STATUS OF GEOTHERMAL ENERGY WORLDWIDE & IN LATIN AMERICA

7º Congreso Bolivia Gas & Energía 2014

20-21 August

Centro de Convenciones del Hotel Los Tajibos

Santa Cruz de la Sierra, Bolivia

David Sussman

Resource and Exploration Manager

EDC Latin America

Santiago, Chile

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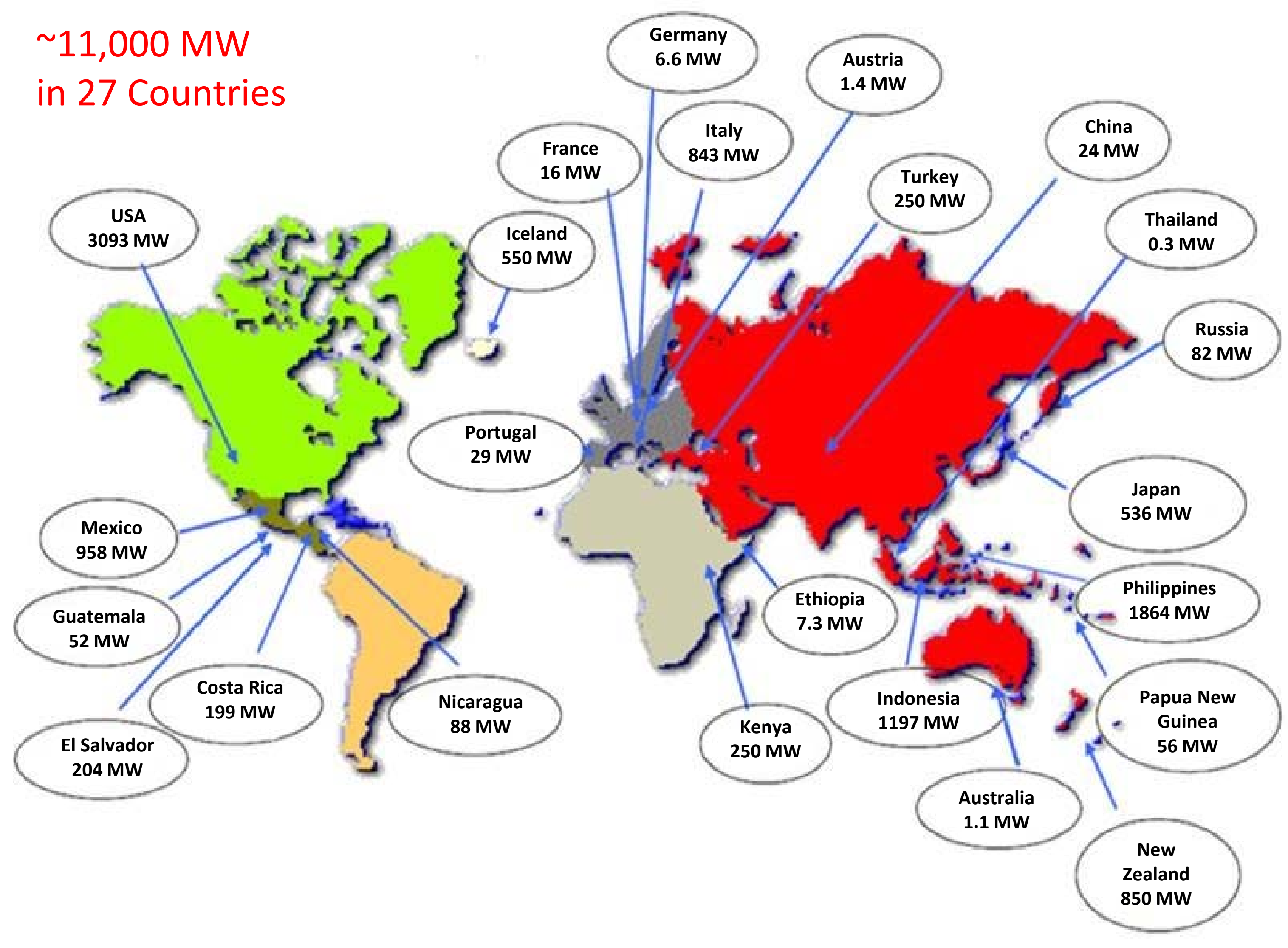
OVERVIEW

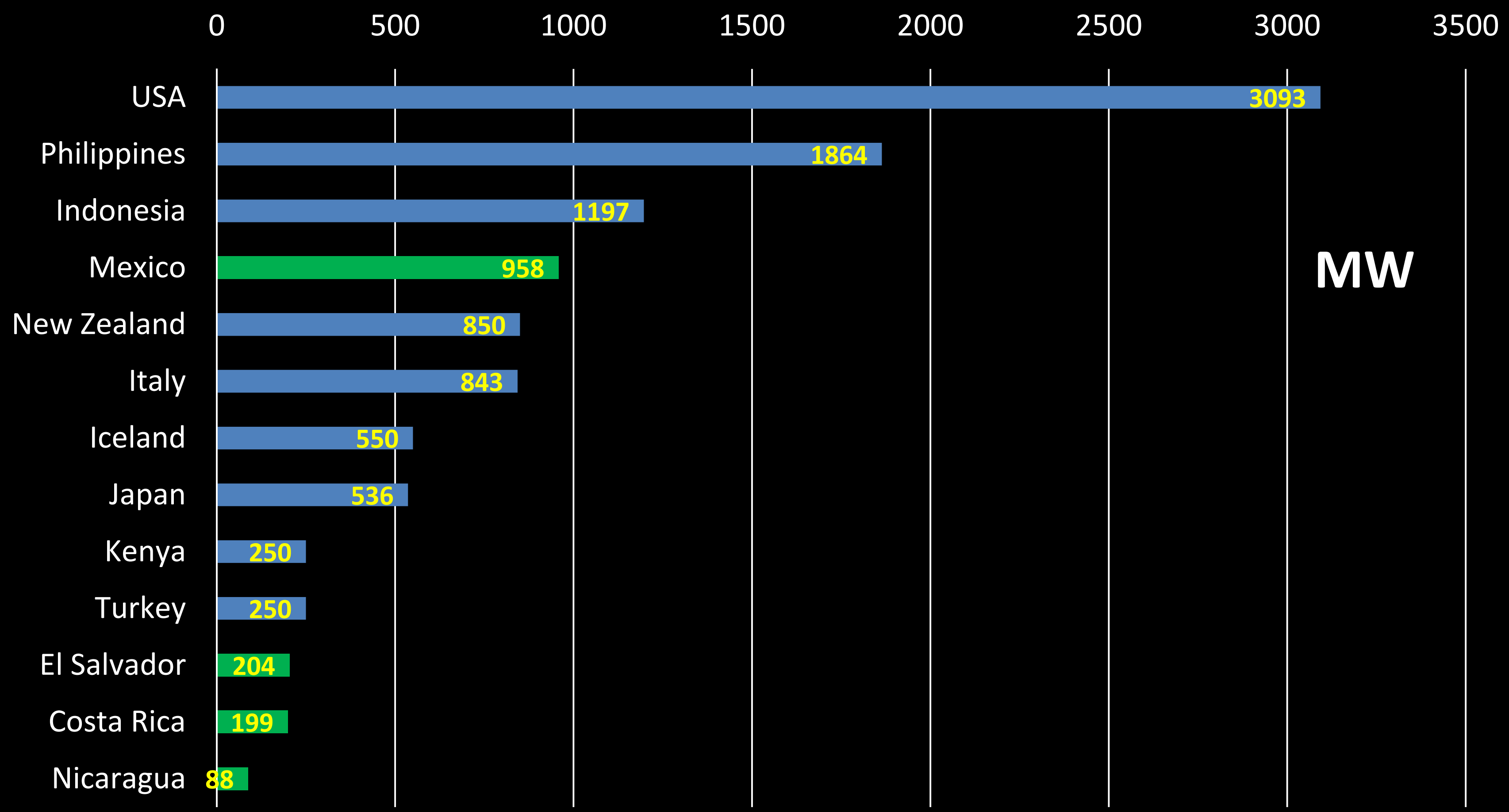
- WHAT IS GEOTHERMAL AND WHERE IS IT?
- GEOTHERMAL ENERGY WORLDWIDE
- STATUS IN LATIN AMERICA
- FACTORS THAT HAVE ENCOURAGED (AND DISCOURAGED)

  GEOTHERMAL DEVELOPMENT

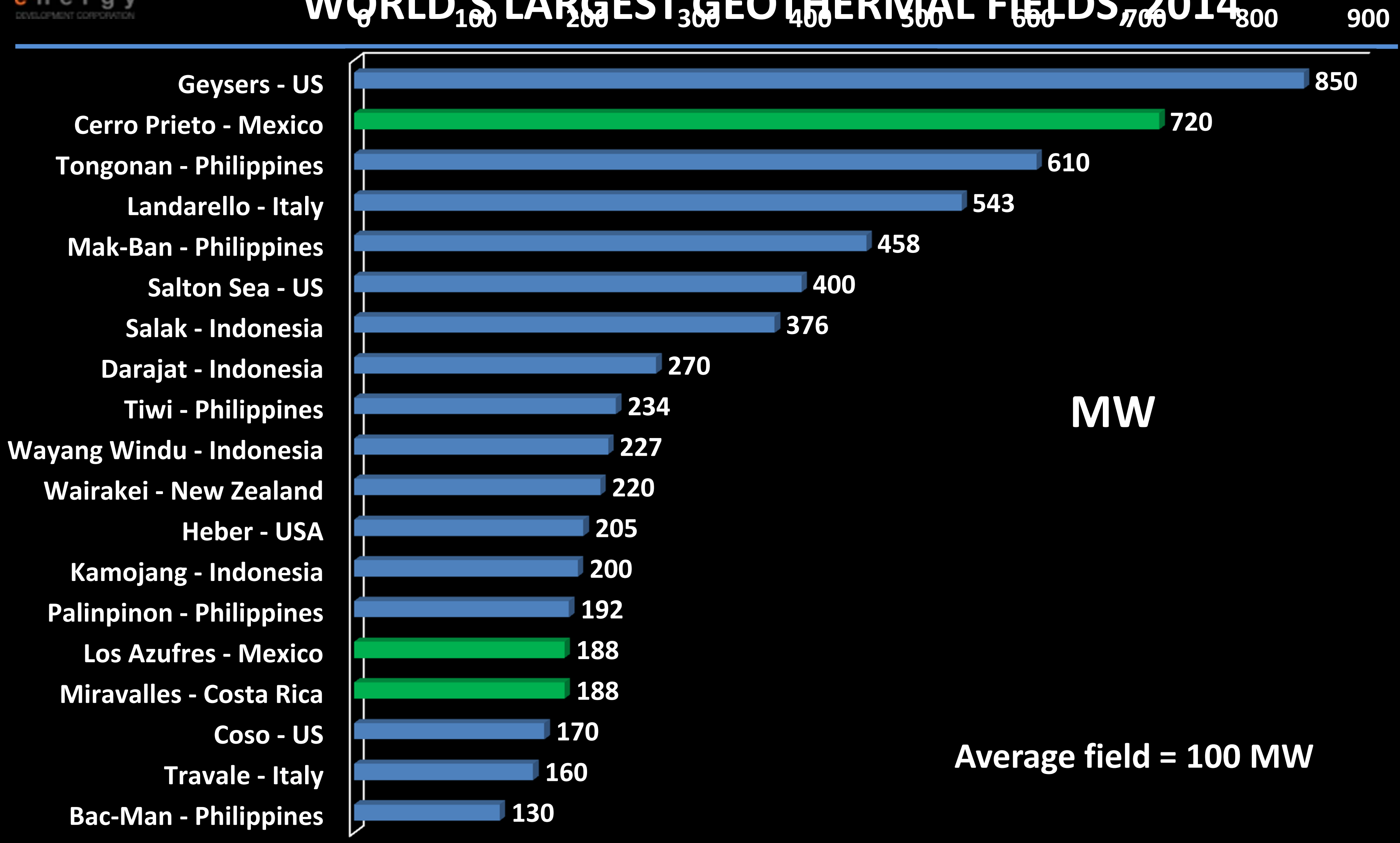
INSTALLED GEOTHERMAL CAPACITY WORLDWIDE 2014



GEOTHERMAL CAPACITY BY COUNTRY (TOP 13)



WORLD'S LARGEST GEOTHERMAL FIELDS, 2014



GEOTHERMAL ENERGY IN THE PHILIPPINES

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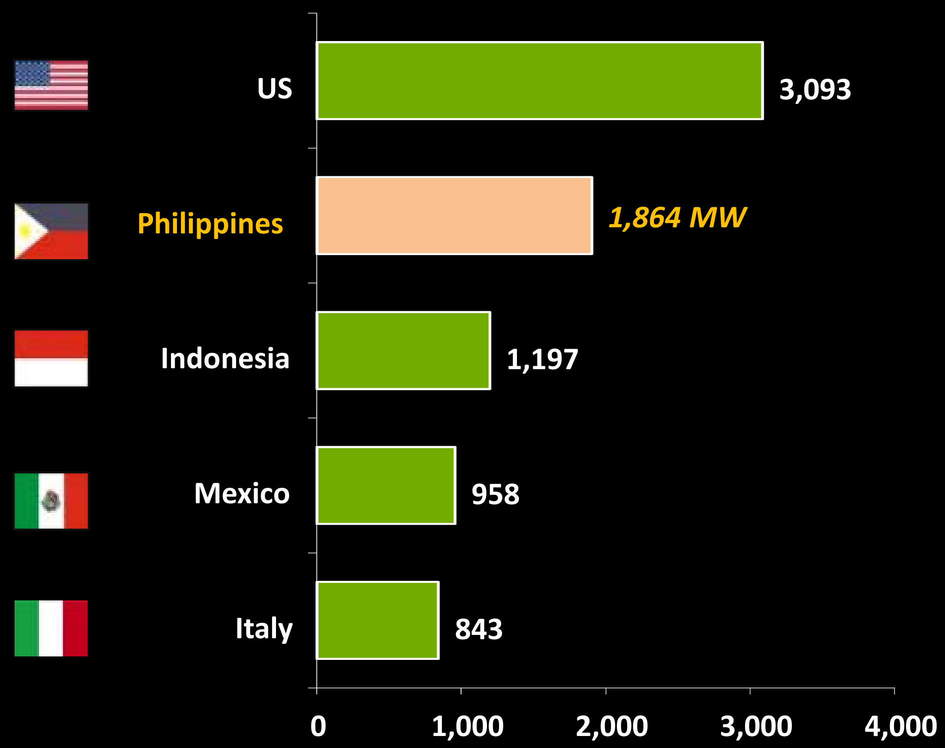
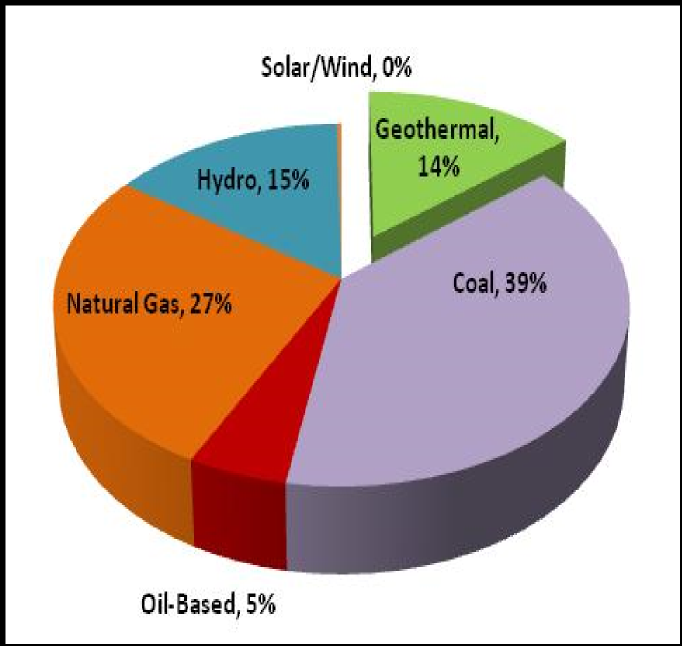
GEOTHERMAL ENERGY ACCOUNTS FOR 14% OF TOTAL INSTALLED CAPACITY IN THE PHILIPPINES

Geothermal Energy Capacity (MW)



