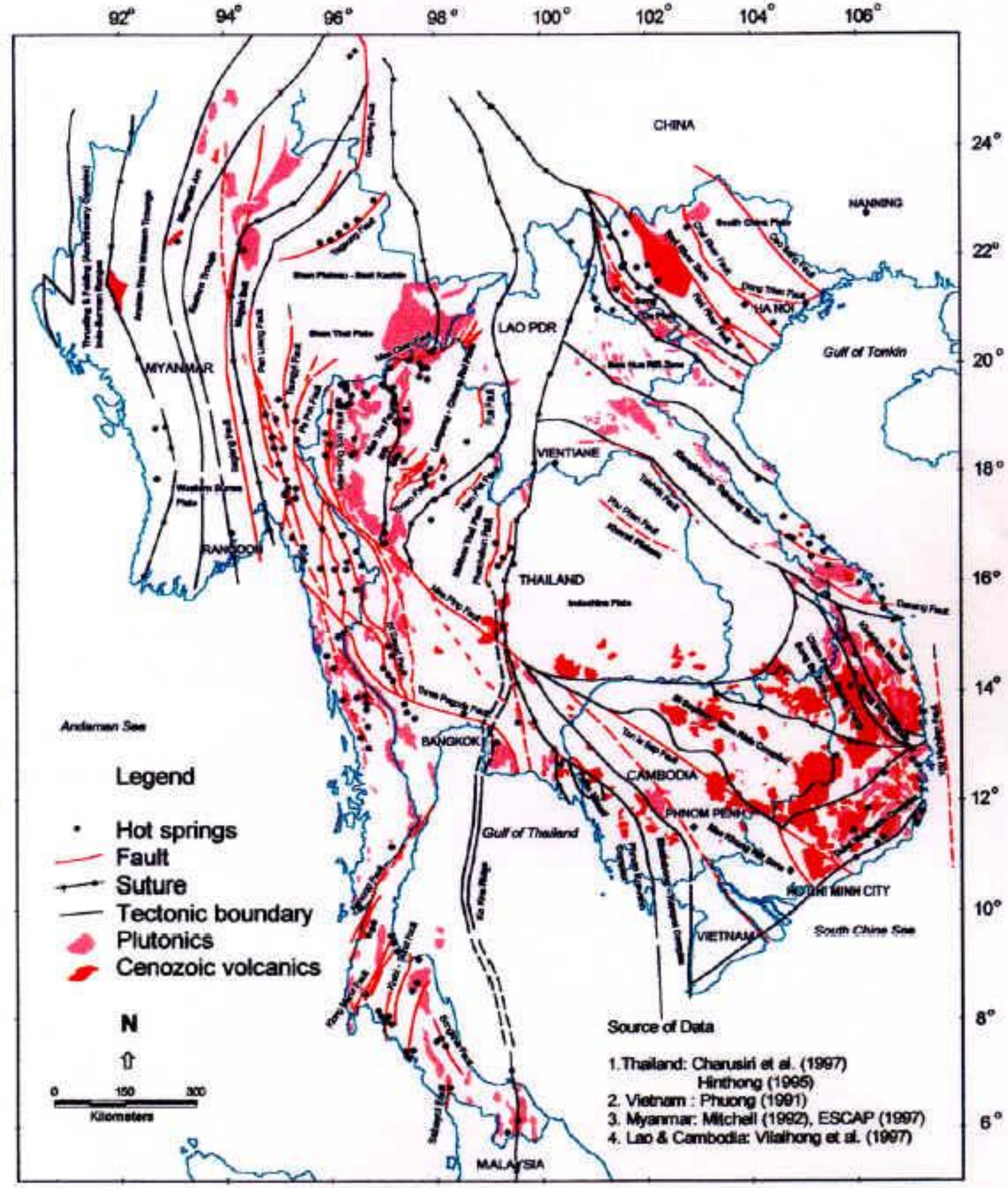
Current Status of Exploitation

- During April and May 1995, Geologists from MOGE and CAITHNESS RESOURCES INC. from United States performed reconnaissance surveys by collecting water samples from 10 hot springs out of 43 hot springs which MOGE has preliminary investigated.

Preliminary Investigation Conducted by MOGE during January to June 1986.

