

*Consideraciones ambientales para el
desarrollo de la Geotermia y
modelación de reservorios
geotérmicos*

Santiago, 26-29 Mayo 2014



CEGA

CENTRO DE EXCELENCIA EN GEOTERMIA DE LOS ANDES

New challenges for the Geothermal Research in Chile

FONDAP-CONICYT Project N° 15090013

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Fac. Cs Físicas y Matemáticas

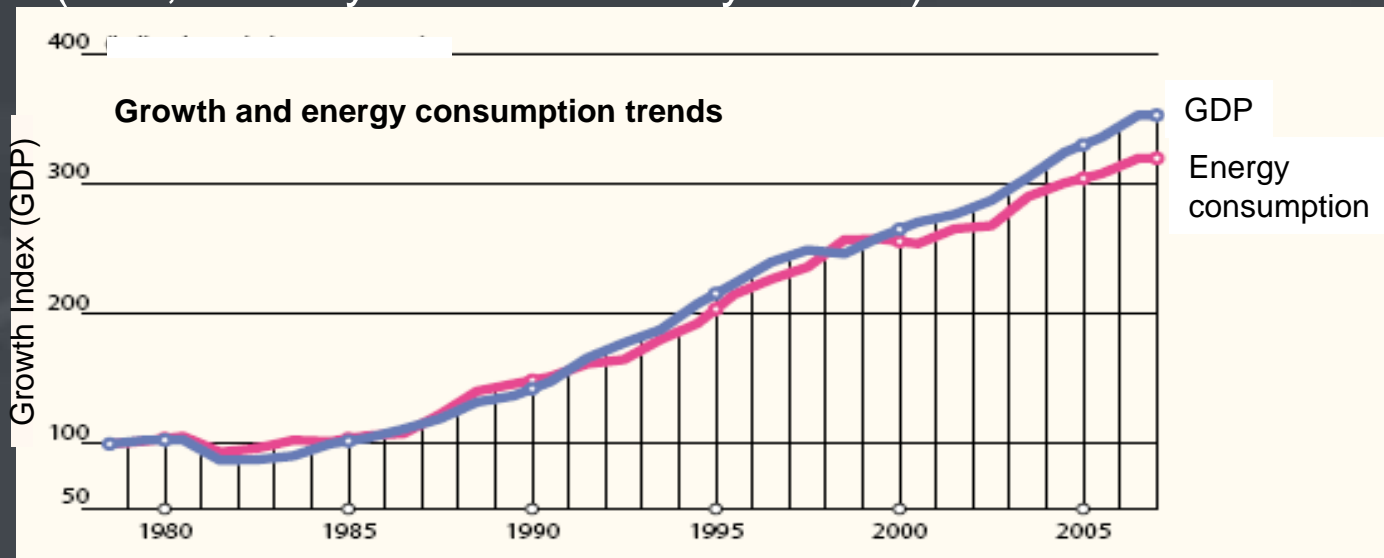
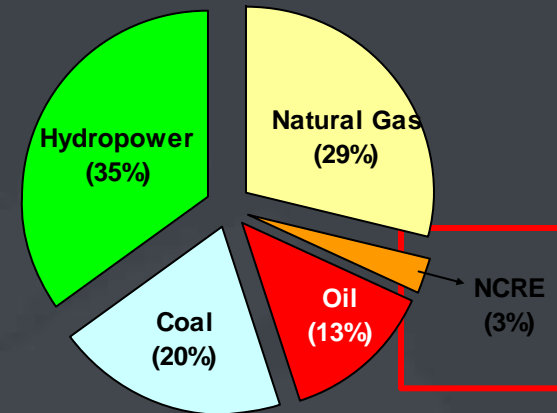
Universidad de Chile



Chile's Energy Critical Scenario

- Supply at risk due to climatic conditions (hydroelectric) and import dependence (fossil fuels).
- Crisis in 1998/99 (drought) and 2007/2008 (shut-off of natural gas supply from Argentina) led to electric rationing.
- Government target of 20% supply from non-conventional renewable energy sources by 2020 (now, 20% by 2025 & 30% by 2030?).

Electric Energy Sources
(2012, source: Ministry of Energy)

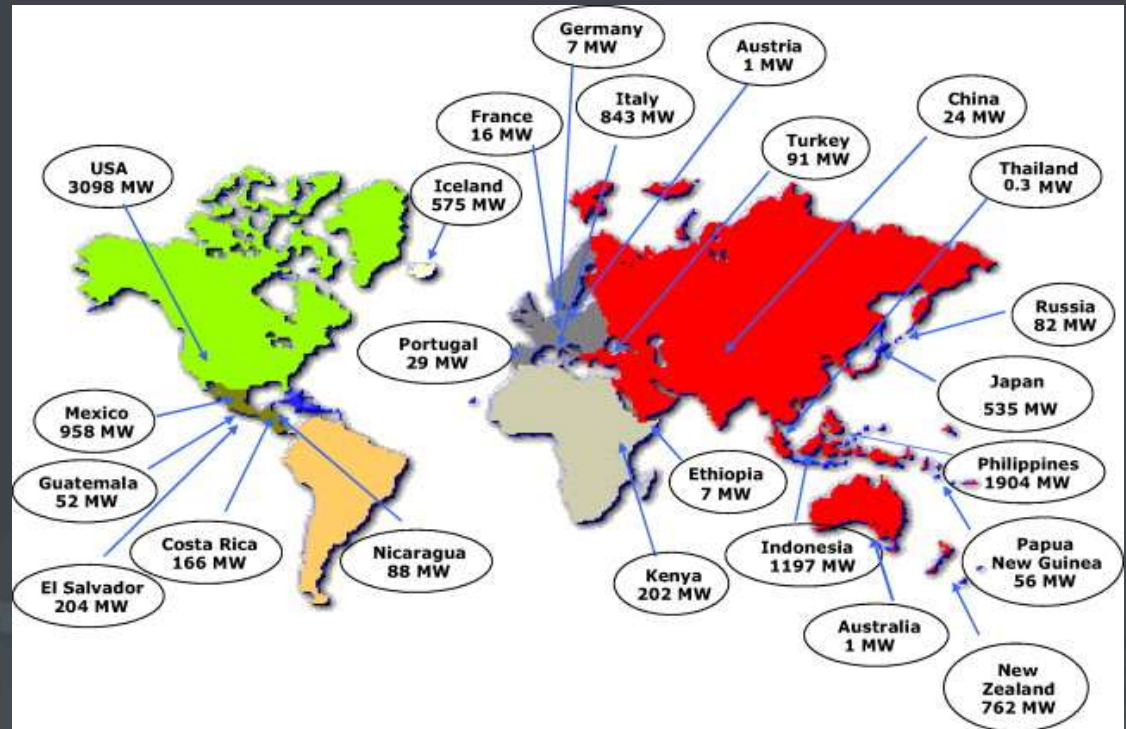


Total electric capacity:
17.5 GW
(2012)

