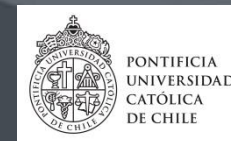




Geothermal Development and Research in Chile: the Andean Geothermal Center of Excellence (CEGA)

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Universidad de Chile



CONICYT
Ministerio de
Educación



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)

“Prehistory” of the geothermal research in Chile:

ANÁLISIS DE LAS AGUAS DE APOQUINDO.

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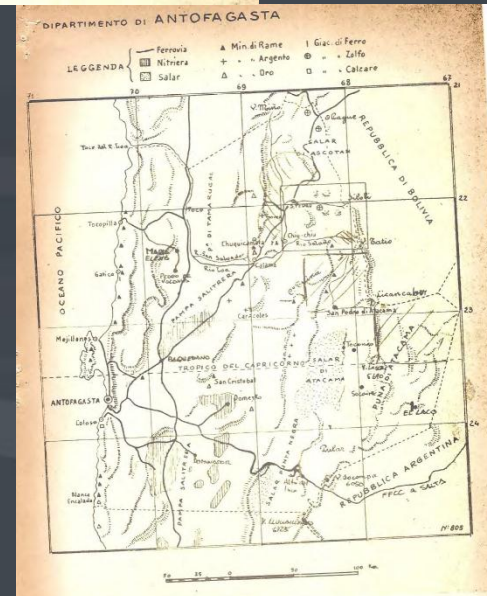
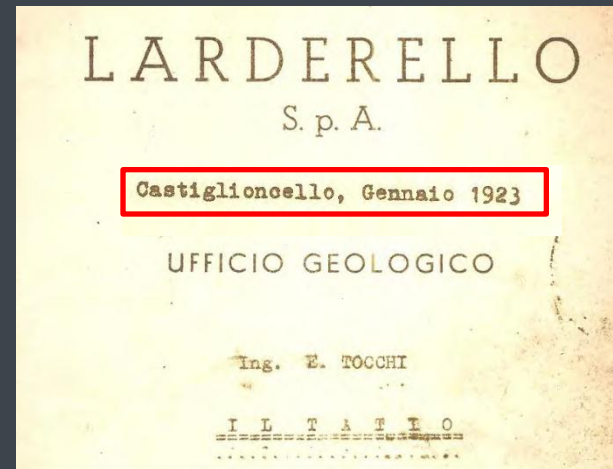
MEDICINA.—Aguas minerales de Apoquindo, analizadas por don Ignacio Domeyko i don Manuel José Domínguez.