See: Appendix (1)

APPLICATION OF GEOTHERMAL RESOURCES OF THAILAND, VIETNAM, AND MYANMAR TO TECTONIC SETTINGS



. Simplified tectonic map of SE Asia showing some major active faults and distribution of plutonics, Cenozoic volcanics, and hot springs.

Myanmar

- In Myanmar, information deduced from our LANDSAT and NOAA image Interpretation, petroleum exploration drilling data and our field survey, indicate that high geothermal gradients are concentrated in areas closely related to Cenozoie volcanics, Mesozoic to Cenozoie granites, and active faults.
- The latter are quite more cryptic, since the geothermal springs are likely to follow the N-trending left-lateral Sagaing and Papun active faults in Myanmar along which Cenozoic- Mesozoic intrusions have taken place. In addition, several hot spring locations in southern Myanmar aligned following the northward extension of Three Pagoda Fault of westem Thailand.
- Although some thermal springs in Myanmar are also associated with volcanism, the more common features are those within the granite regions where faulting are still active.
- Therefore, it is likely that the hot springs are predominantly triggered by the active tectonic faults where underlying shallow-depth magma bodies are currently cooling down. We therefore consider that the geothermal resources of Myanmar have been triggered by extension tectonics in seismically active areas.

Myanmar (Contd,)

- In Myanmar, the hot springs seem to be associated with the on-going left-lateral fault movement in regions underlying on- cooling shallow-depth magmas.

Thailand and Vietnam

See: Appendix (2)

Appendix (1)

Sr. No.	Location State / Division	Hot Springs	Surface Temperature Degree F	Estimated Subsurface Temperature Degree F
1.	***Kayin State***	Kayinchaung (Thandaung)	100	304
2.		Kanchoni (Thandaung)	143	218
3.		Thandaung (Thandaung)	188	230
4.		Pathichaung (Thandaung)	117	260
5.		Tilon Hot Spring (Hlaingbwe)	120	529
6.	***Sagaing Division***	Halin Hot Spring (Wetlet)	120	177
7.		Ywatha Hot Spring 1 (Yinmabin)	85	331
8.		Ywatha Hot Spring 2 (Yinmabin)	85	-
9.		Ywatha Hot Spring 3 (Yinmabin)	85	-
10.		Ywatha Hot Spring II (Yinmabin)	85	-
11.		Myogyi Hot Spring (Yinmabin)	80	-
12.		Myekyetsu (Yinmabin)	80	-
13.		Ywadaung (Yinmabin)	85	-
14.		Hnawyo Hot Spring (Yinmabin)	85	-

Sr. No.	Location State / Division	Hot Springs	Surface Temperature Degree F	Estimated Subsurface Temperature Degree F
15.	***Taninthayi Division***	Maungmagan (Launglon)	125	324
16.		Wagon Hot Spring (Dawei)	135	406
17.		Wazuchaung (Dawei)	117	423
18.		Maliwun Hot Spring(Kawthaung)	150	396
19		Yebu Hot Spring 1 (Taninthayi)	135	583
20		Yebu Hot Spring 2 (Taninthayi)	110	-
21		Taninthayi (Taninthayi)	100	550
22.	***Magway Division***	Suyitkan Hot Spring (Chauk)	100	121
23		Mann Hot Spring (1)	120	188
24		Mann Hot Spring (2)	90	-
25	***Mandalay Division***	Yebu Hot Spring (Thazi)	87	346
26		Pyinyaung Hot Spring (Thazi)	103	408
27.	***Mon State***	Chaunghnakwa Yebu (Kyaikmaraw)	120-125	670
28.		Damathat Yebutaung(Kyaikmaraw)	120	414
29		Bonet Hot Spring (Chaungzon)	140	283
30		Wegali Hot Spring 1(Thanbyuzayat)	100	-
31.		Wegali Hot Spring 2(Thanbyuzayat)	125	497
32		Palanchaung (Ye)	125	497
33.		Bingyi Cave Hot Spring (Thaton)	103	458