Countries Generating Geothermal Power in 2010

Country Installed Capacity (MW)*

01. USA	3,098
02. Philippines	1,904
03. Indonesia	1,197
04. Mexico	958
05. Italy	843
06. New Zealand	762
07. Iceland	575
08. Japan	535
09. El Salvador	204
10. Kenya	202
11. Costa Rica	166
12. Turkey	91
13. Nicaragua	88
14. Russia	82
15. Papua New Guinea	56
...	
21. Germany	7.1
Chile	0



Installed capacity in 2010 worldwide:
10.9 GW (electricity) and 48.5 GW (direct uses)

*(Bertani, 2012, Lund et al. 2011)



Chilean Geothermal potential



Aguas Calientes, Cordón Caulle region, Central Chile

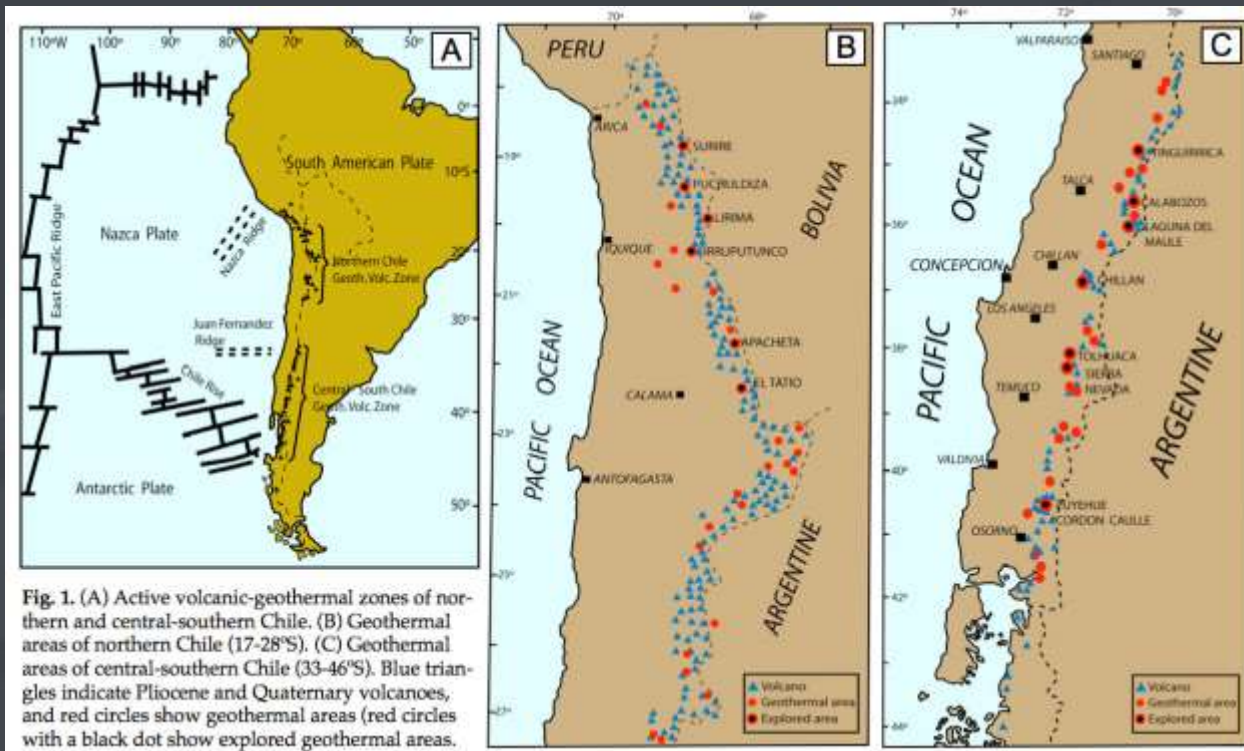


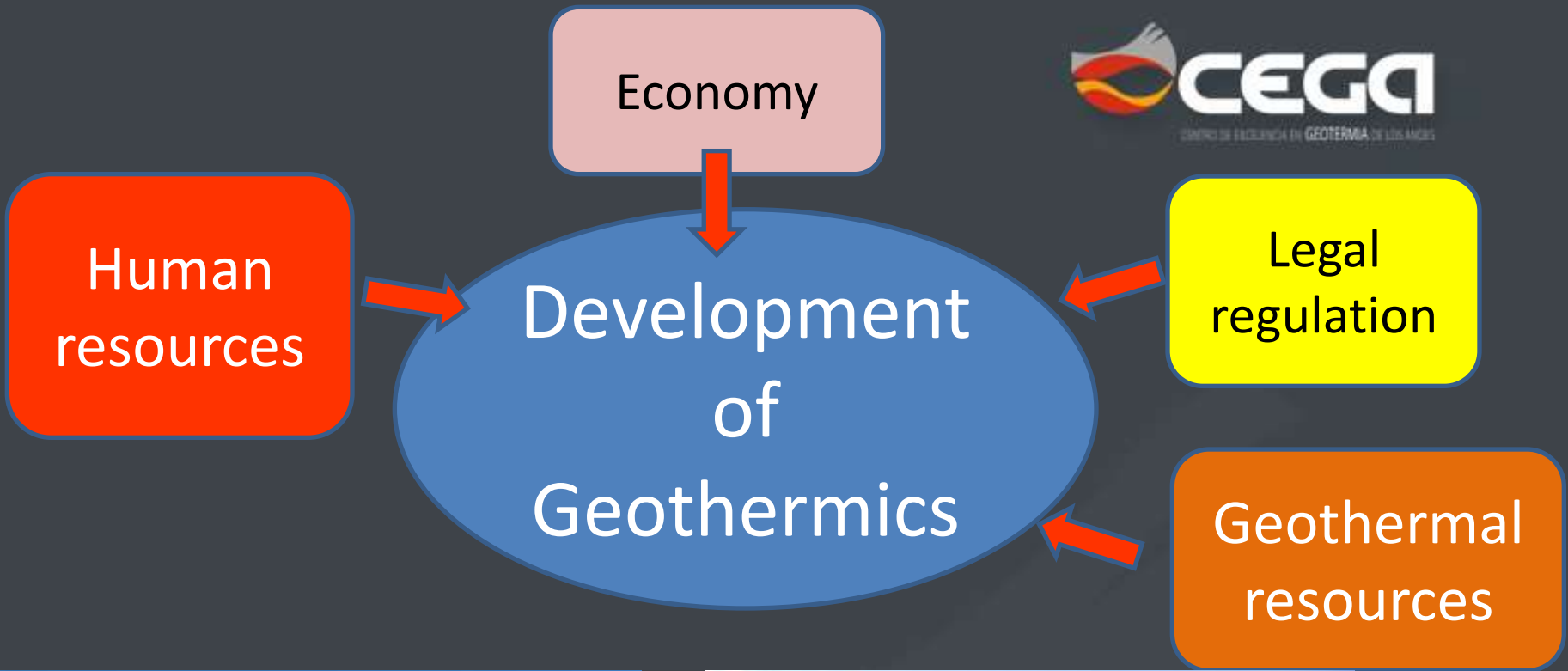
El Tatio Geyser, Antofagasta region, North Chile