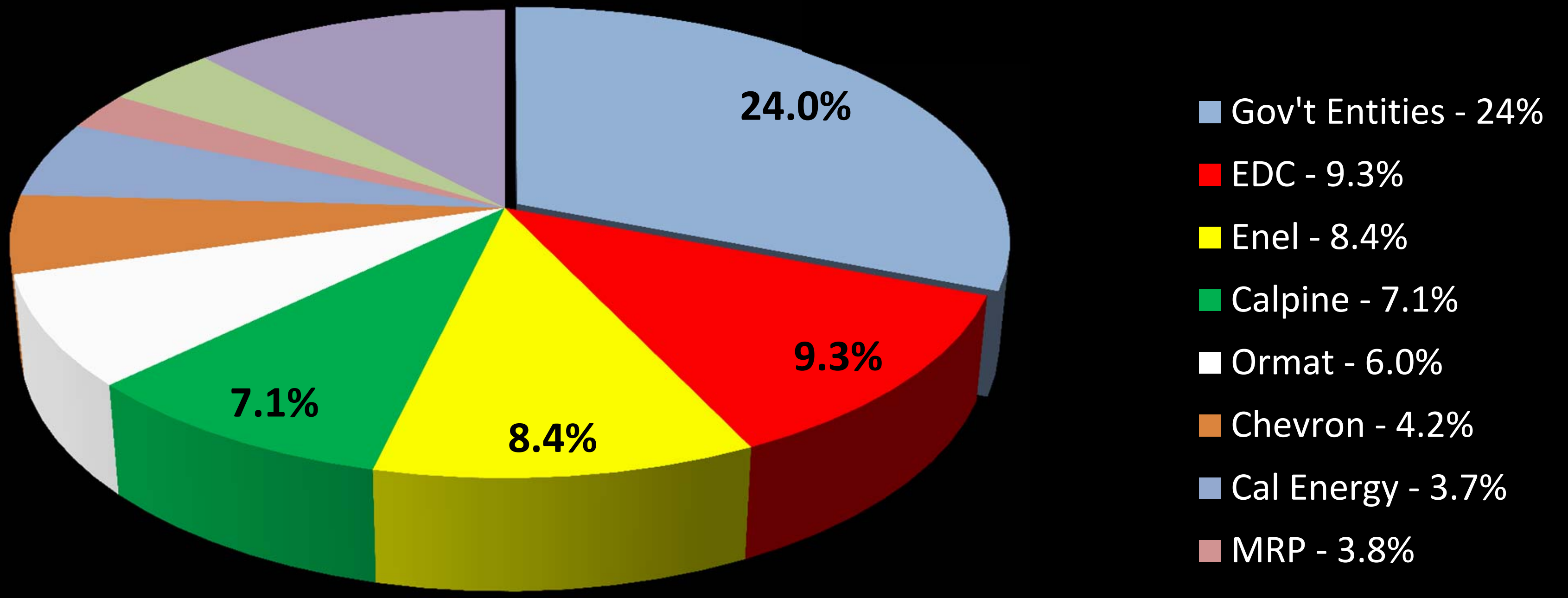
2013



EDC IS THE WORLD'S LARGEST VERTICALLY INTEGRATED GEOTHERMAL COMPANY…

Field	MW (2014)	MW (expected 2015)
Leyte	610	610
Palinpinon	192.5	192.5
Bac-Man	75	130
Mt. Apo	104	104
Totals	981.5	1036.5

Geothermal Plant + Resource Operators



EDC'S PORTFOLIO CONSISTS OF 1113MW OF GEOTHERMAL AND HYDRO PLANTS

Geothermal

Leyte

125.0 MW Upper Mahiao
233.5 MW Malitbog
180.0 MW Mahanagdong
50.9 MW Optimization

Mindanao

52.0 MW Mindanao I
54.0 MW Mindanao II

Leyte

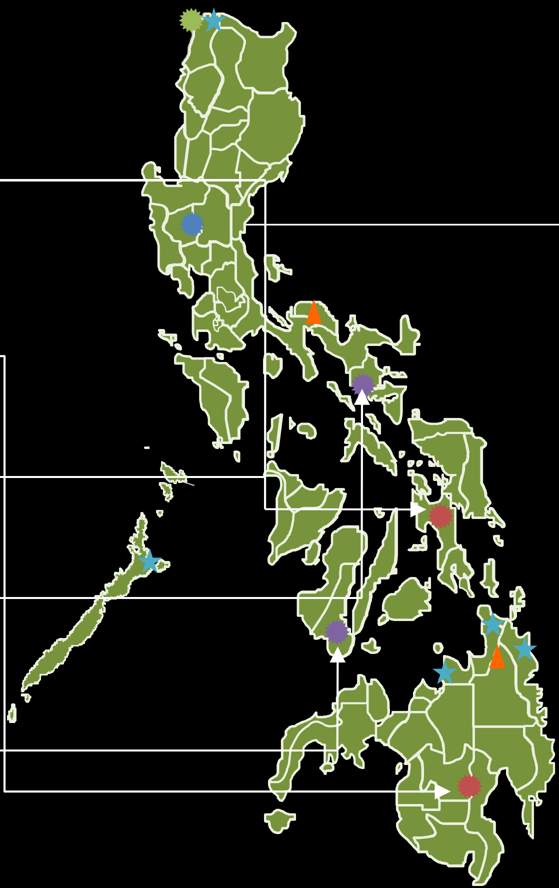
112.5 MW Tongonan

Bac-Man

110.0 MW Bac-Man I
20.0 MW Bac-Man II

Southern Negros

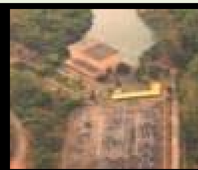
112.5 MW Palinpinon I
80.0 MW Palinpinon II



Hydro

Pantabangan

120.0 MW Pantabangan [1]



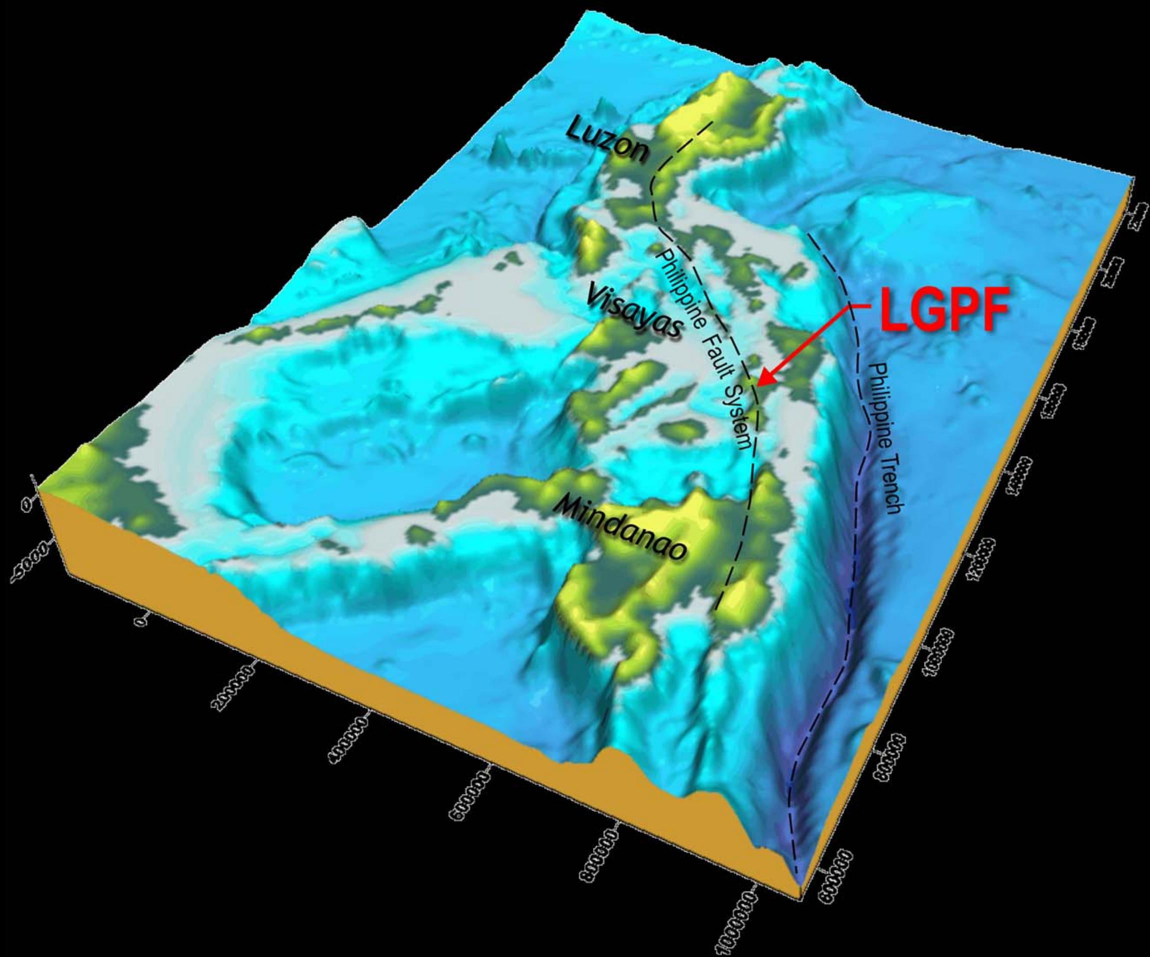
Masiway

12.0 MW Masiway

Integrated geothermal steamfield & power plant (EDC)
Steamfield (EDC) and power plant (EDC subsidiary)
Hydroelectric power plant (EDC subsidiary)
New geothermal concessions under RA9513
New wind concessions

Note: Capacity figures are Net Output
[1] Post rehabilitation

LEYTE PRODUCTION FIELD

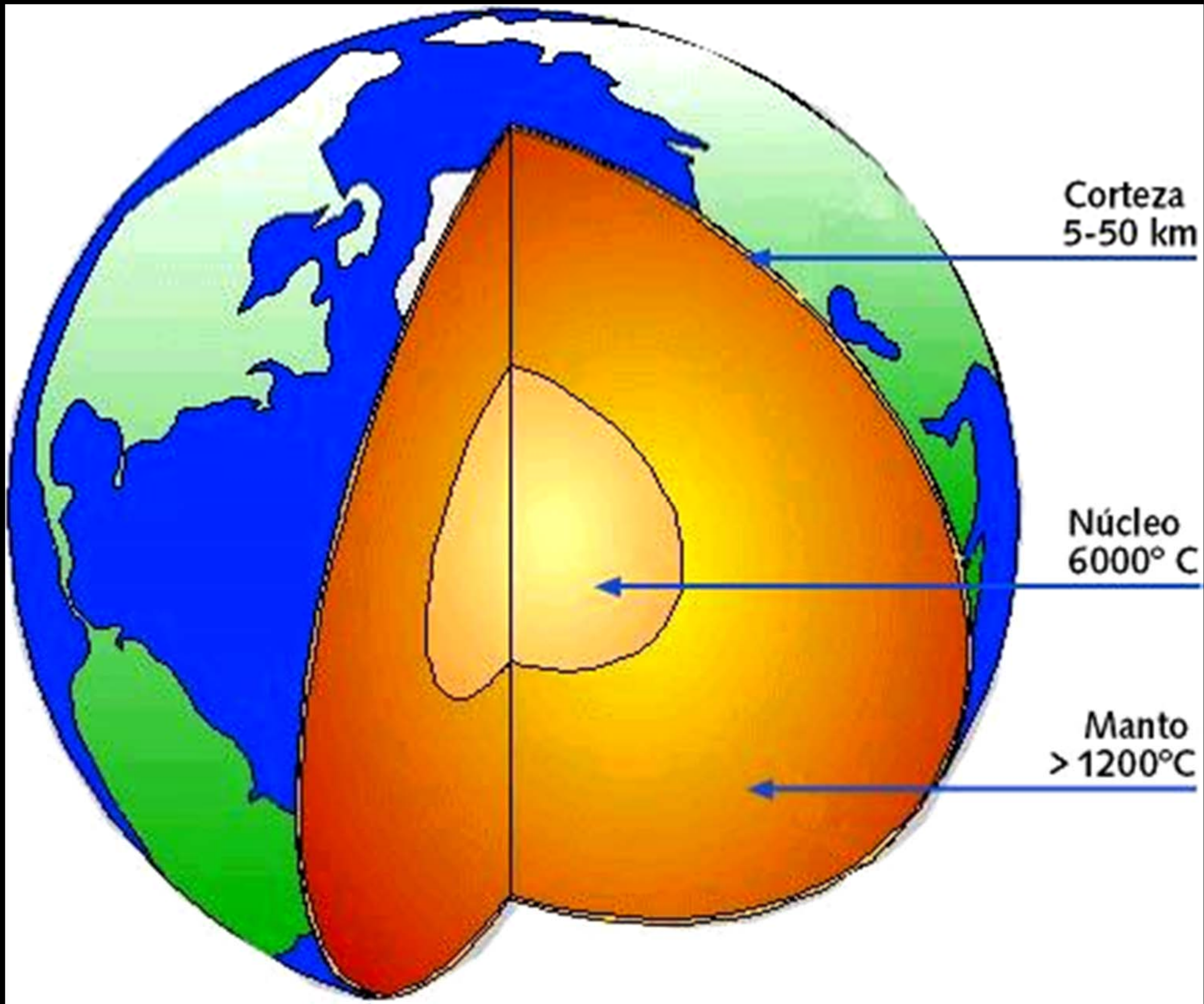


- •World’s largest liquid-dominated geothermal field in operation
- •Installed capacity of 650 MW
- •More than 180 production and injection wells

NATURAL GEOTHERMAL ENDOWMENT AND FOCUSED GOVERNMENT POLICY LED TO ITS ACCELERATED GROWTH

- RP is rich in geothermal reserves along the "Pacific Ring of Fire"
- Government gave strong support through laws and policies
- Technology & expertise were acquired internationally (US, NZ, Iceland)

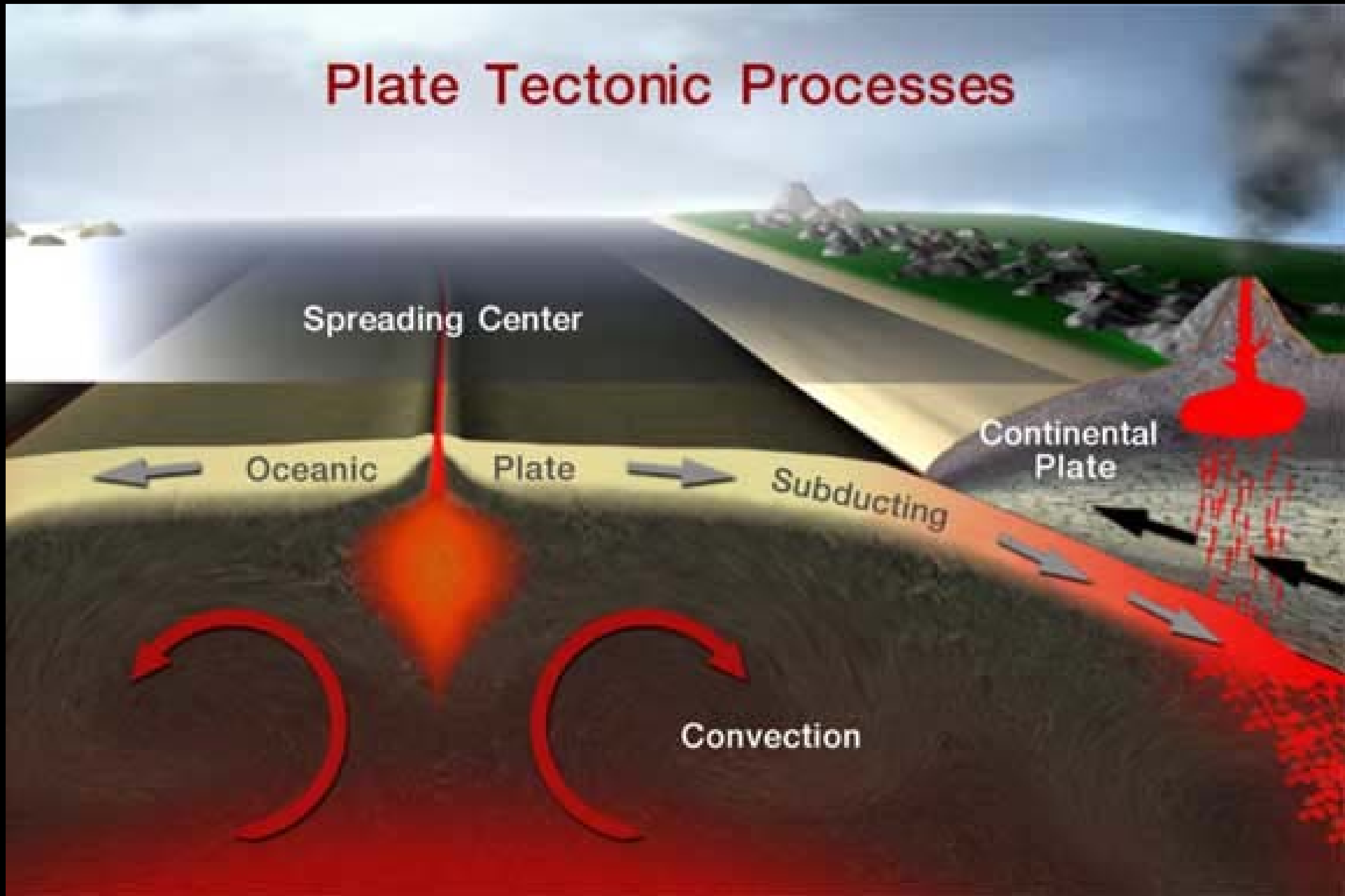
Geothermal = Earth + Heat



THREE TYPES OF GEOTHERMAL SYSTEMS

- Volcano-hosted (magma is the heat source) – 92%
- Deep fracture systems "Basin & Range" – 8%
  - High temperature gradients & near-vertical faults that extend up to ~5km depth
- Enhanced Geothermal Systems ("Hot Dry Rock")
  - Requires hydraulic fracturing, proppants & lots of water like O&G fracking
  - Enormous potential but no commercial EGS systems on-line