Sr. No.	Location State / Division	Hot Springs	Surface Temperature Degree F	Estimated Subsurface Temperature Degree F
34.	***Shan State***	Pauktaw Hot Spring (Nyaungshwe)	85	367
35		Shwelinban Hot Spring (Nyaungshwe)	82	423
36.		Yenwe Hot Spring (Nyaungshwe)	85	486
37.		Nyaungwun Hot Spring (Nyaungshwe)	130	385
38.		Kaungdaing Hot Spring (Nyaungshwe)	110	416
39.		Yenwe Hot Spring 1 (Taunggyi)	117	419
40.		Yenwe Hot Spring 2 (Taunggyi)	95	-
41.		Yenwe Hot Spring 3 (Taunggyi)	110	-
42.		Lashio Hot Spring	120	682
43.		Nawng-Ang (Kyaukme)	105	498

Appendix (2)

THALAND

HOT SPRING AND HEAT FLOW DATA

- In Thailand the first detailed investigation on geothermal resources is that of Takashima et al. (1979). At present, at least 65 thermal springs in northern and western parts of the country have been studied. In the south, a recent investigation has been made by Chaturongkawanich and his coworkers (this volume), and up to 30 locations have been recorded.
- However the thermal springs in southern Thailand always contain similar values of total dissolved solids (TDS) and some other alkaline values. Comparison between chemical compositions of thermal springs in northern and southern Thailand reveals relatively nonsignificant geochemical Variation.
- Thermal springs in Thailand, based upon our compilation and investigations, indicate that they are located largely within the granite terrain and chiefly characterized by Na and CO3 with some SO4. Chlorine is also detected in some locations.
- In addition, Charusiri et al. (1996) observe that many hot springs, particularly those in northern Thailand, are located in the vicinily of lineament features. These lineaments are interpreted to represent active faults.

- In northern Thailand, hot springs have generally stronger mineral constituents. The TDS of water very in a large degree from 315 to 700. The Na content ranges from 80 to 176 mg/l. The anion contents seem not changed very much, ranging from 16 to 65 mg/l for SO, and from 1.7 to 31.0 mg/l for Cl.
- In the south, investigation on thermal springs have been carried out very recently, so far data on physio-chemical characteristics of thermal springs are much more scarce. Less than 10 locations have been observed for their geochemical concentrations and the contrast among them in this region is not much.
- Quite commonly, ranges of the TDS and Na contents for thermal springs become higher in some areas of southern Thailand due to sca water invasion. Surface temperatures vary from 60 to 99 °C in the north and from 55 to 85 °C in the south.
- Based upon exploration drilling, subsurface temperatures averagely range from 120 to 130 °C in the north and approximately 110 to 120 °C in the south. Although with some high - temperature hot spring areas in northern Thailand where main reservoir temperatures are up to 200 °C (see Raksaskulwong and Thienprasert, 1995), further detailed studies are required to carry out in areas with highest temperatures in order to enhance more confidence prior to development of geothermal energy for power plants being launched.

- In the light of heat flow information, it was reported that heat flows in northern Thailand (Takashima et al., 1989) vary from l to 2 HFU (microcalories/cm' l HFU = 41.87 mWlm') which is not high.
- However, the more recent data on heat flow of Thailand by Thienprasert and Rasaskulwong (1984) and Raksasakuwong and Thienprasert (1995), depict variable values from < l HFL' up to > 2.5 HFLI. In their maps, there are three regions where heat flows were observed to be quite high.
- These are l) Tak (along the Mae Ping Fault) in the westernmost part of Thailand, 2) Lopburi - Phetchabun (along the Phetchabun Fault) in the eastcentral part. and 3) Lampang- Phrae (within the Thoen Fault) in the north, the latter being much smaller inside than the other two regions.

- In Vietnam, the Situation is rather similar to Thailand in that only few researches concerning geothermal resources were carried out. However, there are few unpublished data to indicate thermal springs (see Tram Du Lounge and Nguyen Xuan Boa, 1982).
- Presently, about 60 locations of hot springs have been observed. Geochemical monitoring and results on thermal springs reveals that most of the springs are dominated by the Na- and 003 - rich water. However, the occurrence of some C1 contents in several locations leads us to consider some difference in the water type. In addition, the disappearance of the SO4 content of the springs make more contrast in geochemical thermal - spring characteristics between Vietnam and Thailand.
- Additionally, it was also observed that thermal springs in northern Vietnam are much more HCO3 - dominated. However, hot springs in central Vietnam show the enrichment of Cl, apart from the Na and CO3 contents, whereas in the south it is characterized by high concentrations of both Cl and HCOs values. It is important to note herein, that the thermal springs and some surface water, particularly in deltaic environment such as Mekhong and Red River flood plain areas, are characteristically manifested by the appearance of CH4.