“One of the largest undeveloped geothermal prospects of the world” (Lahsen et al. 2005)

Geological setting

- Geothermal resources of the Andean region of Chile occur in close spatial relationship with active volcanism, which is primarily controlled by the convergence of the Nazca and South America Plates.
- Two main volcanic zones can be distinguished within the Chilean Andes: the **Northern Volcanic Zone** (17°S-28°S) and the **Central-Southern Volcanic Zone** (33°S-46°S) parallel to the coast. At present, the Andean volcanic arc represents one of the largest undeveloped geothermal provinces of the world.

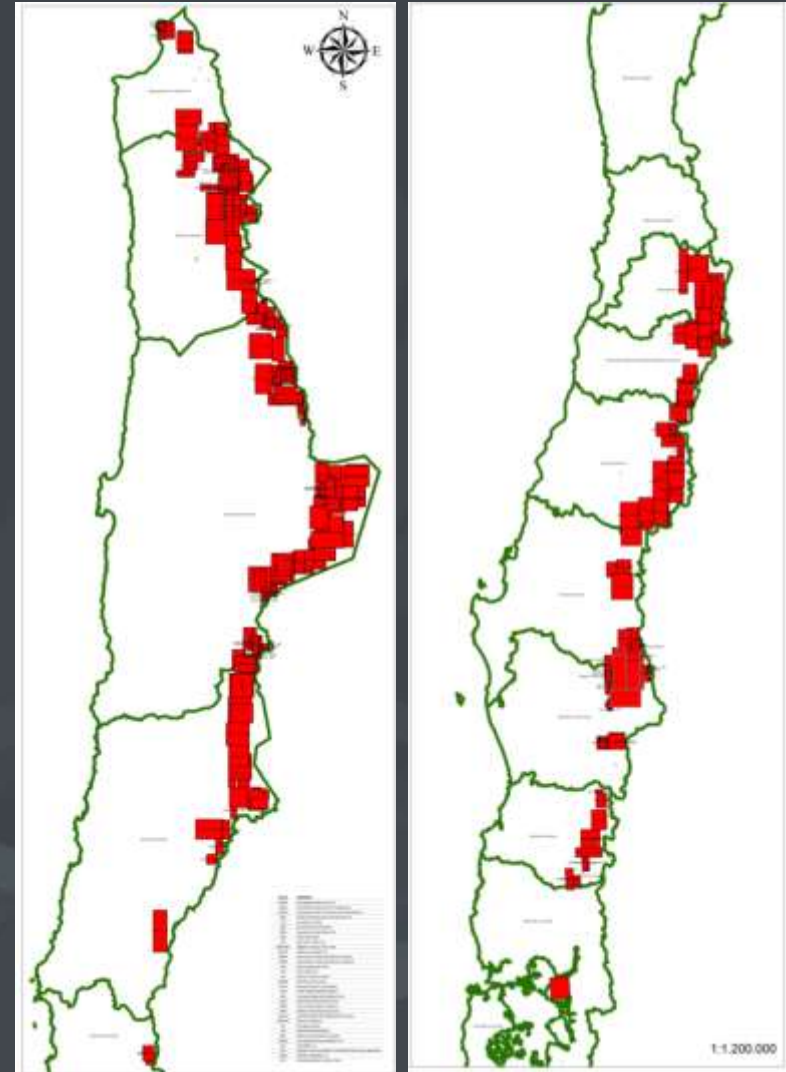




Ahuachapan (El Salvador)