FOCUSING ON VOLCANIC SYSTEMS:
HEAT IS GENERATED FROM ONGOING TECTONIC PROCESSES
--but commercial systems are typically <500,000 years old



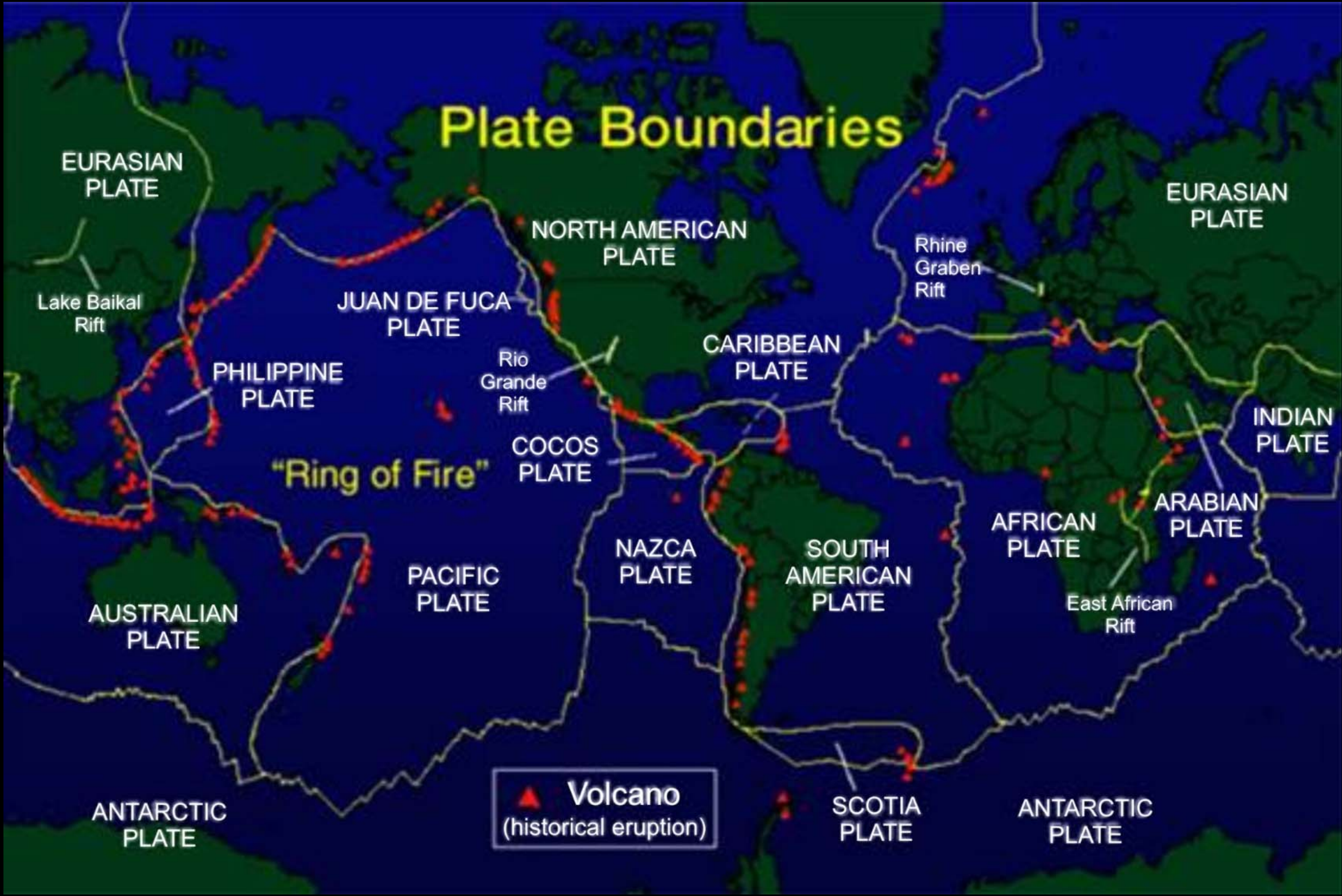
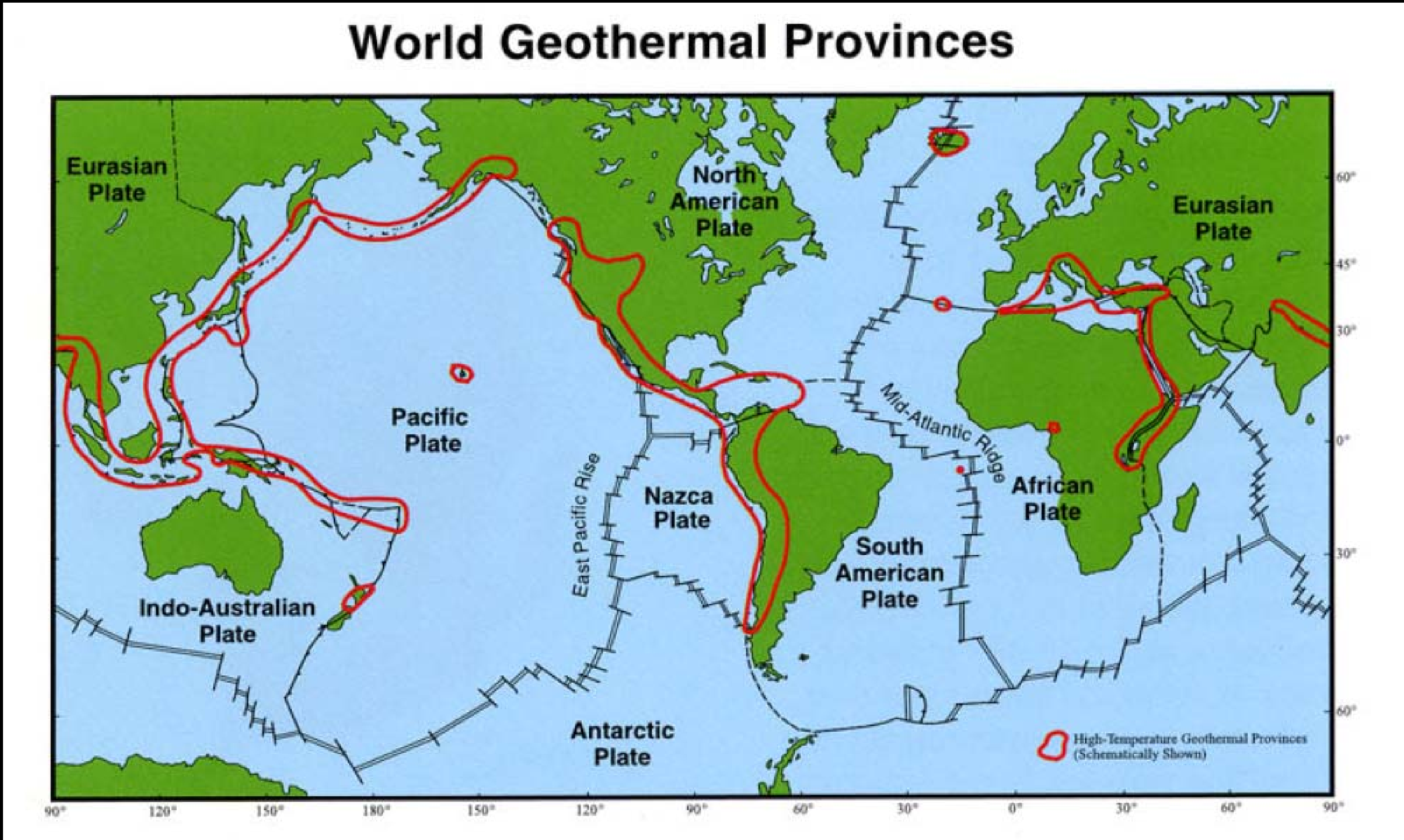
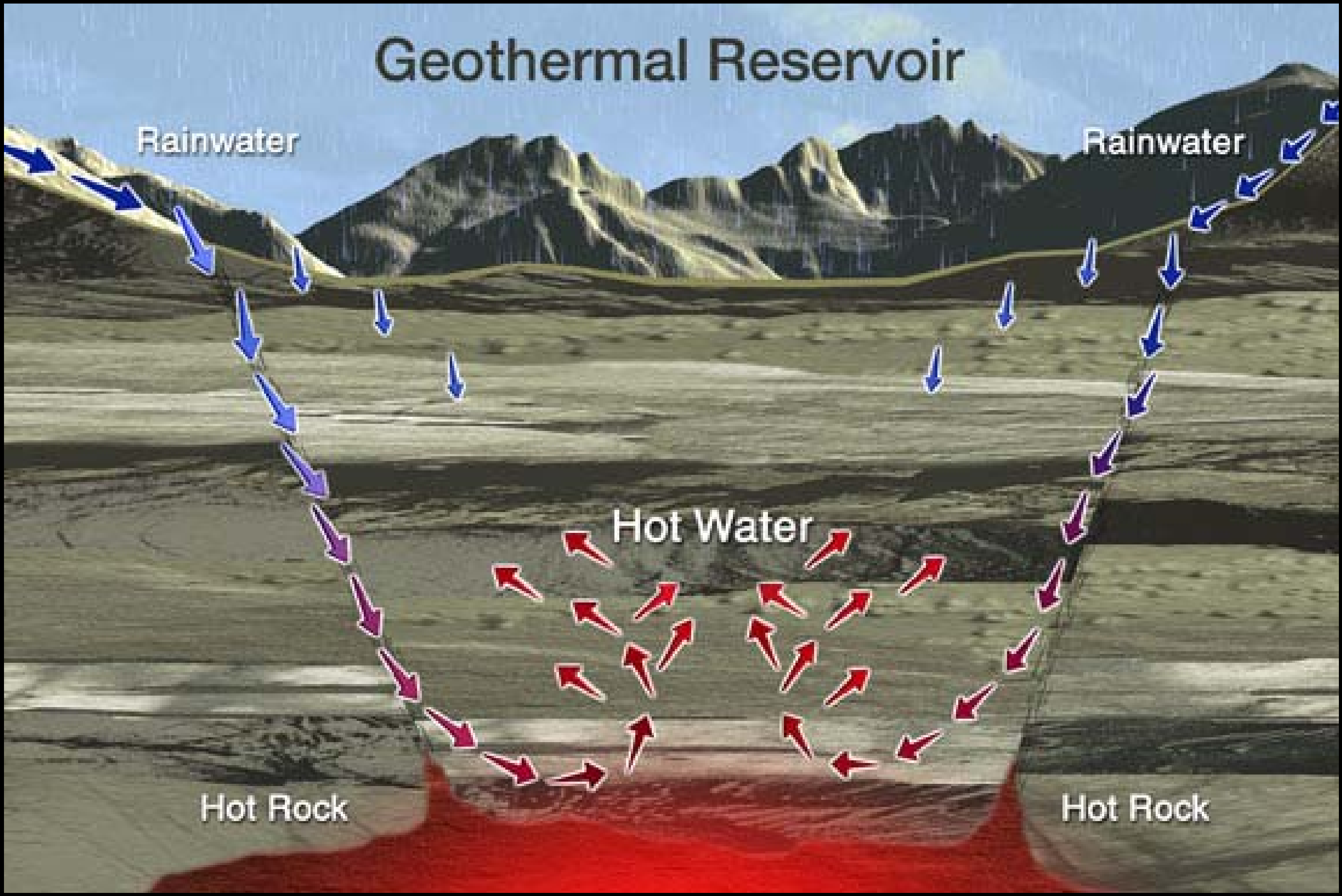


Plate Boundaries
EURASIAN PLATE
Lake Baikal Rift
PHILIPPINE PLATE
JUAN DE FUCA PLATE
NORTH AMERICAN PLATE
Rio Grande Rift
CARIBBEAN PLATE
Rhine Graben Rift
EURASIAN PLATE
INDIAN PLATE
"Ring of Fire"
COCOS PLATE
ARABIAN PLATE
AFRICAN PLATE
NAZCA PLATE
SOUTH AMERICAN PLATE
PACIFIC PLATE
AUSTRALIAN PLATE
East African Rift
ANTARCTIC PLATE
Volcano (historical eruption)
SCOTIA PLATE
ANTARCTIC PLATE