APPLICATION TO TECTONIC SETTINGS

THALAND

- The medium values of heat flows in the Khorat Plateau, although without any hot spring relationship, probably advocate the NW-trending elongate and narrow zone of the uplifted region compatible with the Phuphan Fault.
- The alignment of hot springs associated high heat flows and Cenozoic vulcanic.activities in the Phetchabun basin along the Khorat Plateau which extends to eastern Thailand (Chonburi) and to the Gulf of Thailand along the Ko Kra Ridge, probably indicate the edge of the fault-bounded pull apart basins. In areas of southern margin of Khorat Plateau, young basalt volcanism, though reported by Hoke and Cambell (1995) not to be related to any tectonic features, are considered by us to be controlled by the occurrence of E-trending lineament associated with Cenozoic tectonic thrusting.
- This tectonothermal lineament corresponds very well with the sutlire between Cham Pasak - Stung Treng - Song Ba and Sisophon - Siam Rieb tectonic units (Fig.). Moreover, lloke and Cambell (1995) and Hoke (1997) depicts, using C and He isotope systematic signatures, that Cenozoic basalt volcanism in Lampang, northern Thailand, may indicate an active intraplate mantle degassing. We infer that the Lampang region and nearly (Lampang - Chiaiig Rai plate in Fig.) may be occupied by thin layers of sedimentary materials overlying the thicker paleo-oceanic crust.