Chilean geothermal exploration background

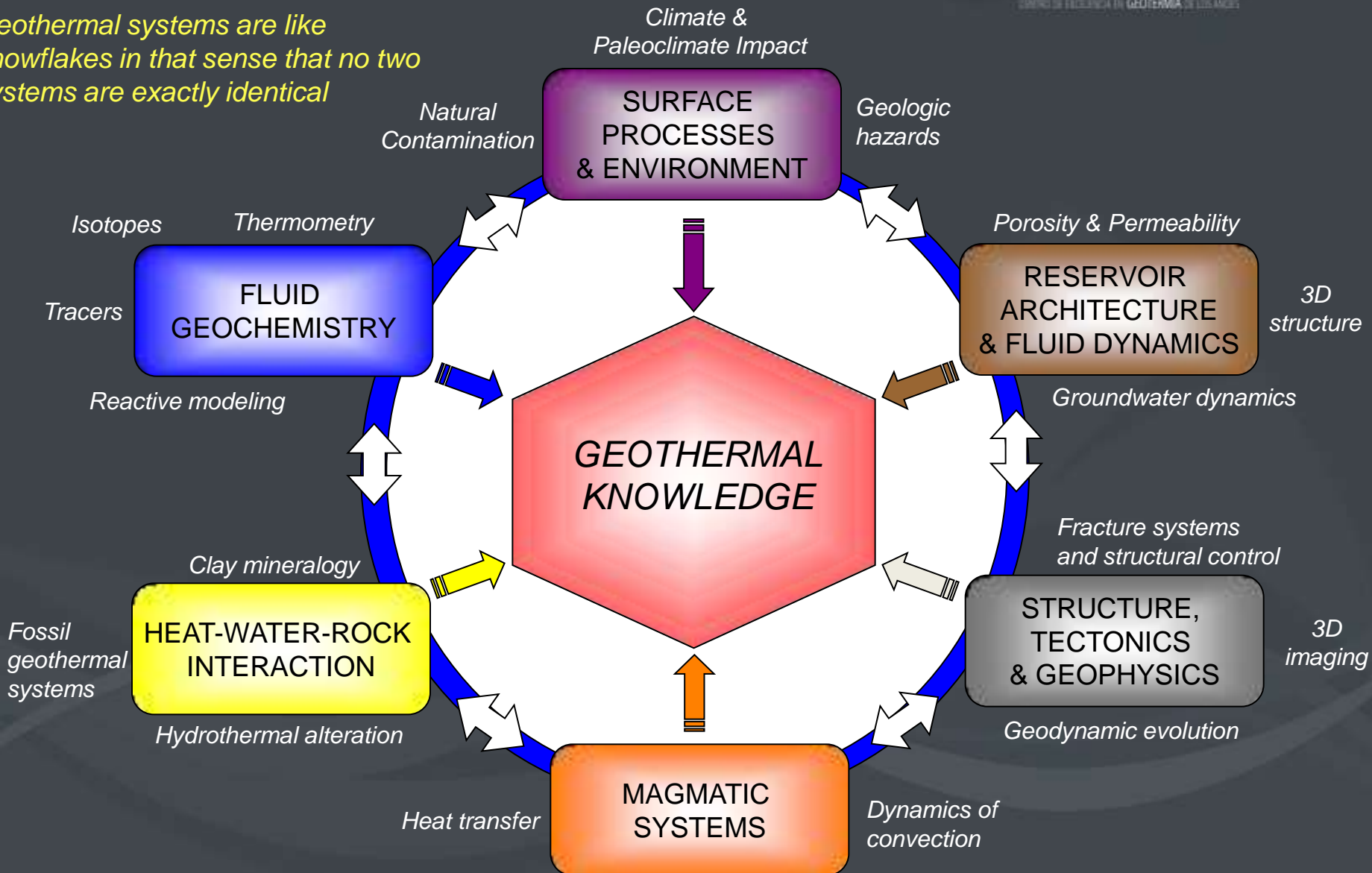
- Italian pioneers started the first geothermal exploration program in Antofagasta (1920's)
- By the late 60's the Chilean state starts to promote geothermal exploration at the northernmost part of the country
- At the end of 1979 geothermal explorations were paralyzed
- Up to 1995 the research of the geothermal resources were carried out solely by the University of Chile
- A new law in 2000 renewed interest in geothermal exploration and exploitation of resources in Chile
- 2011 CEGA began operations with the aim to generate and improve geothermal knowledge in Chile and the rest of the Andean countries



Current geothermal concessions

Research lines

Geothermal systems are like snowflakes in that sense that no two systems are exactly identical



Training and Research Activities (2011-present)

- Courses, seminars and workshops
- Departments of Geology (UCH, UdeC, UCN, UA), Geophysics (UCH, UdeC), Mechanical Engineering (UCH), Civil Engineering (UCH), Structural Engineering and Geotecnic (PUC)
- Undergraduated and post-graduate (MsSc & PhD) theses
- Post-graduate programs UCH, PUC, UCN
- Analytical facilities and state-of-the art instrumentation
- Joint research among national institutions and with foreign centers, and outreach activities

Some courses...

CURSO DE POSTGRADO (TEÓRICO - PRACTICO)

DEPÓSITO DE SILICA SINTERS EN SISTEMAS GEOTERMALES



MIÉRCOLES 22 DE MAYO

- 1) Introducción a sistemas geotérmicos y el papel del geólogo
- 2) Tipos de energía geotérmica
- 3) Identificación de riesgos sísmicos en sistemas geotérmicos
- 4) Identificación de los riesgos y factores de control
- 5) Tipos de sinter: sintérmico y sintérmico de arena

MIÉRCOLES 23 DE MAYO

- 1) Tipos de sinter
- 2) Procesos geológicos de sistemas geotérmicos
- 3) Impacto ambiental: sinteres en el medio geológico y en sistemas geotérmicos: identificación de factores de riesgo y riesgo ambiental

VIERNES 24 DE MAYO

- 1) Tipos de sinteres: silíceo y sintérmico de arena
- 2) Caracterización de sinteres: silíceo sintérmico y sintérmico de arena
- 3) Identificación de los riesgos sísmicos: sintérmico de arena
- 4) Tipos de sinteres: sintérmico de arena y sintérmico de arena
- 5) Tipos de sinteres: sintérmico de arena y sintérmico de arena

VIERNES 25 DE MAYO

- 1) Descripción de los tipos de sinteres de sintérmico a sinter silíceo
- 2) Tipos de sinteres: sintérmico de arena y sintérmico de arena
- 3) Tipos de sinteres: sintérmico de arena y sintérmico de arena

EXPOSITORES: DR. BRIDGES Y LYNNIE & DR. GARRY SMITH
UNIVERSITY OF AUCKLAND, NEW ZEALAND

INSCRIPCIÓN: \$400.000

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MAIL: YANALBA.FERRER@CEGA.UBA.AR



22 AL 25 DE MAYO
9.00 A 16.00 HRS.

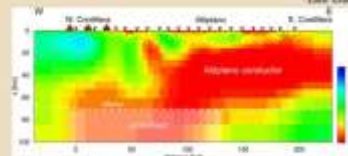
CURSO DE POSTGRADO
[Fundamentos de métodos electromagnéticos para la exploración geotérmica]

Expositor
Dr. Heinrich Brasse
Freie Universität Berlin

FECHAS DEL CURSO
11, 12, 13, 14 y 17 de octubre 2011



- TEMARIO***
- * Teoría básica de los métodos electromagnéticos
 - * Geoelectricidad de corriente continua, potencial espontánea, inducción polarizada
 - * Magnetotelúrica
 - * Métodos activos en dominio de frecuencia y tiempo
 - * Georadar
 - * Estudios de caso
- *Las clases se dictarán en inglés.



INSCRIPCIONES - INFORMACIONES
en esterce@ing.achile.cl
entre el 20 de septiembre y el 05 de octubre
40 clases
Valor curso: \$350.000
Gratuito para alumnos de doctorados nacionales acreditados



CURSO DE POSTGRADO
[Structural Controls in Geothermal Systems]

Del 30 de agosto al 01 de septiembre
Expositor
Dra. Julie V. Rowland
University of Auckland, NZ



- TEMARIO***
- * Geothermal resources and structure: introduction
 - * Factors affecting hydrothermal fluid flow
 - * Brittle deformation and conditions for development of high-flux fluid conduits
 - * Permeability and fault zones
 - * Fault zone complexity, district-scale architecture and directional permeability
 - * Influence of magmatism and volcanism on fluid pathways
 - * Case study: Physical controls on fluid flow, Taupo Volcanic Zone, New Zealand
 - * Tracking fluid flow through time: Coromandel to Taupo Volcanic Zone arc-related hydrothermal activity
 - * Vectors to geothermal / epithermal discovery: application to Chile
- *Las clases se dictarán en inglés.