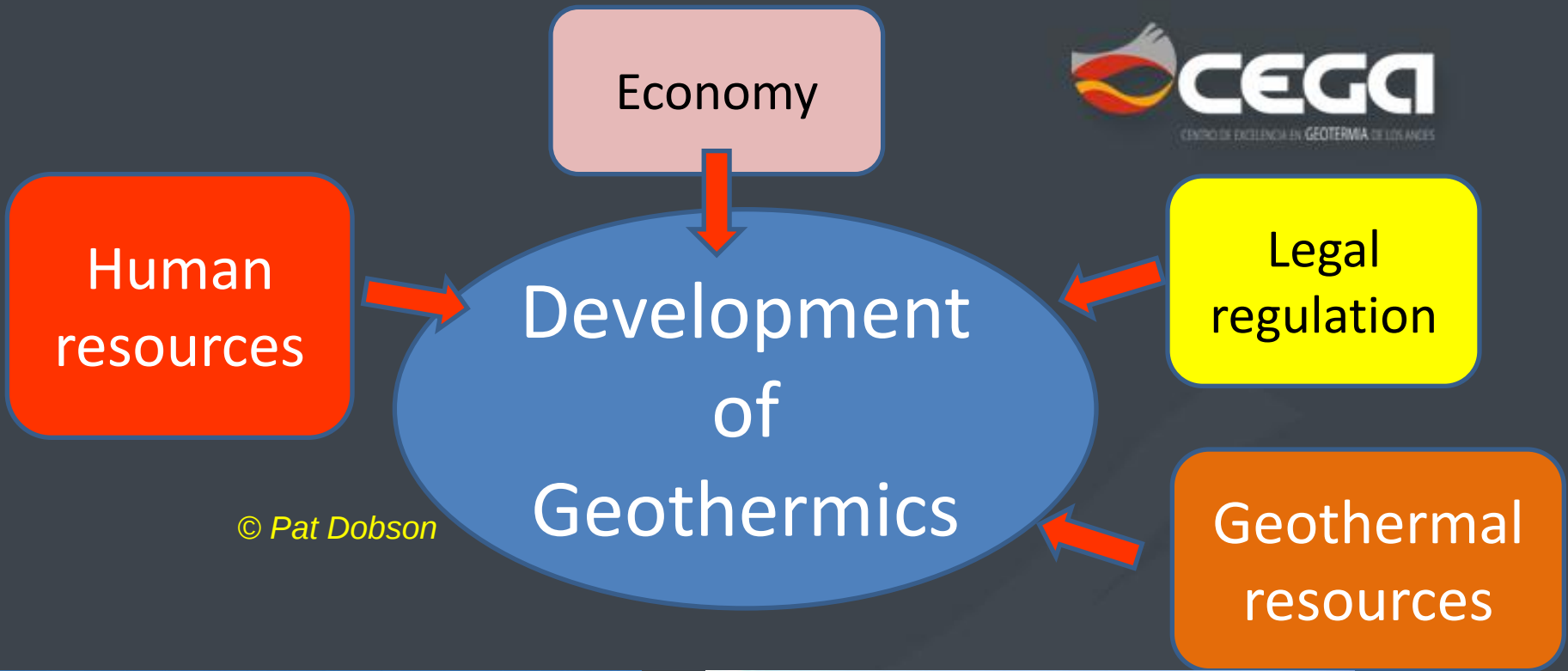
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ANALES.—ENERO DE 1866.

Parece indudable que constituyendo las sustancias cloruradas casi la totalidad de las sales disueltas, es a estas sales a quienes deb en las aguas de que nos ocupamos su accion medicinal; sus aplicaciones en jeneral deben ser, por consiguiente, las mismas que las que han sido reconocidas en las demas de su especie. Pero no habiéndose encontrado hasta el presente, ni en Europa ni en ninguna otra parte que en Chile, aguas minerales cloruradas que ofrezcan como elemento predominante el cloruro de calcio, i esto aun en dósis tan considerable, ¿cuál será el modo de obrar de este último? ¿Cuáles las aplicaciones especiales que este carácter da a las de Apoquindo? Hé aquí una