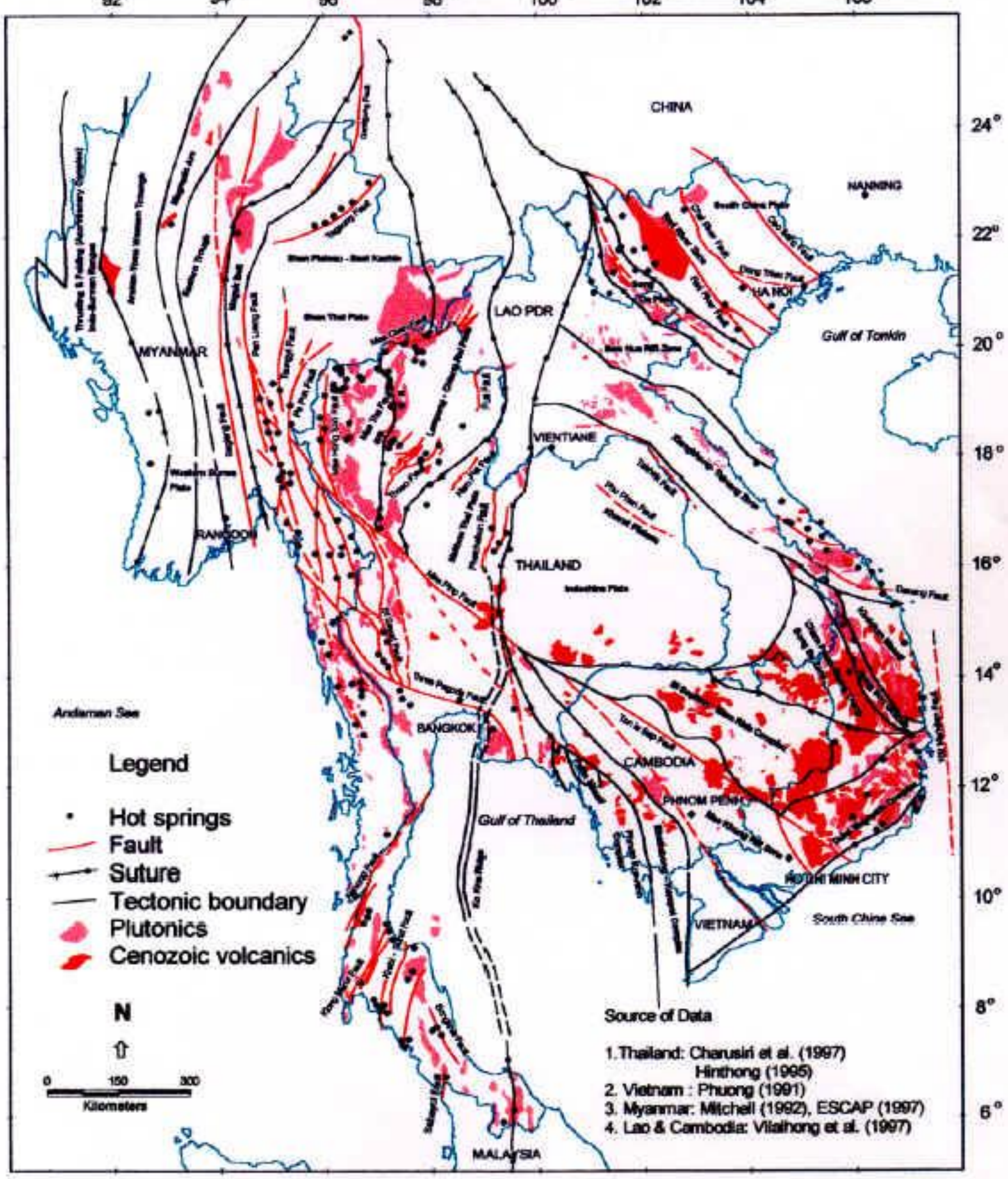


Figure 1. Simplified tectonic map of SE Asia showing some major active faults and distribution of plutonics, Cenozoic volcanics, and hot springs.

- In Thailand, mostly thermal springs are associated with both actively cooling down, shallow magmatic bodies in the west, northwest arid south (of Shan Thai plate), as well as the hot mantle plumes beneath volcanic terrains (Lampang - Chiang Rai and Nakhon Thai plate houndaries), all of which are, to some extent, controlled by the lithospheric extentional tectonics.

VIETNAM

- In Vietnam, tectonic subdivision of Vietnam (see Tran Van Tri, 1994, Le Van De. 1997), as simplified and illustrated in Fig. l, can be well explained by the geochemical contrast of thermal springs. In the north particularly Song Da plate between Red River and Song Ma (Ma River) Fault Zones (Fig.) where active thermal springs are mostly predominated.
- The spring waters are also characterized by the presence of CH4. The difference in geochemistry of thermal springs between this region and the others in Vietnam, i.e., HCO3 type-dominated in the north, C1-type in the central. and CH4 -type in the south. suggest the difference in tectonic units. In addition, isotope geochemistry of helium and carbon in areas predominated by Cenozoic basalts, as reported by Hoke (1997), are also interesting.
- The isotopic results, particulariy those in the central and the south, may indicate the mixing between active magmatic and thick crustal sedimentary-organic rich components.The latter corresponds to the Precambrian Kontum massif and Paleozoic strata of the Indochina continent (Xieng Khong-Danang Zone, in Fig.), particulariy those to Dong Ho Fault and a suture zone encompassing Khontum massif.

Conclusion

- This seminar is intended to introduce “Geothermal Energy” as a potential energy source which is now providing over 8200 MW of electricity in 21 countries and benefiting more than 60 million people.
- After the US (2800 MW), Philippines is second in the world generating nearly 2000 MW from geothermal energy and accounts for nearly 30% of electricity production. Indonesia produces nearly 600 MW from geothermal.
- With the oil prices at USD 100 per barrel and getting scarcer and price increasing, it is important to look for alternative sources of energy and for countries with geothermal resources to seriously consider developing the resource.
- Geothermal is reliable and available 24/7 and is not effected by weather changes.
- It is considered a renewable resource* and sustainable for a long time an most of the water can be recycled by injecting back in to the reservoir.
- Geothermal produces minimal air pollution and CO2 emmision is extremely low. As it is a combustion-free process, no burning takes place and only steam is emitted from the facilities.

Conclusion (Contd.)

- As discussed earlier, Myanmar is one of the countries endowed with numerous geothermal resources (97) that could be represented as an additional source of energy to fulfill future energy needs.

- These resources are generally located in remote and less developed areas within the Union and can be considered to develop the rural population and economies by generating electricity using one of the technologies discussed. Specific locations in Kayin State, Mon State, and Tanintharyi Division where most occurrence exists can be further investigated and feasibility studies conducted to establish a geothermal plant.

- There are very few papers and data on geothermal resources and technology available in Myanmar for researchers and interested resource persons and it is hoped that more interest will be generated from this seminar and more research papers will be produced in the future regarding this important and reliable source of energy which is naturally occuring in our country.

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Thank You

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