INSCRIPCIONES - INFORMACIONES
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entre el 20 de julio y el 13 de agosto
40 clases
Valor curso: \$350.000
Gratuito para alumnos de doctorados nacionales acreditados



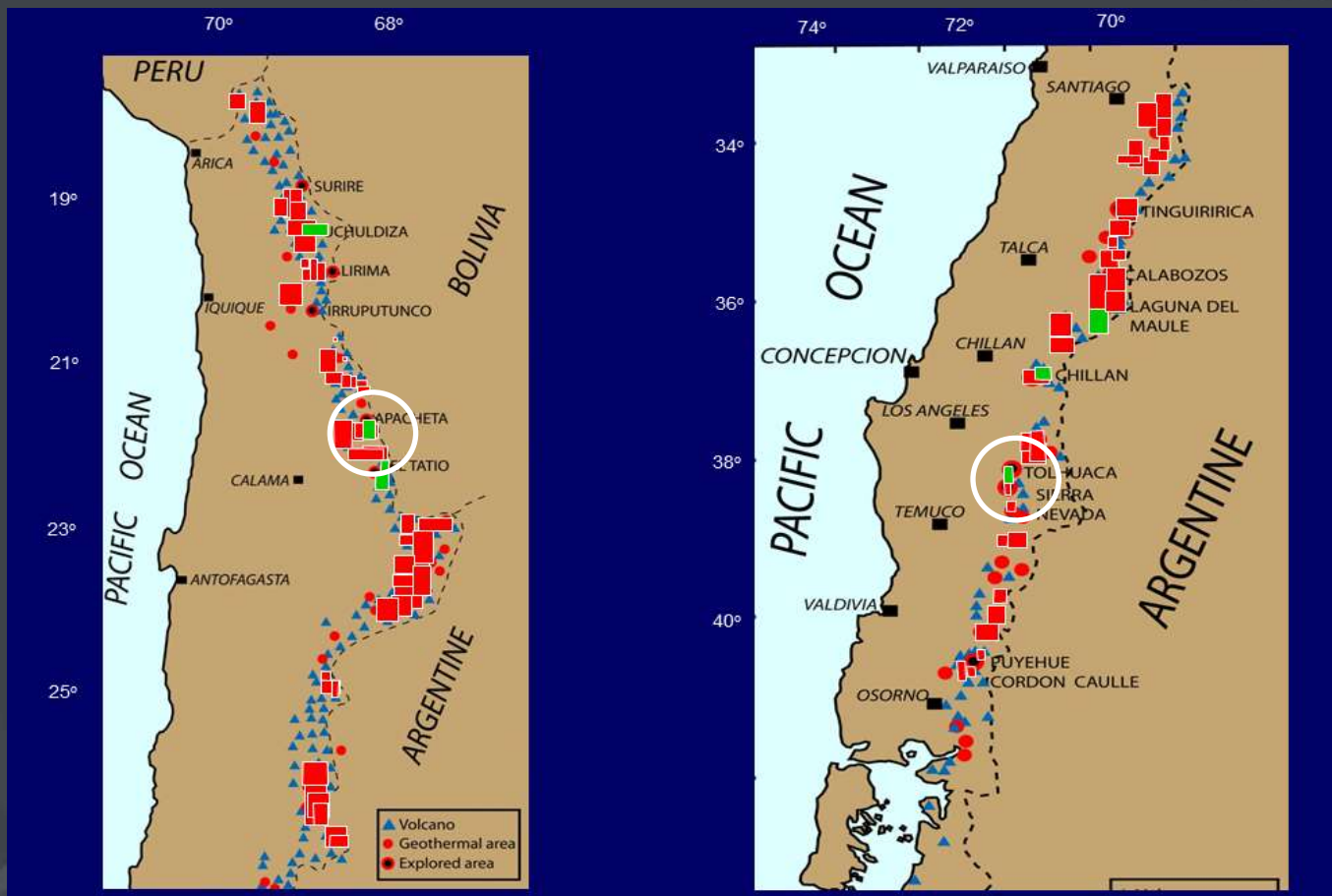
CEGA's analytical facilities

- Mineralogy (XRD+SEM+FTIR+XFR-EDX+HR-TEM+FI)
- Water and rocks Geochemistry (ICP-AOS+IC+AAS+ICP-MS-Q, IC)
- Isotopic Geochemistry (LA-ICP-MS-MC)
- Gas Geochemistry (GC)
- Micro-CT (PUC)
- Geophysics (MT+Gravimetry)

(equipments in orange: new CEGA acquisitions;
> US\$ 2 Millions)



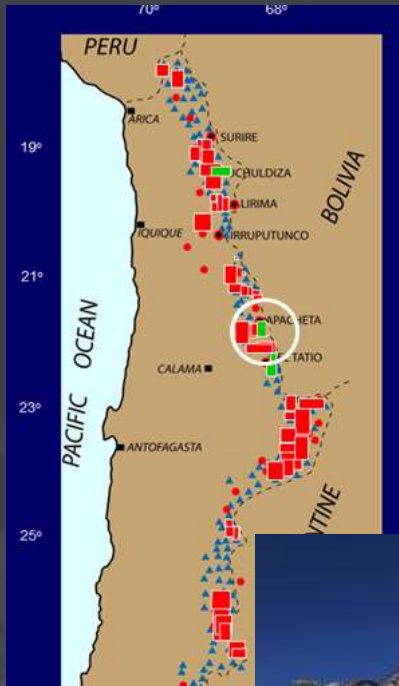
Geothermal projects update (2013)



- About **76** exploration concessions and 5 exploitation concessions
- 13 companies
- All with thermal manifestations at surface
- 2 projects in the Environmental Impact Study stage

Concesión Apacheta

1. ENG S.A./GDN S.A. (Enel + Enap)



Pozos geotérmicos
3

EIA 55 MW

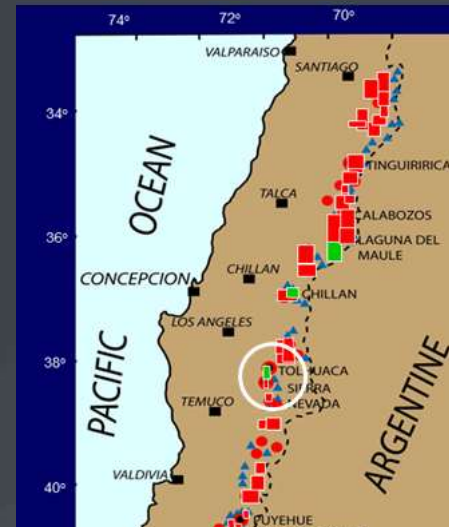
Generación
+/- 2015-16



Apacheta

Concesión Tolhuaca

1. MRP (ex GGE Llc.)



Pozos geotérmicos
2

EIA 12 MW
(potencial de 70 MW)