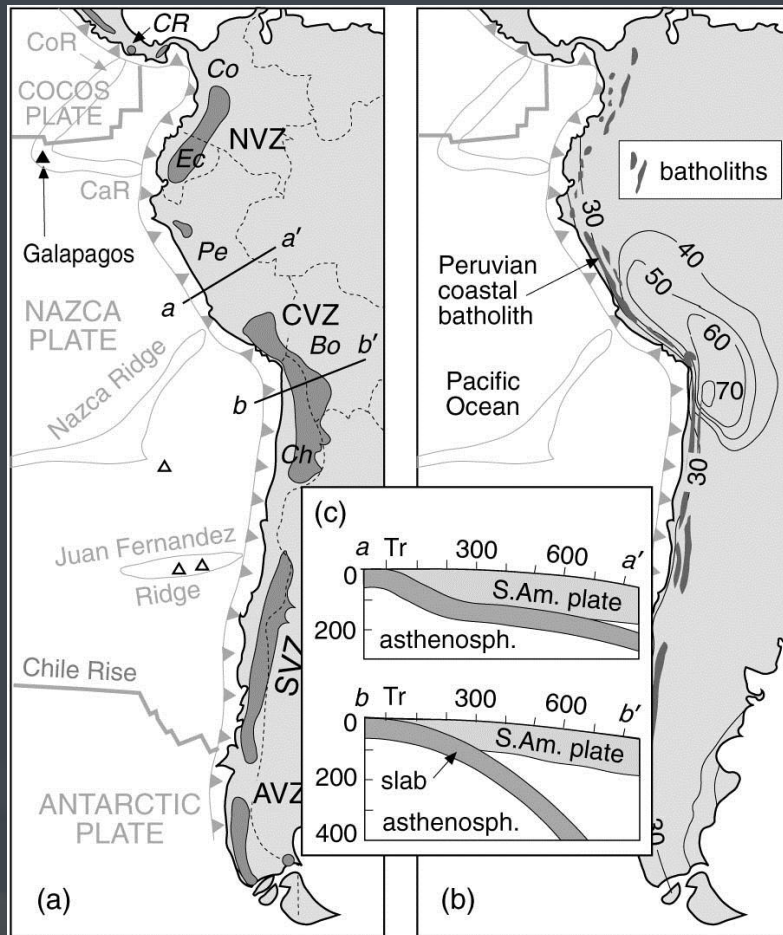
Essendomi occorso, in altra occasione di dover tradurre in cifre ad uso di persone d'affari le mie impressioni sul Tatio, parlai della possibilità di installarvi una centrale di 50.000 kW, ritenendo, come ritengo ancora in base alle cose sopra dette, che tale potenza vi sia perfettamente raggiungibile, purché la prosecuzione dei così bene avviati lavori di sondaggio, confermi la pratica possibilità di ottenervi il vapore nelle volute condizioni di temperatura e composizione chimica.





Ahuachapán (El Salvador)

Chile: country of volcanoes!



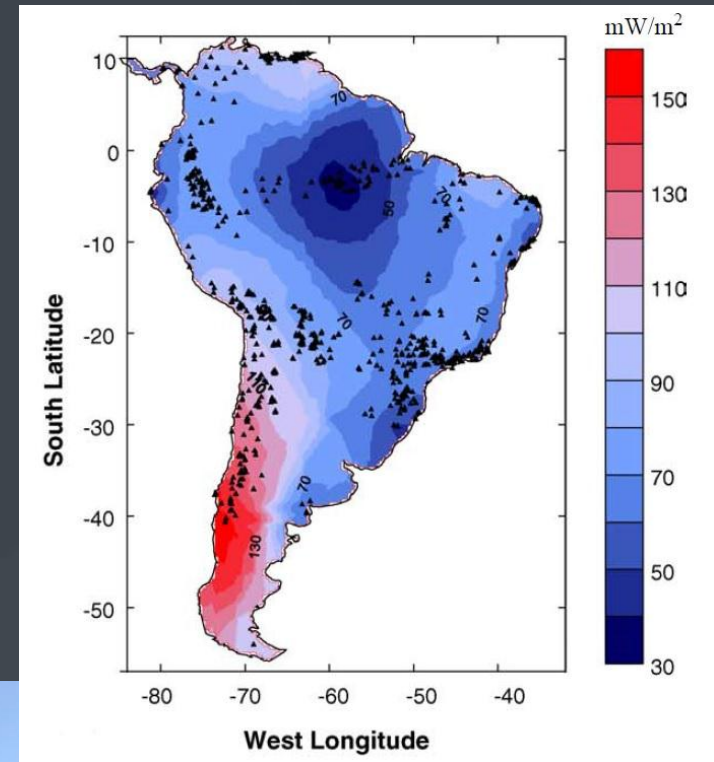
Cordón Caulle eruption, 2011



- Andean Cordillera: over 200 Pleistocene and Holocene Andean arc volcanoes occurring in four main volcanic zones: **NVZ** (2°N-5°S), **CVZ** (14°S-28°S), **SVZ** (33°S-46°S) & **AVZ** (49°S-55°S).
- More than 100 Pleistocene and Holocene volcanoes are located in Chile.
- Segmentation of the volcanic arc is controlled by the dip and morphology of the Benioff zone.