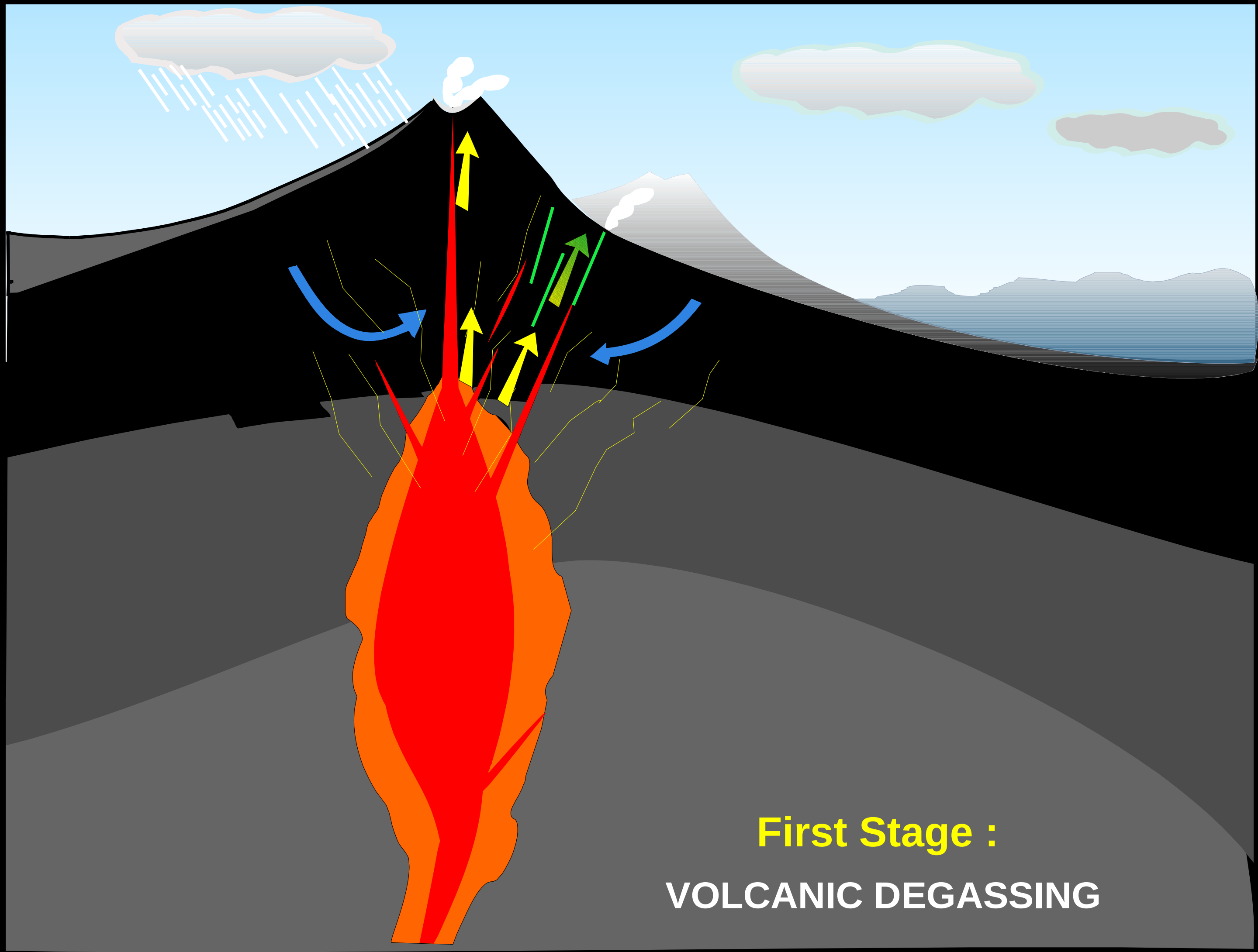
WHERE GEOTHERMAL IS FOUND



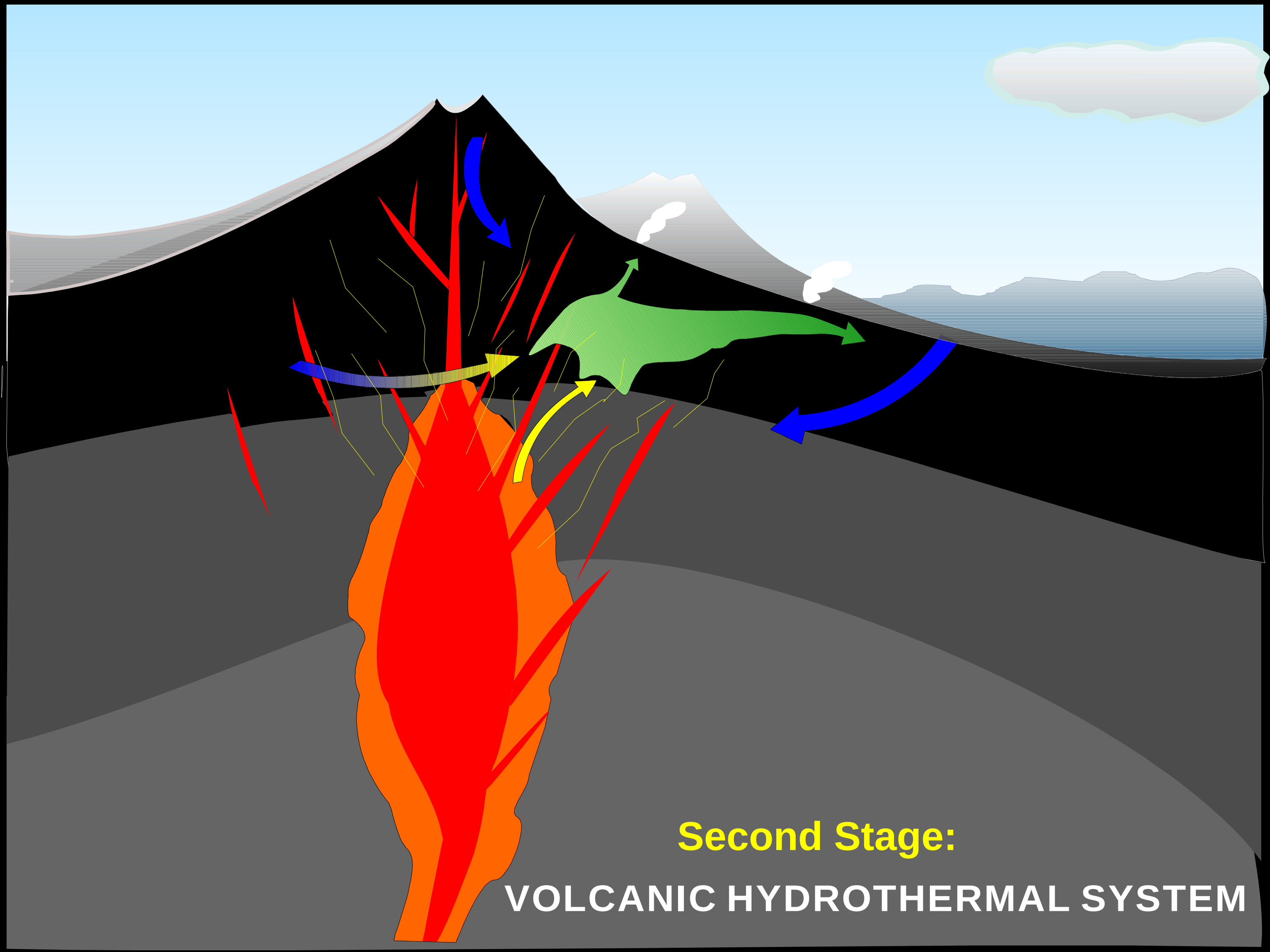
A SIMPLISTIC MODEL



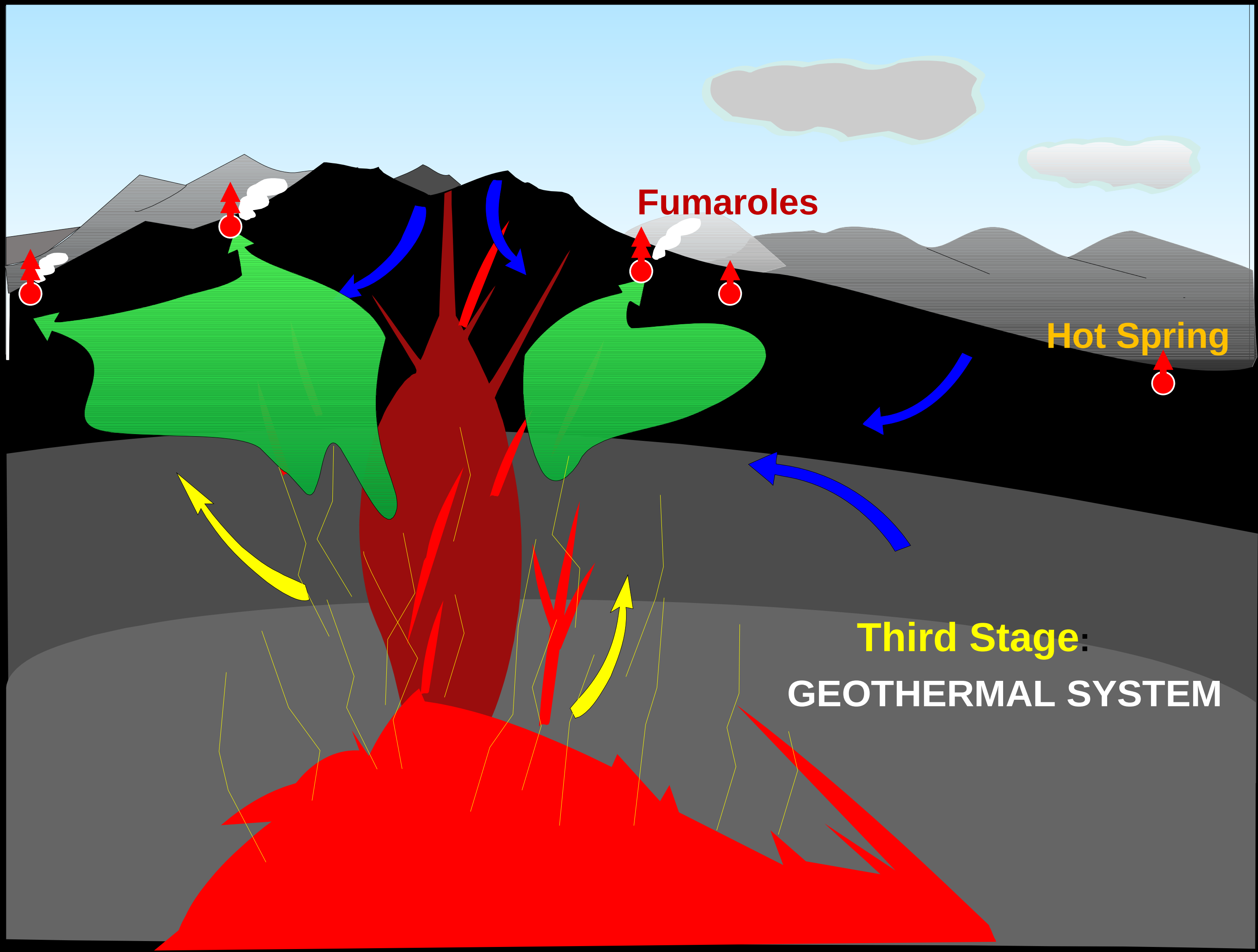
EVOLUTION OF A MAGMATIC-HYDROTHERMAL SYSTEM



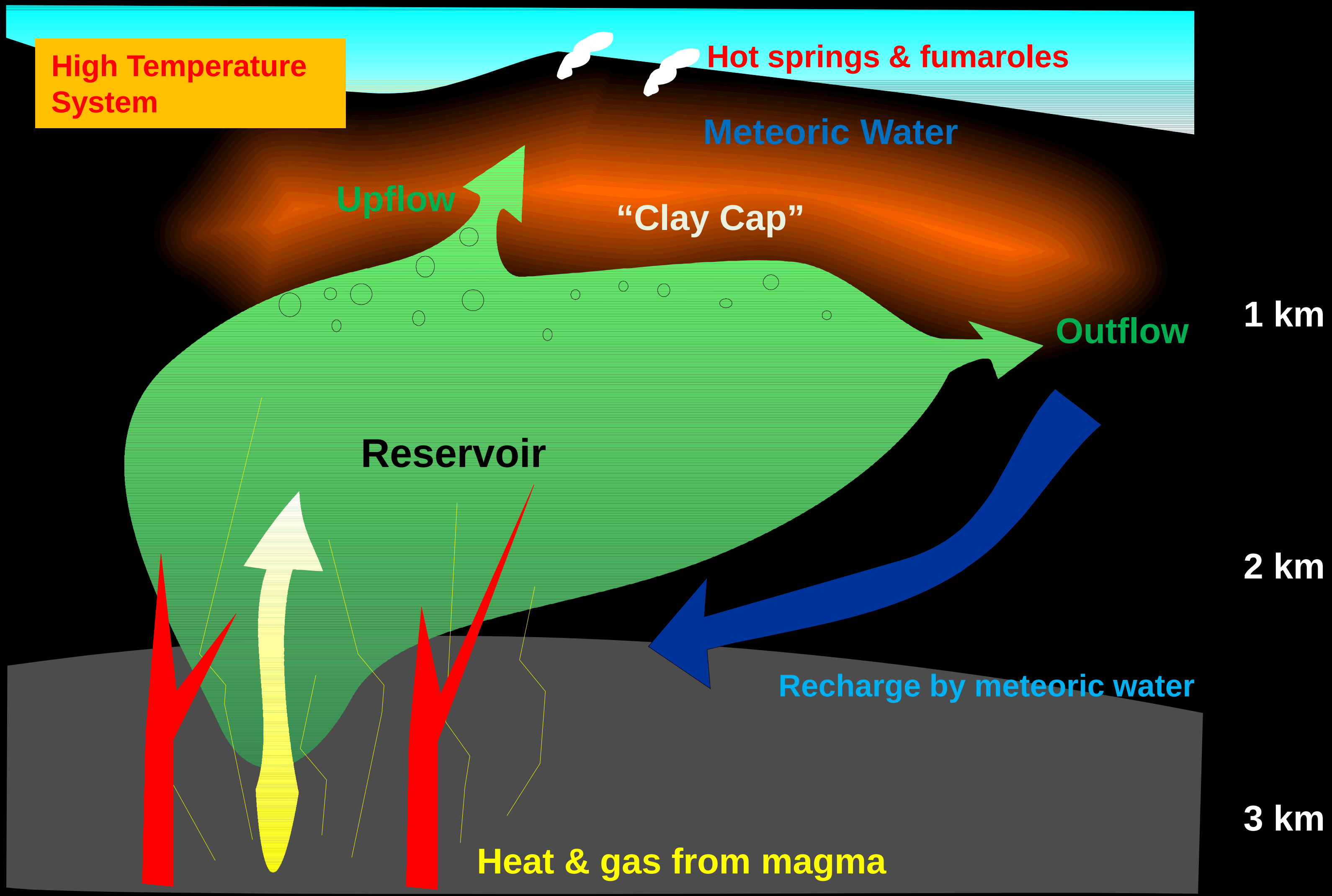
EVOLUTION OF A MAGMATIC-HYDROTHERMAL SYSTEM - 2



EVOLUTION OF A MAGMATIC-HYDROTHERMAL SYSTEM - 3



EVOLUTION OF A MAGMATIC-HYDROTHERMAL SYSTEM - 4



PHASES OF A GEOTHERMAL PROJECT

◆Exploration

- Geoscience studies
- Shallow & deep wells and testing

◆Construction

- Development wells (production & injection)
- ConstructIon of the power plant, steamfield & transmission line
- Commerical testing

◆Operation

- Generate electricity

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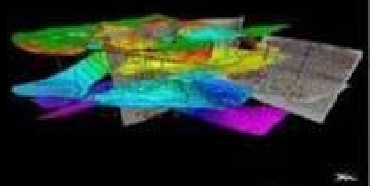
GEOTHERMAL PROJECT DEVELOPMENT STAGES

EXPLORATION | **DEVELOPMENT**

SURFACE EXPLORATION	DEEP EXPLORATION	ENGINEERING & CONSTRUCTION	OPERATION & MAINTENANCE



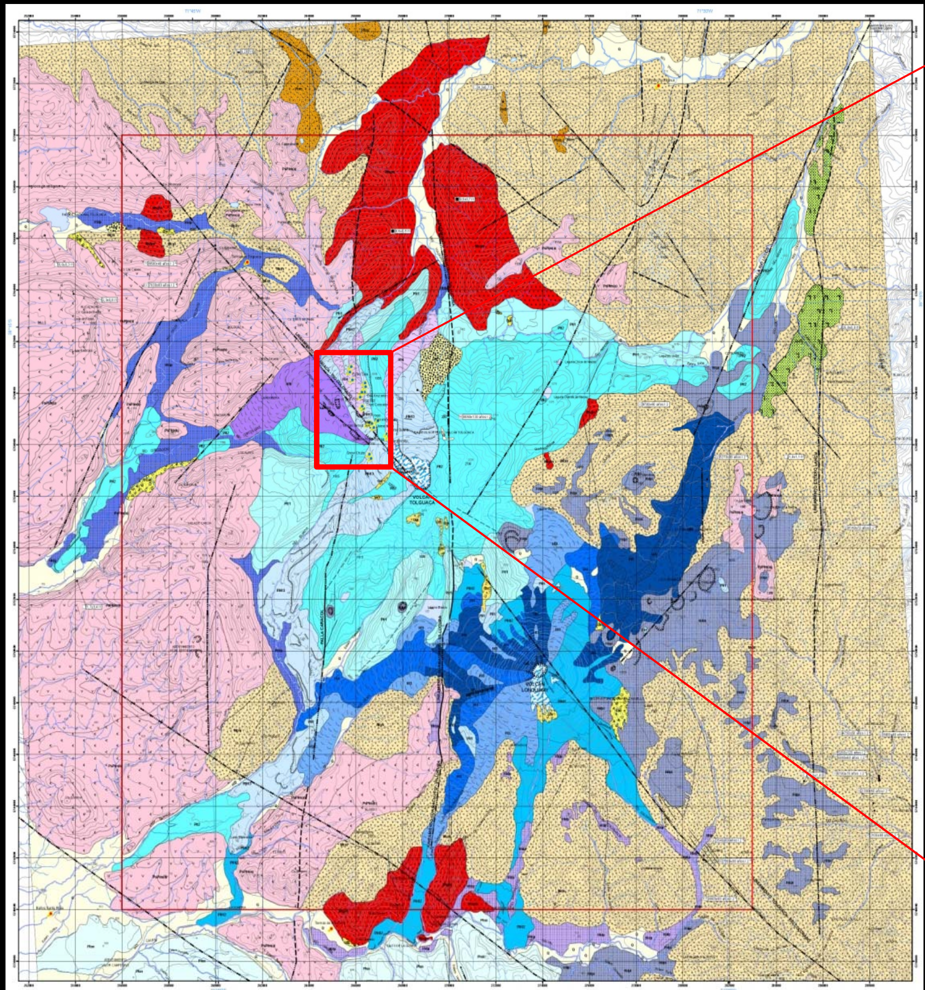
- SURFACE EXPLORATION: 2 years
- DEEP EXPLORATION: 2 years
- ENGINEERING & CONSTRUCTION: 3 years
- OPERATION & MAINTENANCE: Indefinite

GEOTHERMAL EXPLORATION - HOW DO WE FIND IT?