Generación
+/- 2015-16



Tol-4
27/08/2012



Main Current Projects



Low enthalpy

- Heat-flow map in the Santiago and Talca basins

High enthalpy

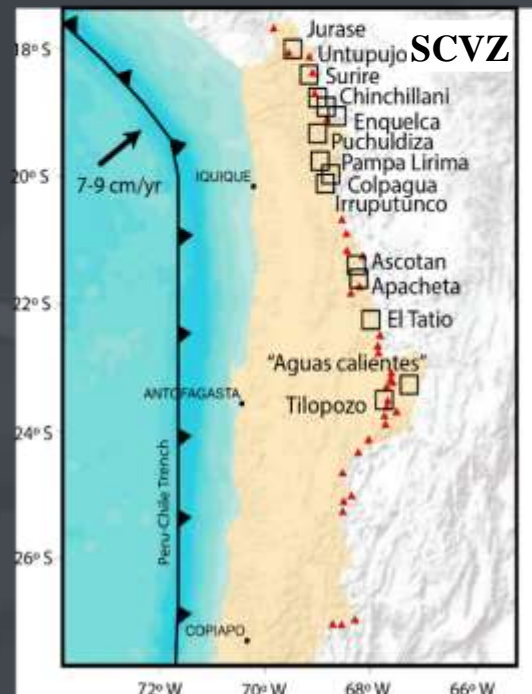
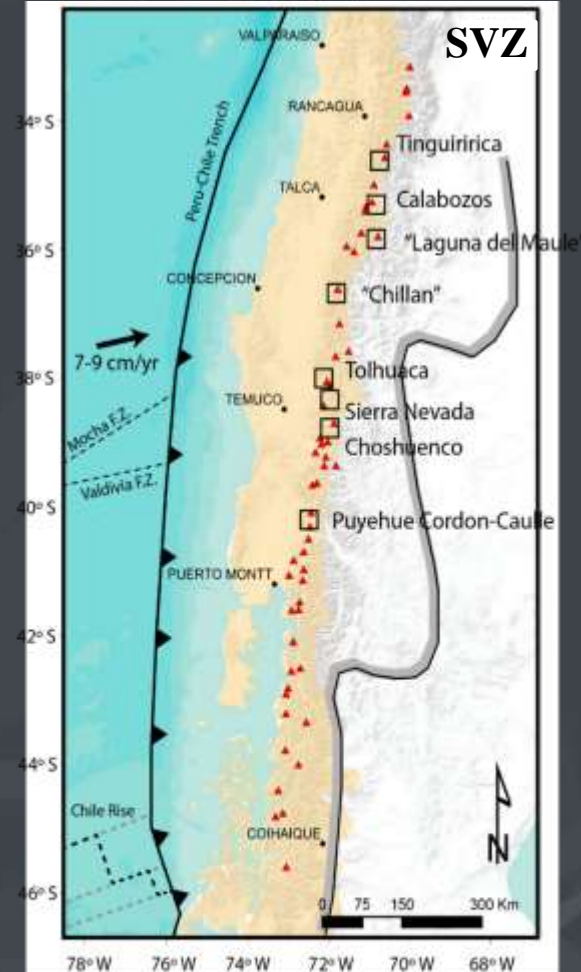
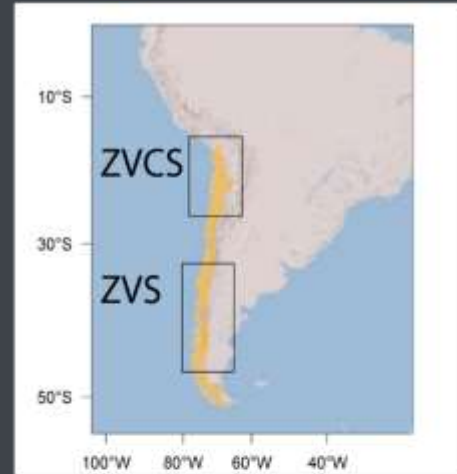
- Alteration patterns in active geothermal fields
- Structural controls on geothermal systems
- Gas geochemistry in selected geothermal areas
- Dynamic of magmatic chambers
- New isotopic systems in geothermal research
- Mineralogy and geochemistry of silica sinters
- Geophysical survey in active and fossil geothermal fields