Chile: high geothermal anomaly!!

- Close relation between recent volcanism and high-T geothermal systems
- High geothermal potential (unexploited!)
- No real estimation about geothermal potential
- Abundant medium and low-enthalpy systems
- Different exploration programs in most of the Andean countries (private companies in Chile)
- Andean countries: mostly used for bathing and spa (≈ 340 MWt; Lund et al., 2011)
- Incipient low-T direct use in Chile (≈ 9 MWt)
- Geological, economical and social barriers



*Heat flow in South America
(from Hamza et al, 2005)*

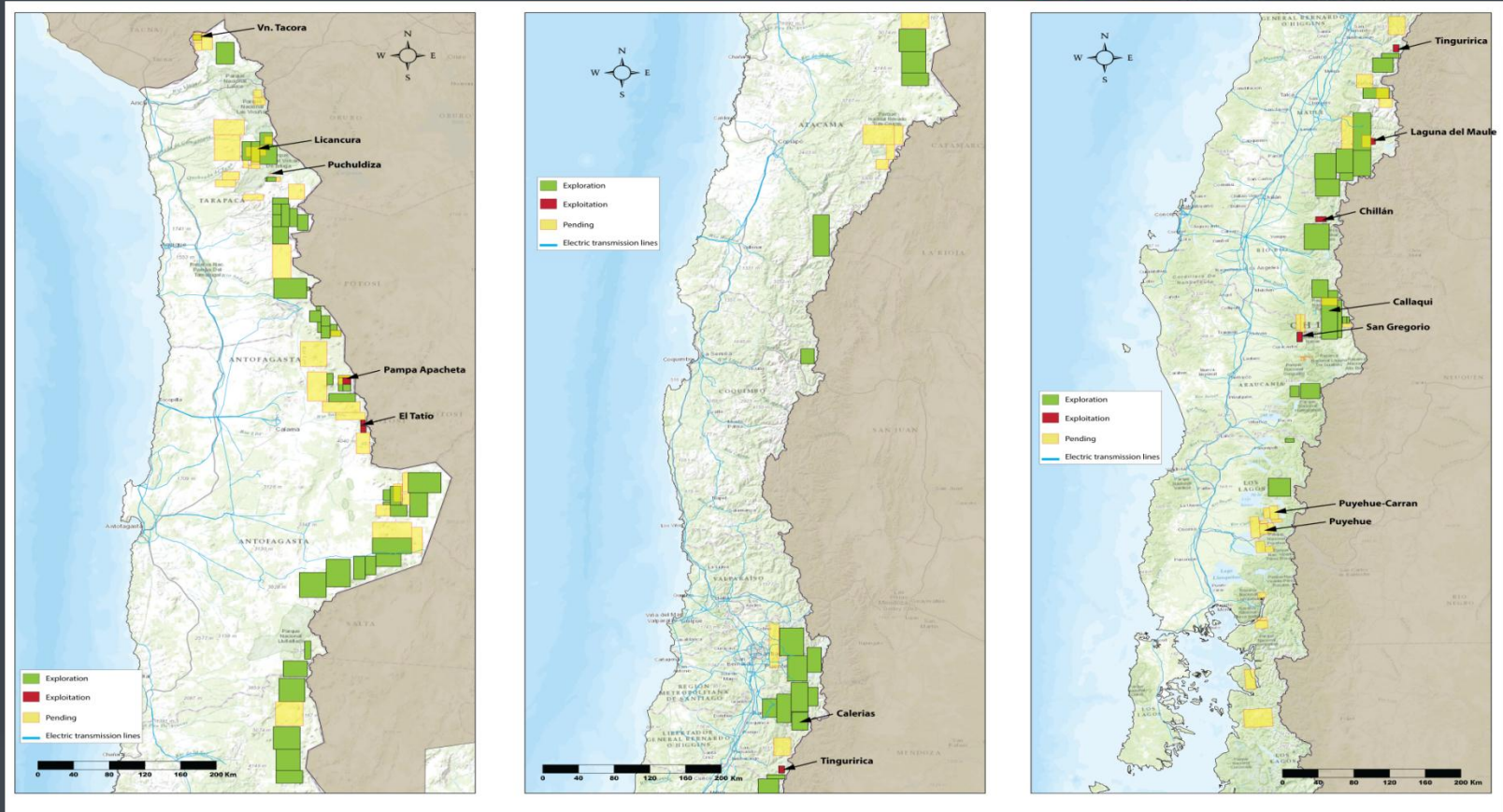


Tolhuaca Geothermal Field (S Chile, MRP)