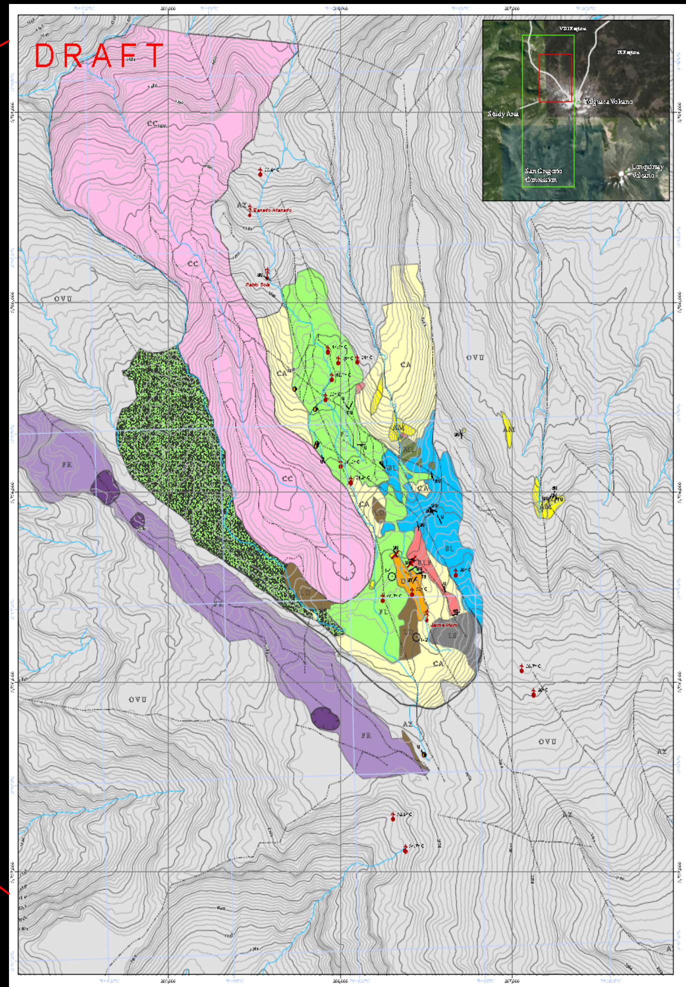
- Geologic Studies
- Geochemical Analyses
- Geophysical Surveys
- Drilling
- Reservoir Testing

GEOLOGY & STRUCTURAL MAPPING

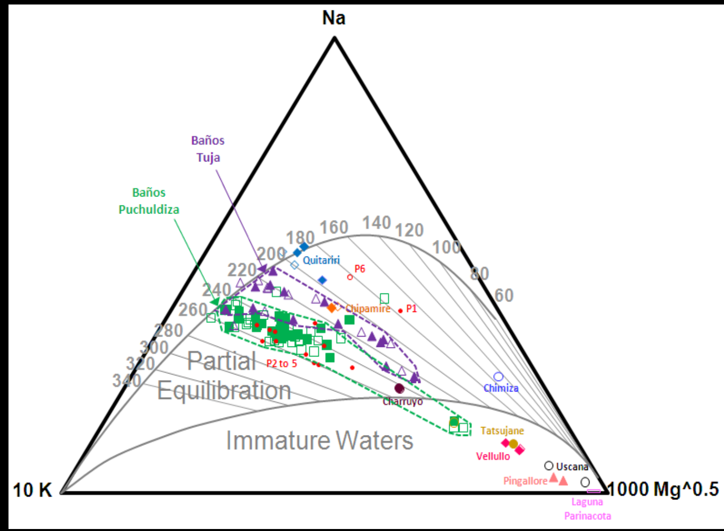
Regional Mapping (1:100,000)

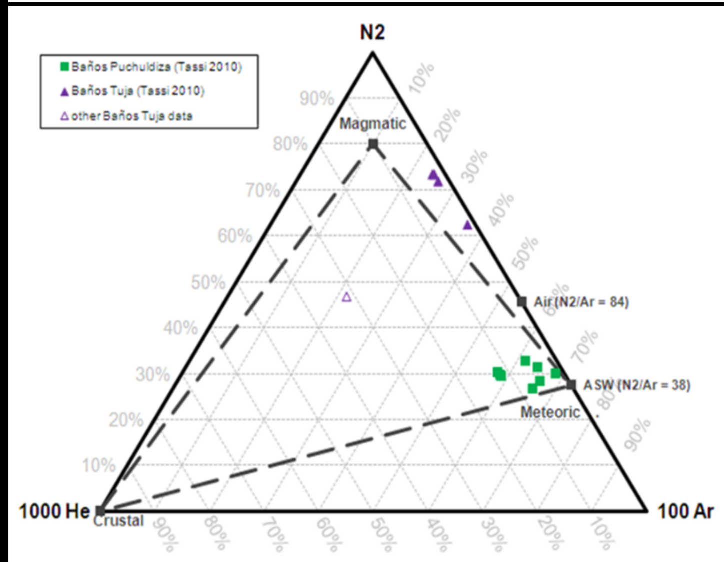


Detailed Mapping (1:10.000)



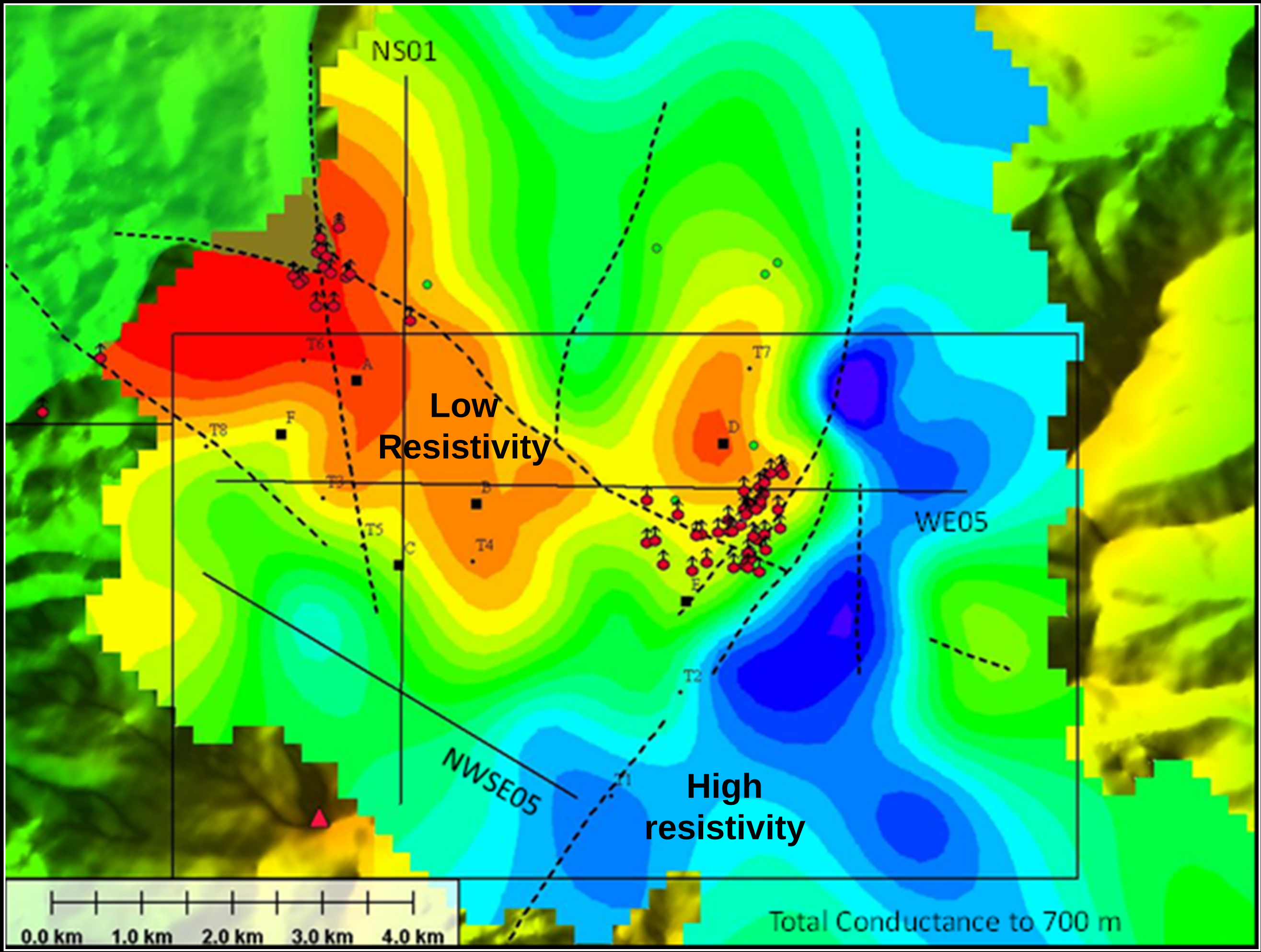
GEOCHEMICAL ANALYSIS OF WATER & GASES





GEOPHYSICS – MT, Gravity, Magnetics

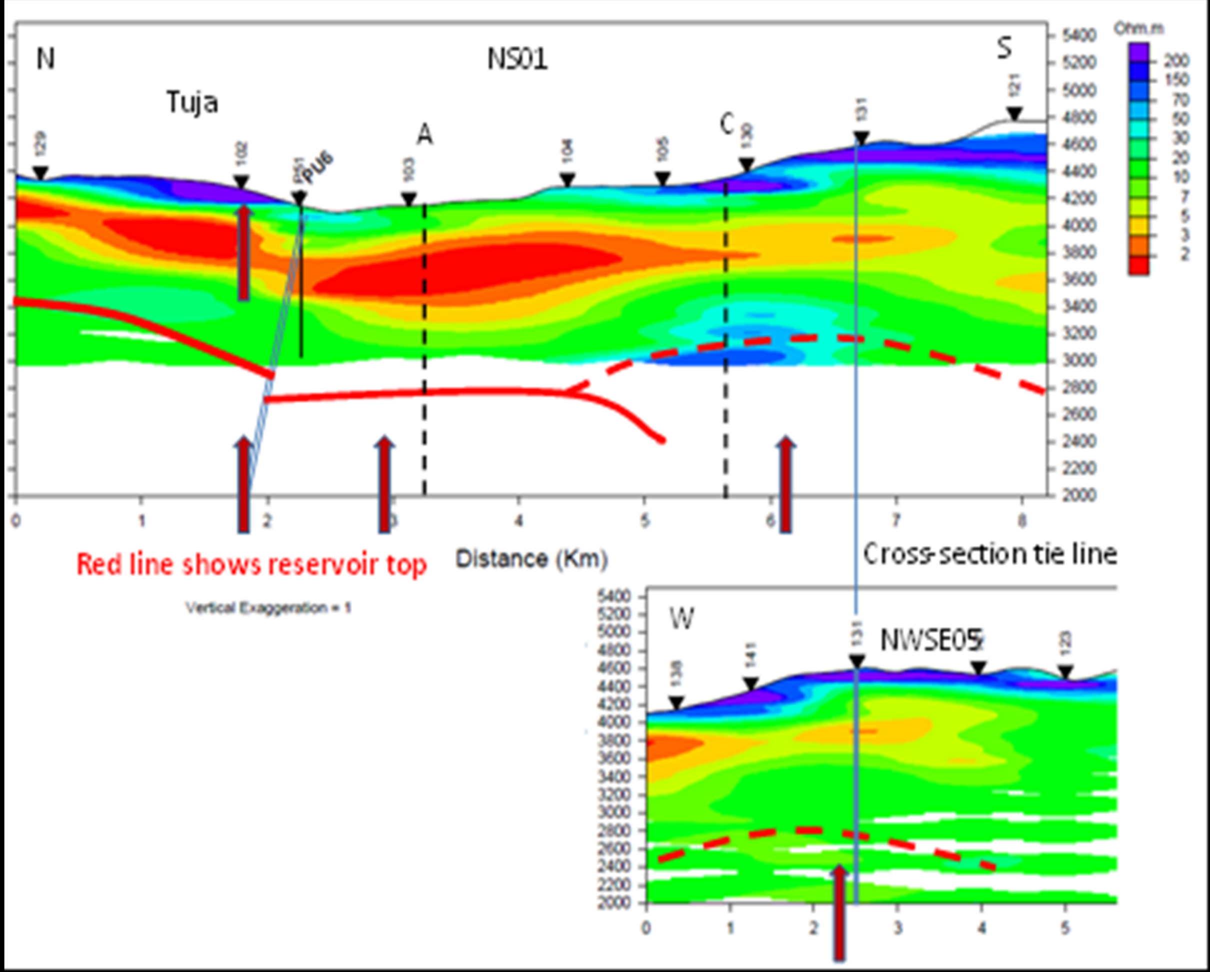
Seismic methods are rarely used



- Low resistivity over geothermal systems is mainly due to smectite clays
- Must be supported by presence of thermal features with attractive geochemistry and geologic evidence of an active system

Map of MT total conductance to 700m depth

MT PROFILES INDICATE A "CLAY CAP"
(= Trap in O&G)



Conceptual Model

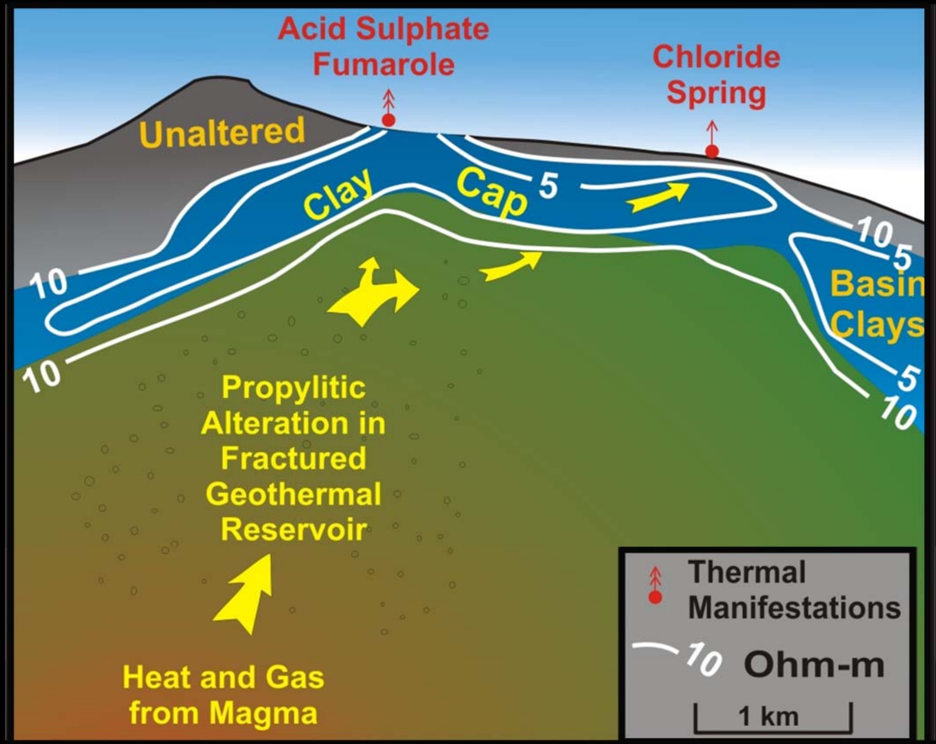
– Top seal or clay cap forms over the geothermal system
– Lower temperature clay is usually low resistivity

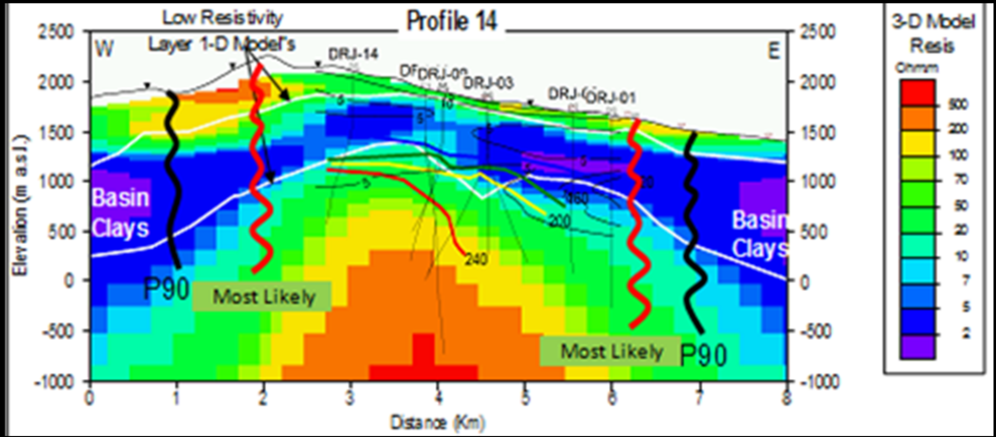
Resistivity (MT and TDEM)

– Mapping of the clay cap and its geometry provides constraints on size and indirect information on temperature