New isotopic systems in geothermal research

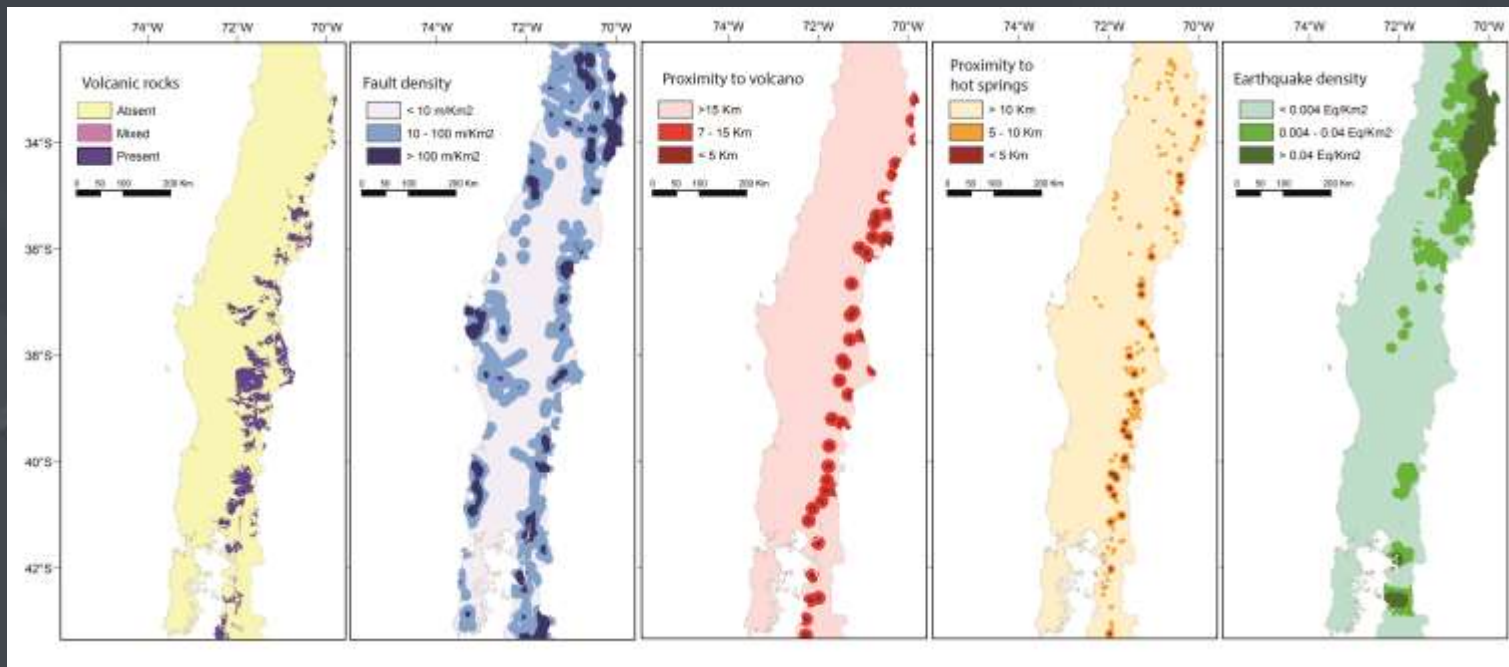
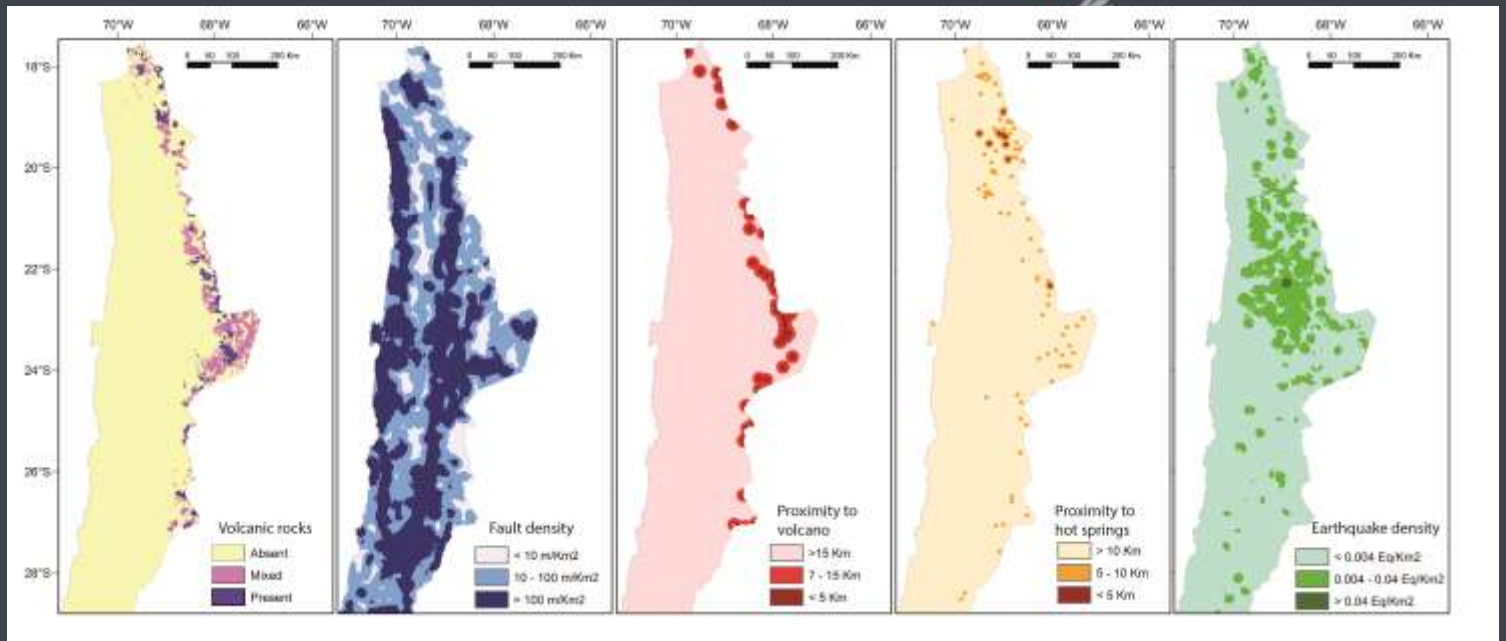
- Recent acquisition and installation of a Neptune plus (MC-ICP-MS) with LA system
- U/Pb geochronology
- U-Th disequilibrium ages in calcites (2014?)
- Non-conventional isotopic systems (2014)
- Trace and ultratrace GQ



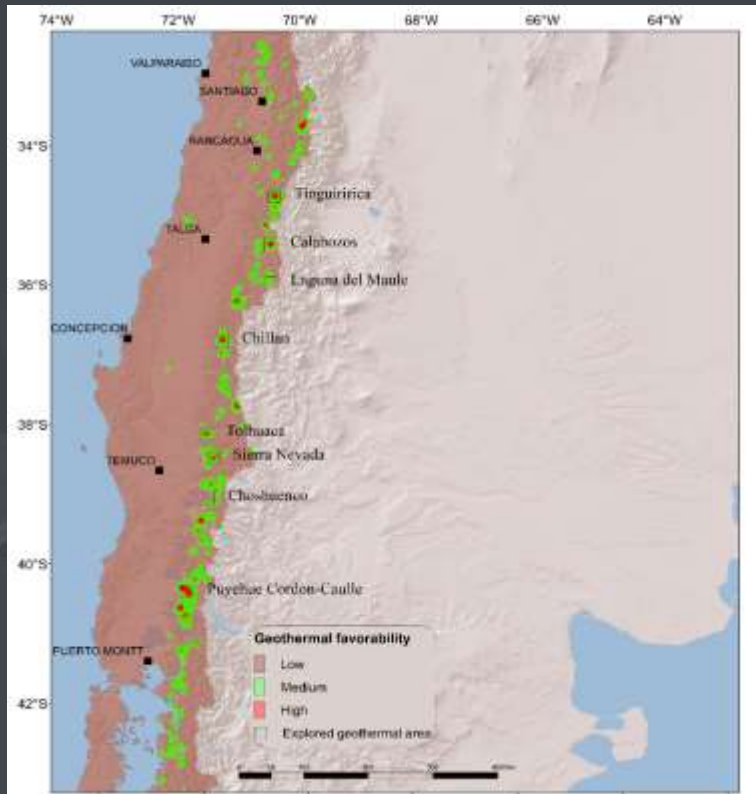
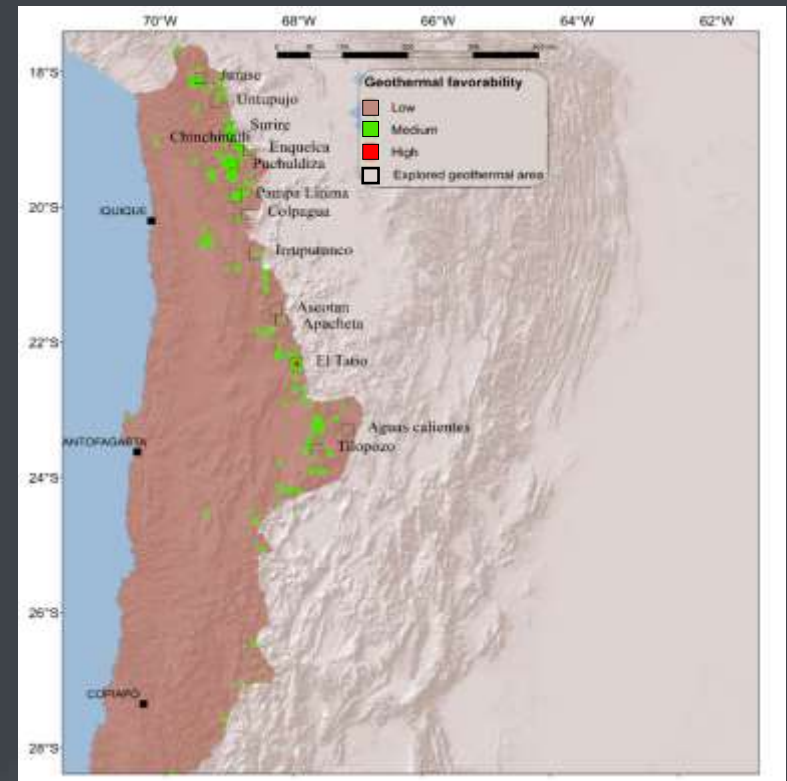
**New
Research
Project
2014:
Geothermal
potential in
Chile &
Favorability
geothermal
map**



- Thermal area
- ▲ Quaternary volcano
- Main city
- Eastern limit of Cenozoic volcanic arc



- 9 out of the 22 areas are located within or adjacent the first priority area (most favorable), 13 are located in the second priority area, and 1 located in the third priority area.
- Other parts of the country show a scarce amount of territory associated with medium and high favorability systems. Mainly due to the low number of hot springs that have been explored in this areas
- A more detailed sampling of these sectors would certainly increase the degree of favorability associated with these areas.



- As expected, there is a clear correlation with eruptive centers, showing areas of high and medium geothermal favorability following the volcanic arc trend.
- Approximately 0.2% of the country would be classified as highly favorable, 3.2% as moderately favorable and the remaining 96% as unfavorable.
- There are numerous other areas that have a high potential for geothermal development. The resulting map is a powerful tool that will allow a better understanding and territory planning for geothermal development.

Future Research (and training) Projects (involving industry!!!)

- Geophysical survey in active and fossil geothermal fields
- Geothermal modeling & reservoir engineering
- Environmental impact
- Plant design
- Mechanical engineering
- Corrosion and material research
- Outreach, dissemination and society

Outreach

- Assist in the development of the Chilean geothermal industry by training courses, workshops and seminars
- Develop communication strategies in order to make information accessible to the scientific community and the Society (scientific and non-technical publications, conferences, webpage, exhibits and science presentations for the general public and primary/high school students)
- Educate local communities on the benefits of geothermal energy development and integrate them into educational programs and activities





CENTRO DE EXCELENCIA EN GEOTERMIA DE LOS ANDES

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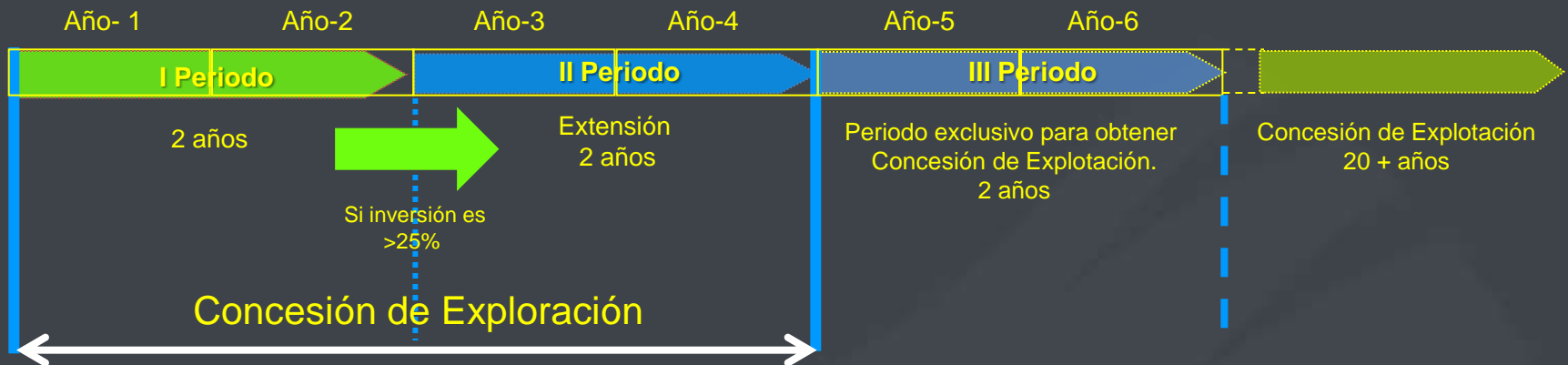
FACULTAD DE CIENCIAS
FÍSICAS Y MATEMÁTICAS
UNIVERSIDAD DE CHILE



COMICYT
Ministerio de
Educación

Gobierno de Chile

Ley Geotérmica N° 19.657 desde el año 2000



Periodo muy corto si:

- Se requiere EIA
- Aplicación de ILO169
- Limitaciones climáticas
- Realizar exploración geotérmica

La existencia de una Ley y su reglamento, sumado a las licitaciones realizadas por el Ministerio de Energía, ha permitido la existencia de una cartera de proyectos de exploración y la participación de numerosas compañías...