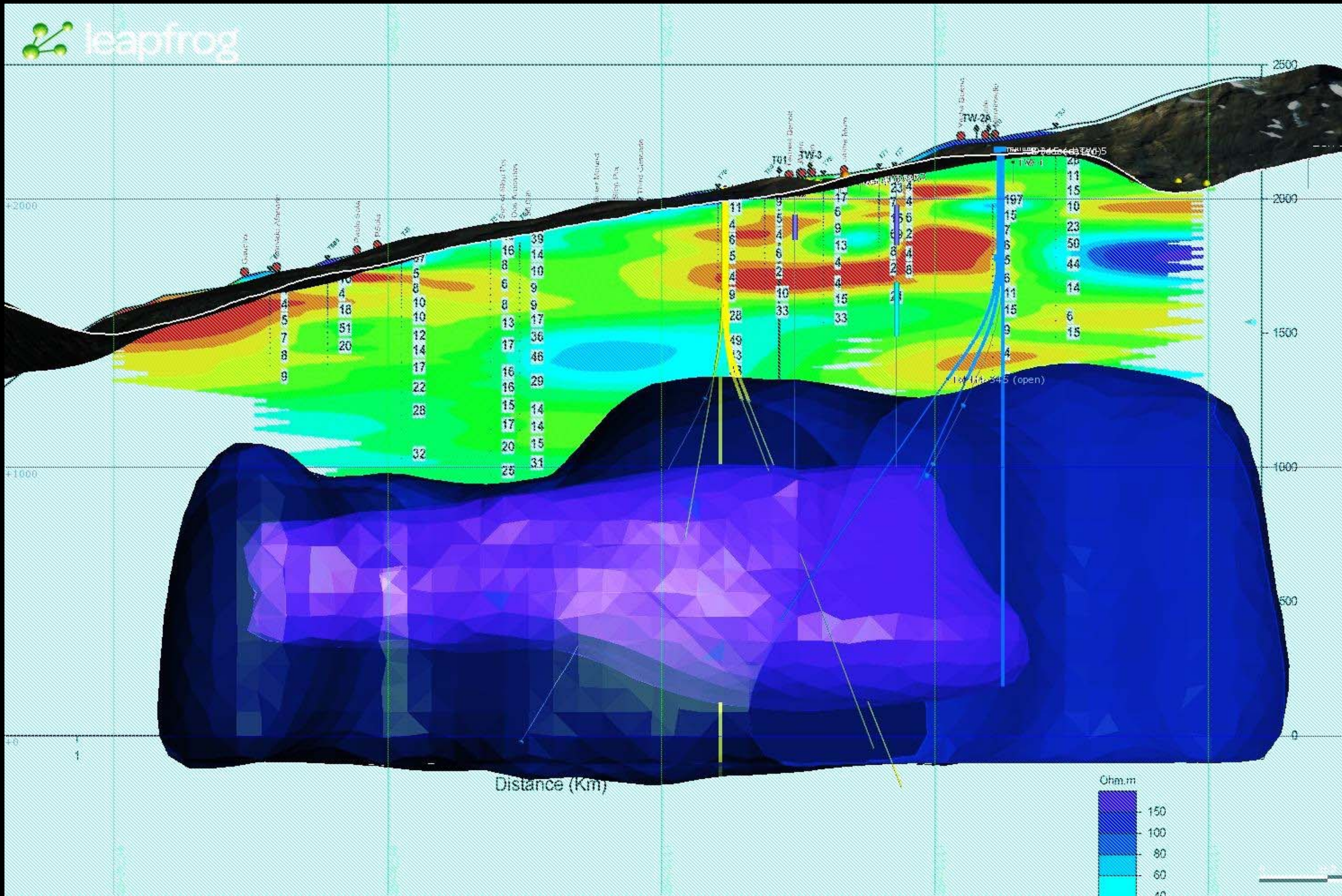
Seismic Reflection

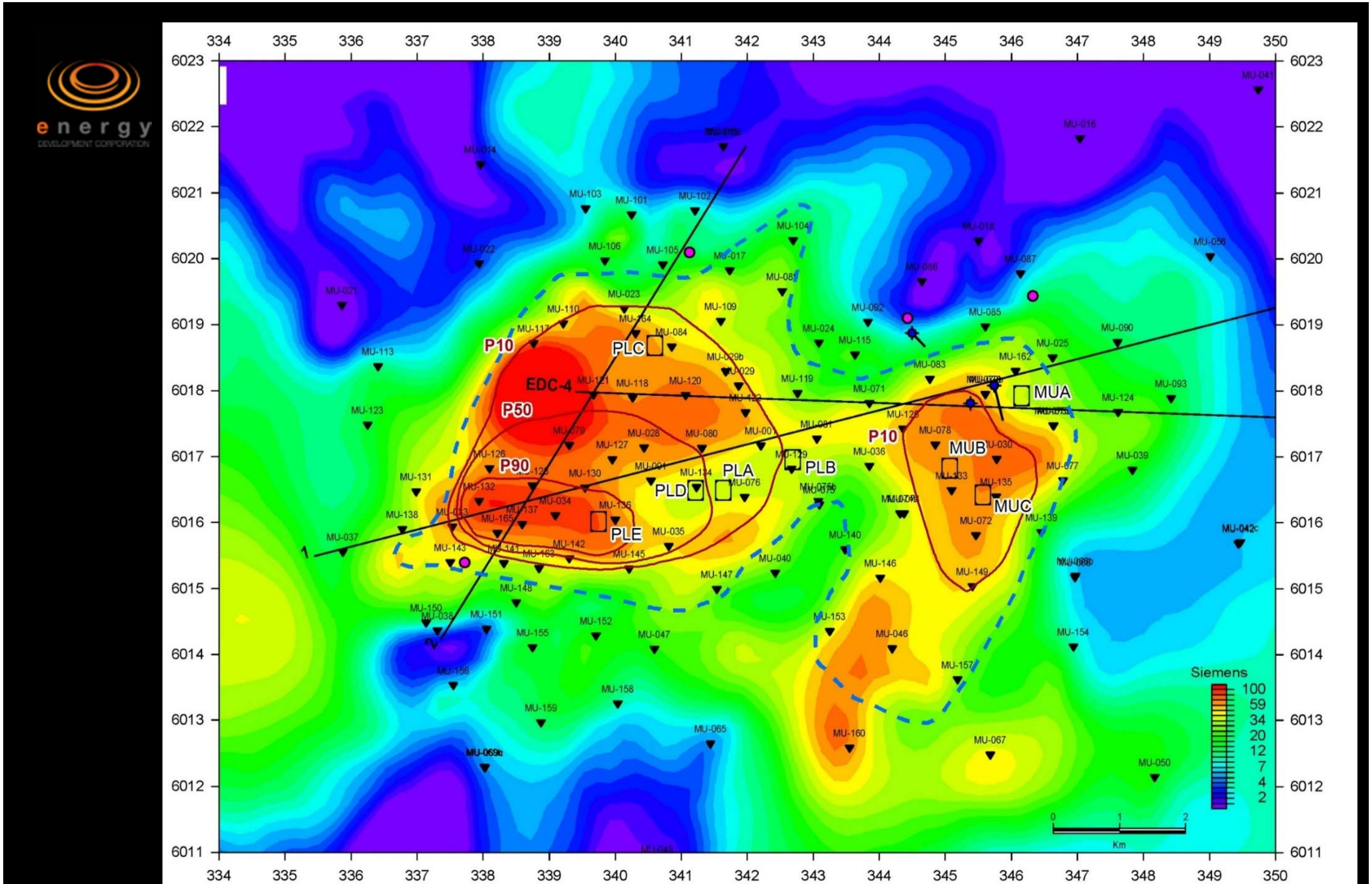
– Not commonly applied, especially in volcanic terrains
– Lack of rock contacts that coherently reflect
– Shallow dense lavas
– Attenuation in clay cap





PROBABILISITIC VOLUMETRIC MODEL AND WELL PORTFOLIO OPTIONS





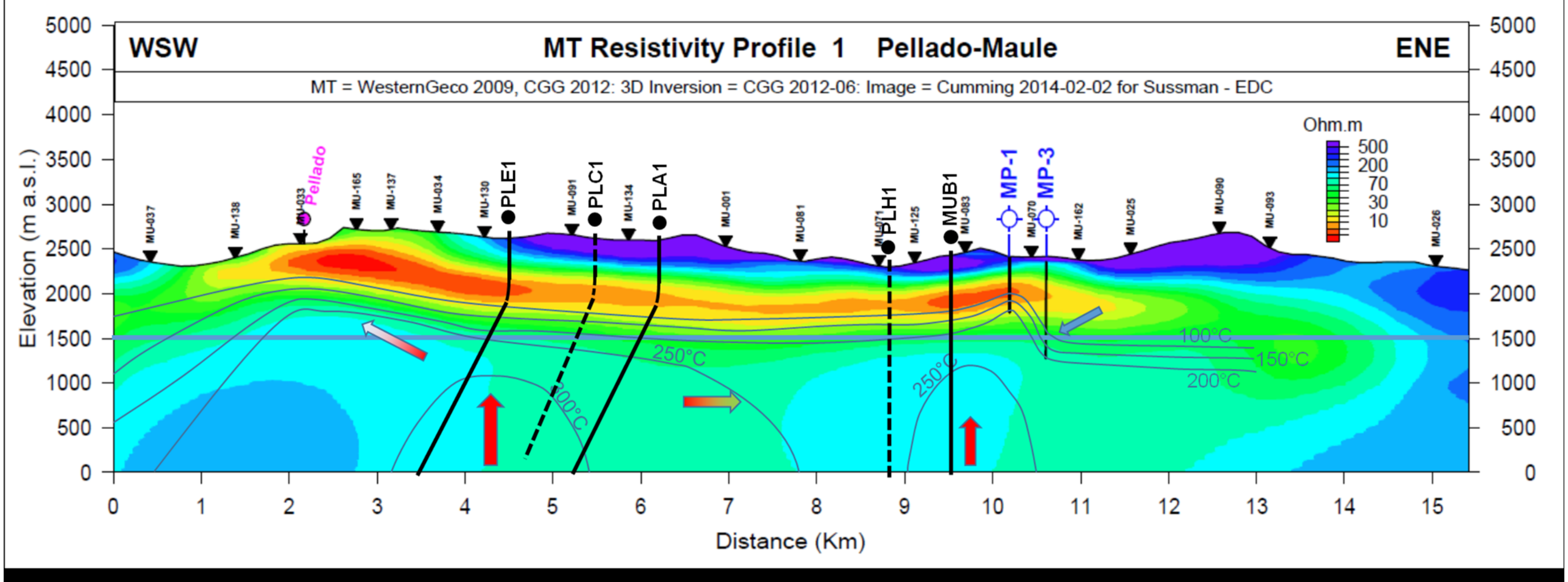
Pellado - Maule Geothermal Prospects

MT = WesternGeco 2009, CGG 2012: 3D inversion = CGG 2012-06: Image = Cumming 2012-02-02 for Sussman EDC: UTM z19S WGS84

MT Conductance from Surface to 1500 m asl

CONCEPTUAL MODELS DRIVE DRILLING STRATEGIES

Geothermal database is small—analogs are important



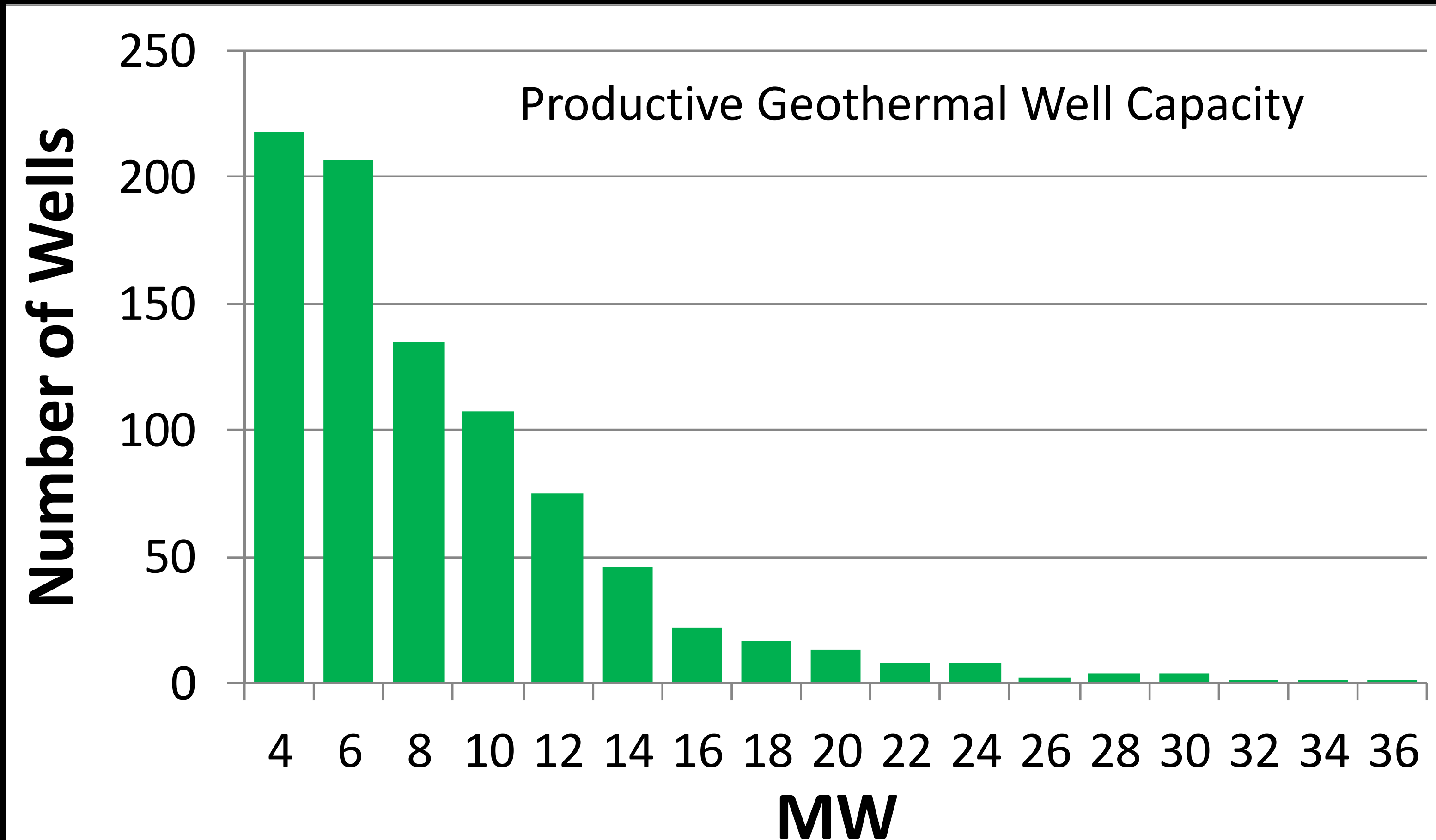
GEOTHERMAL EXPLORATION WELLS

- Shallow Temperature Gradient Holes (<500 m)
- Deep wells (1000-3500 m) using modified O&G rigs, costing US$3-15M in 20-75 days
- Production casing 9-5/8” to 16”
- Liquid systems (95%) drilled with mud & water
- “Dry steam” systems (5%) drilled with air
- Well heat-up is 0-8 weeks prior to flow testing


LONGY
WATER

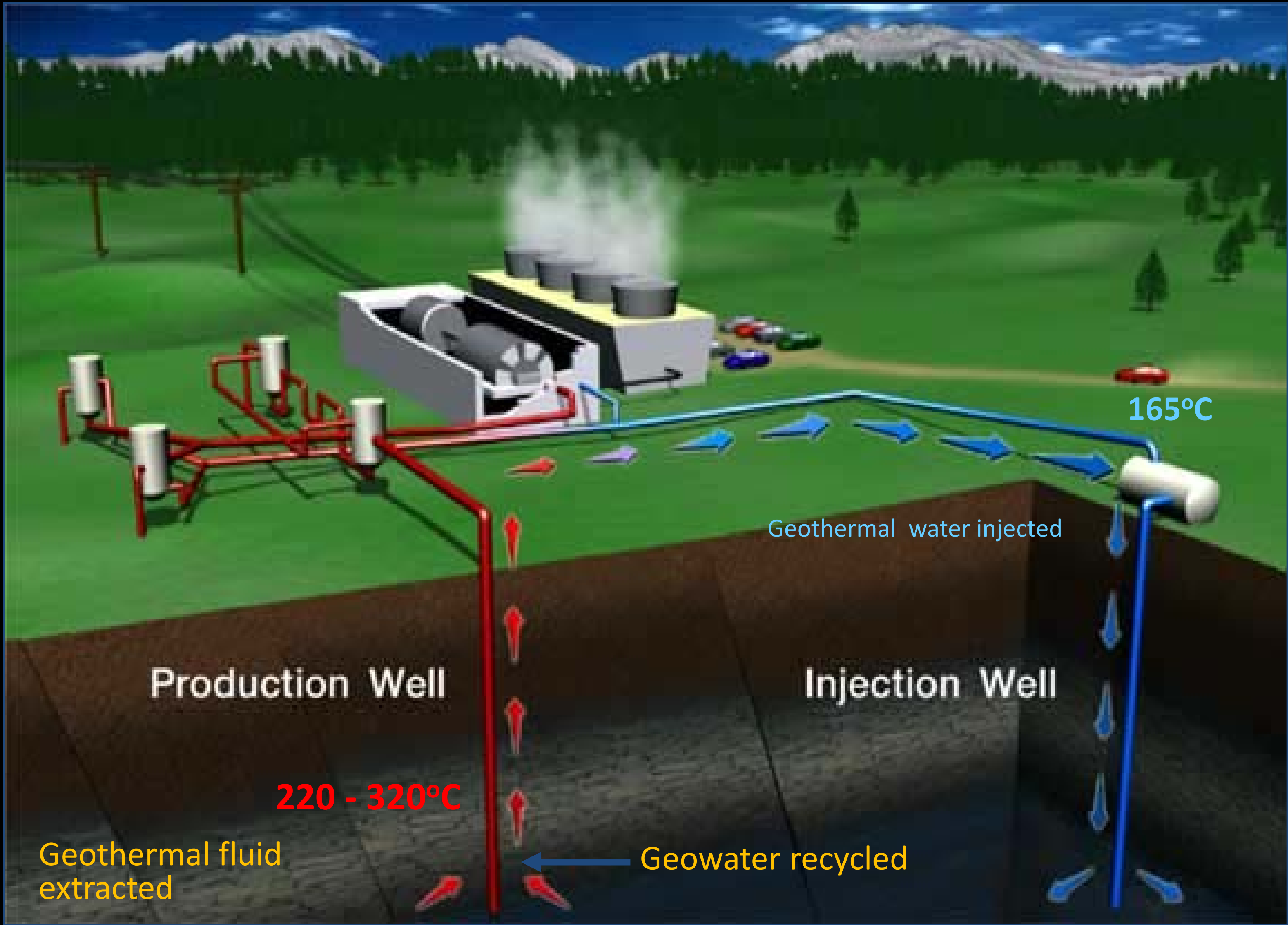

EQ-PIT-004
PRESA 1

EXPLORATION DRILLING SUCCESS

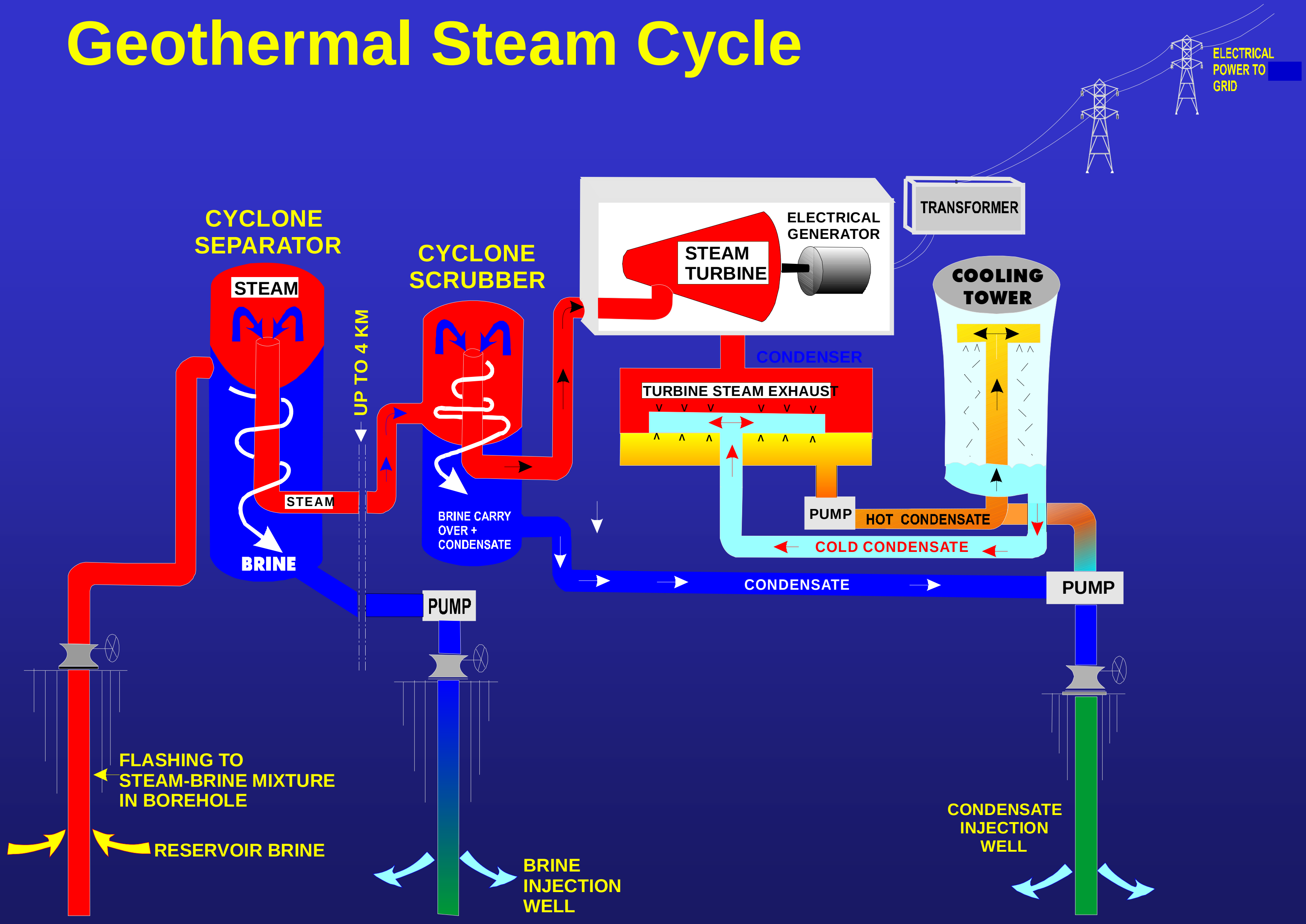


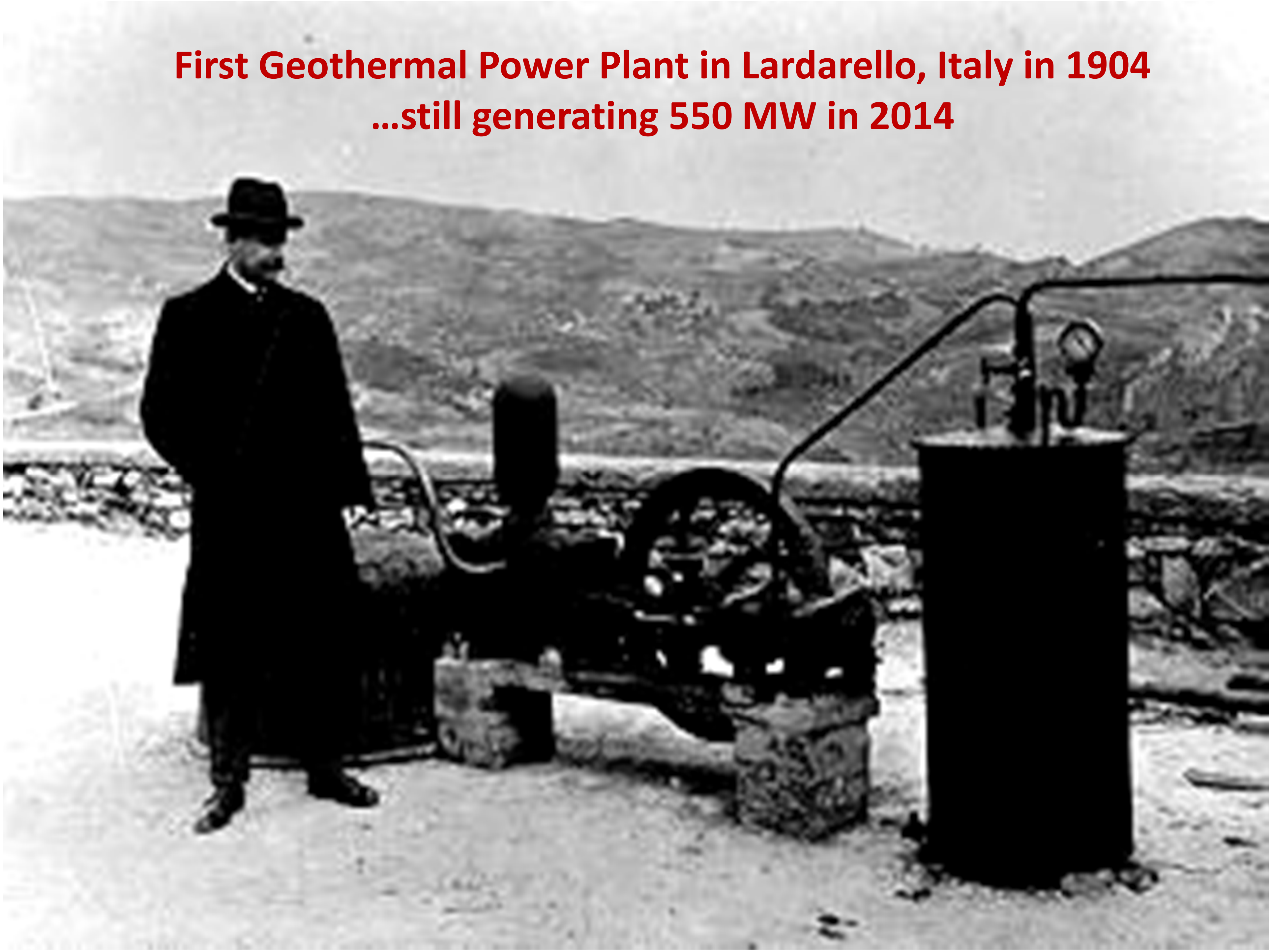
1240 geothermal wells in data set
869 (70%) are productive and 50% exceed a commercial hurdle of 7 MW
POS for random target 7 MW well is 35%

THE CONCEPT OF CONVERTING HEAT TO ELECTRICITY IS SIMPLE BUT REQUIRES A COMPLEX SEQUENCE OF ACTIVITIES



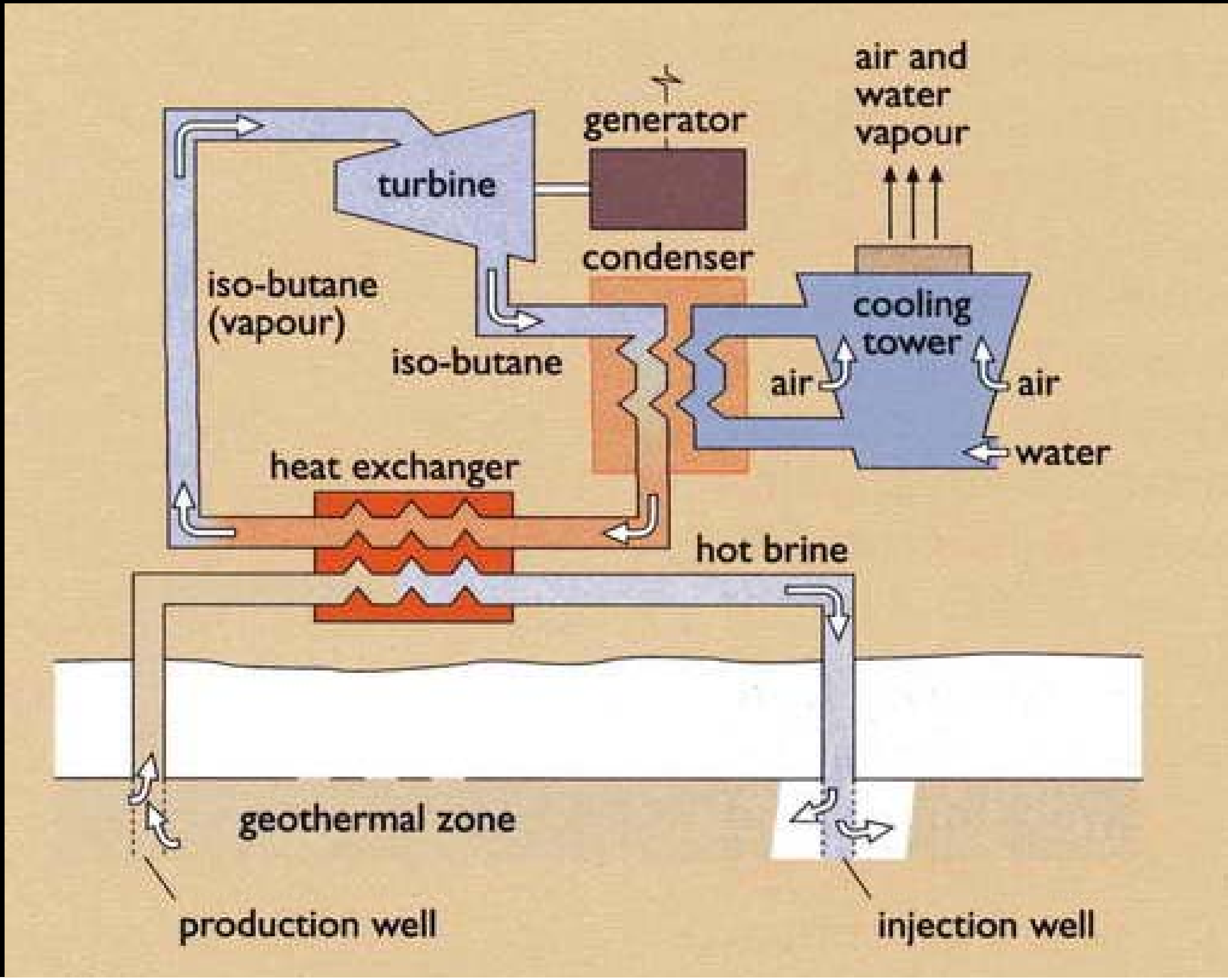
Geothermal Steam Cycle




First Geothermal Power Plant in Lardarello, Italy in 1904
…still generating 550 MW in 2014


Geysers Field, USA
Largest in the world at 850 MW

BINARY CYCLE POWER PLANT
(Fluids <200˚C and <10% of MW installed)



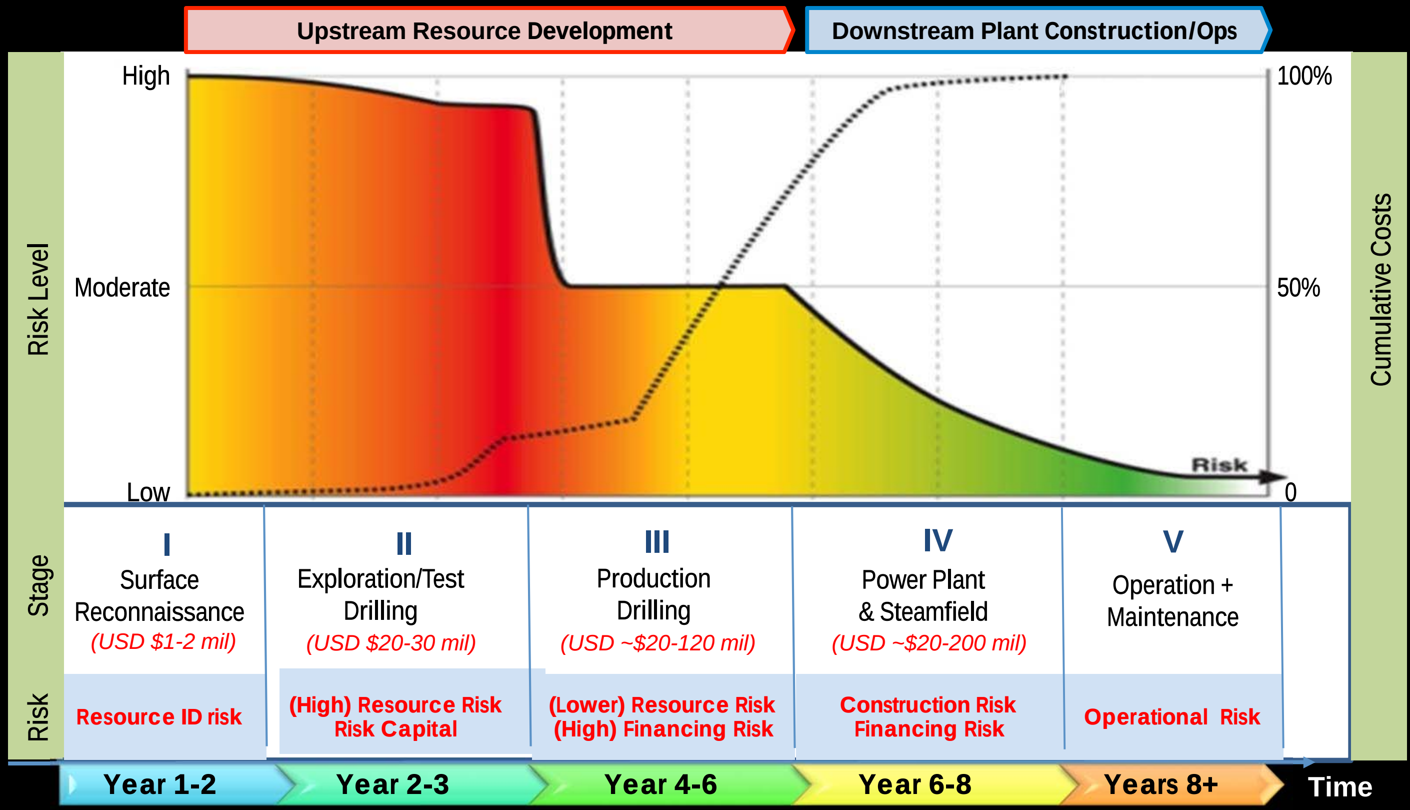
HOW DOES GEOTHERMAL DIFFER FROM OIL & GAS?

	Geothermal	Oil & Gas
Goal	Mine heat	Extract fossil fuels
"Cap"	Usually created by the system itself	Natural physical trap (fault or impermeable formation)
Produced water	Vehicle to transfer heat	Expensive nuisance
Water injection	A requirement for long term exploitation	Pressure support, eliminate waste water & chemicals
Duration	10-100+ years depending on development strategy	Variable (size of deposit & extraction rate)
Abandonment	Insufficient heat remains to economically generate power	Insufficient resource remains

LOWER TEMPERATURE DIRECT USE APPLICATIONS


World's First COMMERCIAL
FOOD DEHYDRATION PLANT
TO BE OPERATED WITH GEOTHERMAL ENERGY
SCHEDULED FOR OPERATION SEPT. 1978
FINANCING BY:
NEVADA NATIONAL BANK
WELLS FARGO, N.A.
LOAN GUARANTEED BY:
U.S. DEPARTMENT of ENERGY
OWNERS & DEVELOPERS:
GEOTHERMAL
FOOD PROCESSORS, INC.

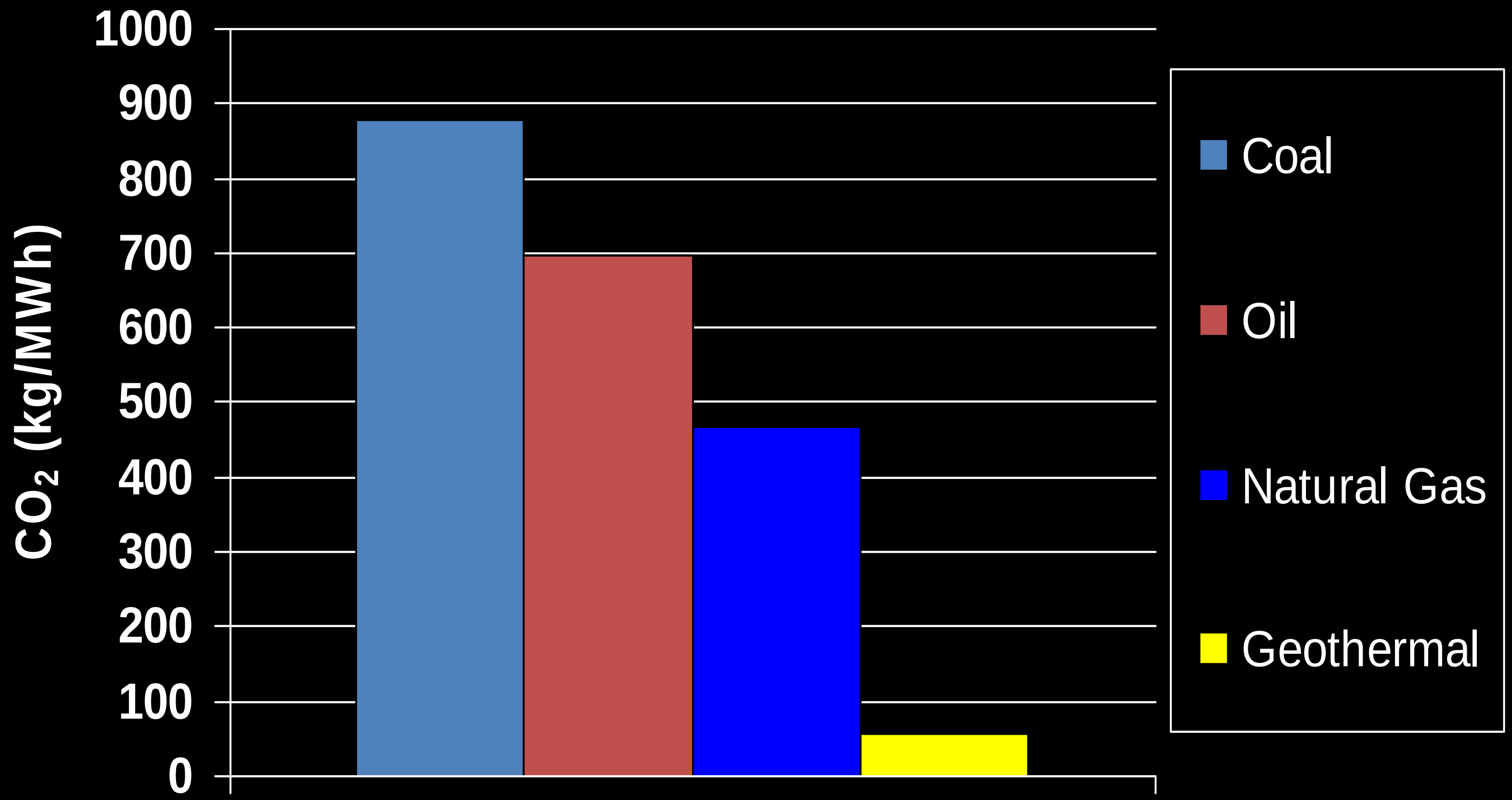
STAGES AND RISKS OF GEOTHERMAL DEVELOPMENT



ADVANTAGES OF GEOTHERMAL

- Clean, base-load, stable energy supply 24/7
- Strategic value for those countries that lack conventional alternatives
- Stable, predictable power sales prices under long-term PPAs (20-30 years)
- Environmentally benign with small development footprint

Power Plant CO_2 Emissions



Geothermal Power Emits 5% Of The CO_2 Emissions Of Coal Power On A Per MWh Basis

CURRENT STATUS OF GEOTHERMAL ENERGY DEVELOPMENT IN LATIN AMERICA

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MEXICO

- Electric power market dominated by thermal (75%) and hydro (19%)
- Geothermal 2% of total generation from four fields
- All currently operating fields driven by national government (CFE), which owns all geothermal resources
- Second largest liquid dominated field worldwide (Cerro Prieto)
- New regulations allow geothermal concession leasing and development to the private sector
- Recently completed 25 MW field development by private developer

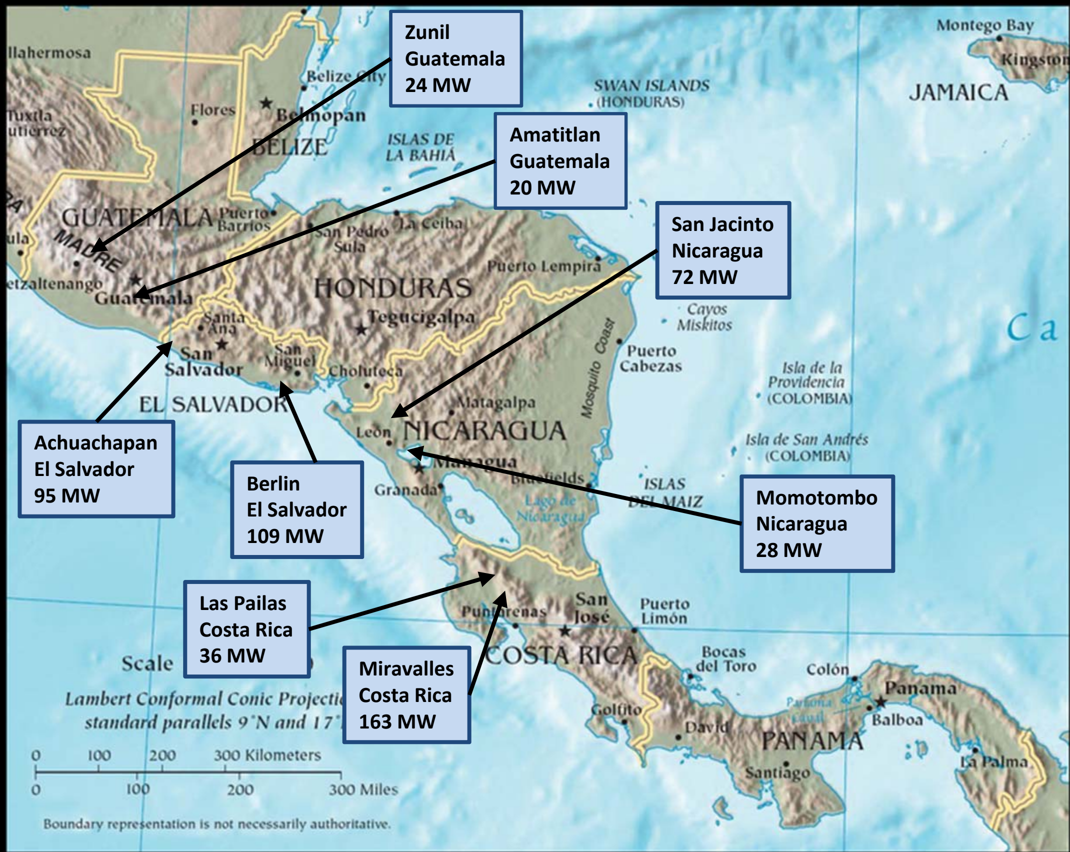
MEXICO

Field	Installed MW	Output MW	Owner	Year On-line	Production Wells	Injection Wells
Cerro Prieto	720	570	CFE	1973	174	18
Los Azufres	194	191	CFE	1982	40	6
Los Humeros	93.4	68.4	CFE	1990	24	3
Tres Virgenes	10	10	CFE	2002	4	2
Total	**1017**	**839**			**242**	**29**

CENTRAL AMERICA

- Electric power market dominated by oil, diesel and hydro plants. Hydro generation is ~45% (average)
- Sustained drought and low reserves of fossil fuels have generated increasing interest in renewable power
- Transmission interconnections from Mexico to Panama allow active power trading market, from 50 MW in 2012 to 350 MW in 2014.
- Largest geothermal developments were led by governments
- Most recent projects are driven by private sector with funding from regional banks and international lenders

CENTRAL AMERICA



CENTRAL AMERICA

Country	Geothermal MW	Site	Owner	Plant Factor %	% of Supply (GWh)
Costa Rica	163	Miravalles	ICE	79	15
	36	Las Pailas	ICE	?	
El Salvador	109	Berlin	La Geo/ENEL	90	24
	95	Ahuachapan	La Geo	90	
Nicaragua	72	San Jacinto	Ram Power	95	15
	28	Momotombo	MPC	43	
Guatemala	24	Zunil	Ormat	62.5	3
	20	Amatitlan	Ormat	98	
Honduras	0	--			0
Panama	0	--			0
Total	**547**				**~8**

SOUTH AMERICA

- Hundreds of volcanoes and thermal features and significant potential (Estimated total = 5,000-10,000 MW)
- Earliest exploration focused in Chile (1960s), Argentina & Peru (1980s), Bolivia, Ecuador & Colombia (1990s).
- Small power plant operated at Copahue, Argentina in 1990s
- Active exploration in Chile and Peru but no plants under construction
- 50 MW project planned at Sol de Mañana (Laguna Colorada) in SW Bolivia by ENDE with JICA funding
- Only a few experienced, well-funded private players in the region (EDC, ENEL & MRP)

BOLIVIA

- Peak electric demand 1243 MW (Feb. 2014) with 33.5% hydro & 66.5% thermoelectric
- 1970s – nationwide geothermal recon survey
- 7 prospects identified of which 3 possible for electricity production
- Laguna Colorada (Sol de Mañana) selected for first deep drilling campaign

SOL DE MAÑANA

- Located in SW Bolivia at 4920 m
- Surface studies 1970s-1980s
- Six wells drilled 1988-1992 from 1180 to 1726 m deep
- Wells produce 6-8 MW each
- Additional drilling to support a 50 MW plant is planned for 2015 with favorable loan from JICA
- Transmission line is ~172 km long

FACTORS THAT HAVE SPURRED AND IMPEDED GROWTH OF GEOTHERMAL

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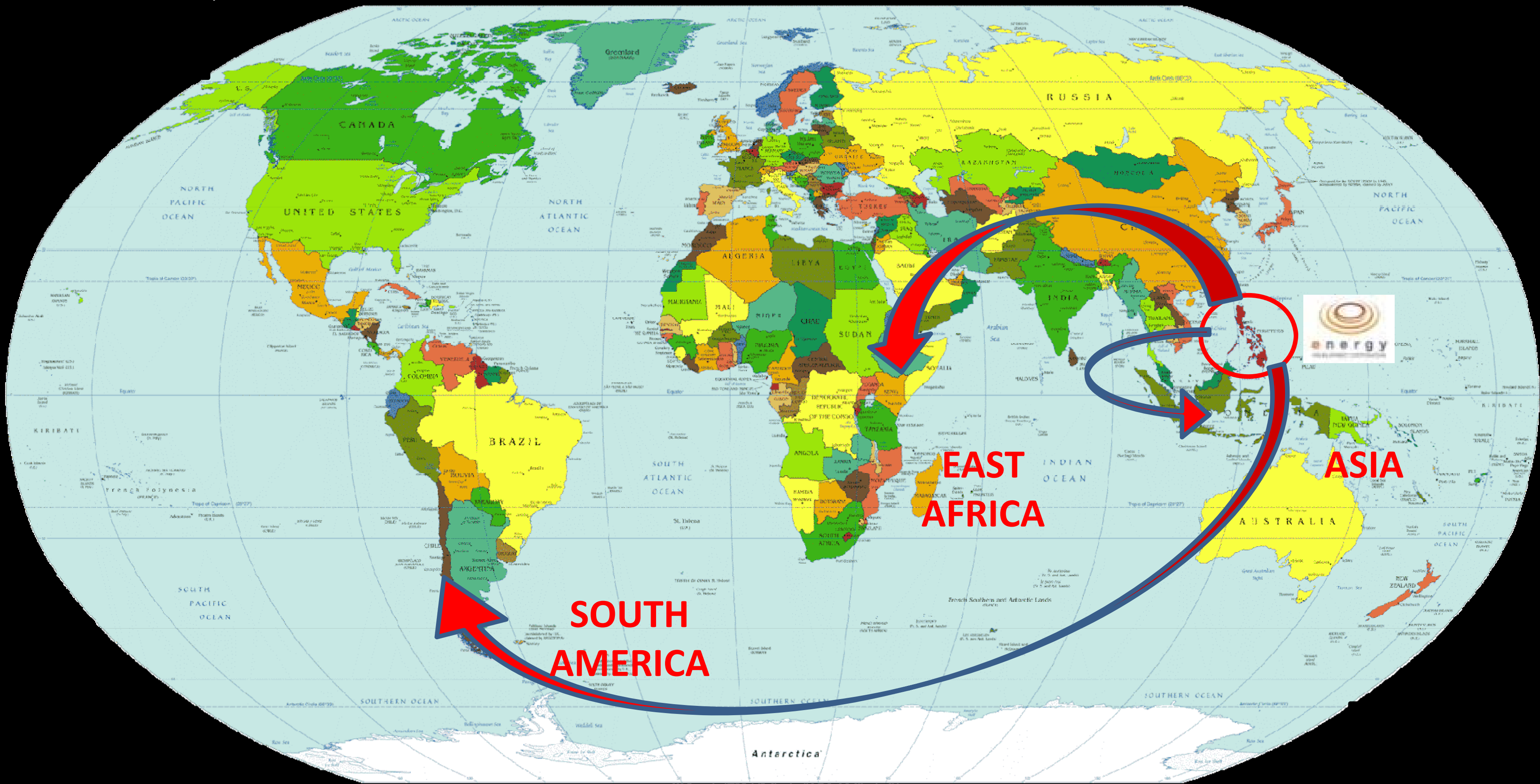
COUNTRIES WHERE GEOTHERMAL HAS BEEN MOST SUCCESSFUL:

- Had abundant young volcanos
- Lacked fossil fuel reserves (Philippines, Iceland, Nicaragua, Costa Rica, Kenya) or over-reliant on hydropower (Costa Rica)
- Strong "environmental sustainability" concern by public & government (USA, Iceland, Costa Rica, NZ)
- National governments took an active role in early exploration (Japan, Mexico, USA, Costa Rica, Kenya, NZ)
- Governments encouraged development with regulatory and economic and tax incentives (USA, Philippines, Indonesia, NZ, Kenya)
- Long-term Power Purchase Agreements (PPA) offered at viable prices by governments or public & private utilities (Renewable Portfolio Standards)

CAN GEOTHERMAL BE A SIGNIFICANT ELECTRICITY SOURCE IN SOUTH AMERICA?

- Currently no geothermal power plants in South America
- Abundant high temperature resources exist
- Strategic energy asset in countries without significant fossil fuels or dependent on hydro
- Drilling and some development costs are high due to high elevations and long transmission lines
- Lack of available long-term PPAs
- Lack of trained technical people to explore & execute projects
- Very few qualified & experienced geothermal development companies willing to take market risk
- Government policies and incentives reflect level of interest

EDC IS GOING INTERNATIONAL



EDC HAS ENTERED INTO SEVERAL COUNTRIES IN THE ASIA-PACIFIC RING OF FIRE AND EAST AFRICA THAT HAVE GEOTHERMAL POTENTIAL

MARIPOSA, CHILE
--EDC EXPLORATION DRILLING 2015

QUELLO APACHETA, PERU
--EDC EXPLORATION DRILLING 2016

EDC IS MOVING TOWARDS THE FUTURE SEEKING TO…

- Be a global clean energy player
- Remain the #1 geothermal producer in the world
- Be a model for corporate governance
- Put geothermal on the map in South America

Economic viability

Technical expertise

Environmental sustainability and social acceptability

GRACIAS!

ENERGY DEVELOPMENT CORPORATION