El Tatio Geothermal Field (N Chile)

Exploration concessions in Chile



Active geothermal concessions	N
Exploration	75
Exploitation	8

New geothermal concessions pending	N
Exploration	56
Exploitation	20



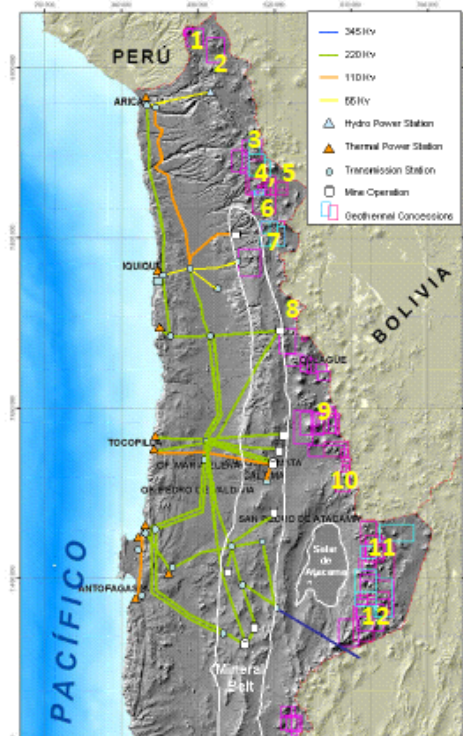
Power resources estimations (after Chilean Geothermal Council)



More advanced projects

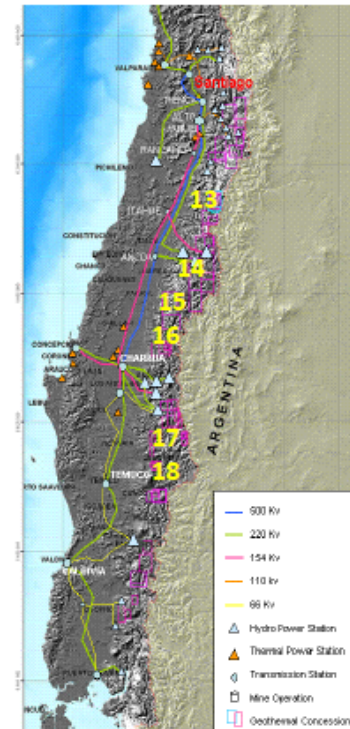
- Slim holes

POTENCIAL PROYECTOS GEOTÉRMICO EN CHILE



PROYECTO (MW)	Mínimo	Máximo
1 TACORA	50	100
2 COLPITAS	30	50
3 POLLOQUERE 1	70	140
4 POLLOQUERE 2	50	100
5 LICANCURA III	70	140
6 PUCHULDIZA	30	100
7 PAMPA LIRIMA	40	100
8 IRRUPUTUNCO	50	100
9 APACHETA	50	140
10 EL TATIO	100	250
11 SAN ALBERTO	50	100
12 TUYAJTO	80	170
13 TINGUIRIRICA	90	200
14 CALABOZO	80	200
15 LAGUNA DEL MAULE	50	200
16 CHILLAN	30	100
17 CALLAQUI	40	100
18 TOLHUACA	40	150
TOTAL (MW)	1000	2440

Potencial en Chile 3500 MW considerando otros proyectos menos explorados que se podrían desarrollar en 20 años.



First power plant in Chile (and South America)?

- Cerro Pabellón (Enel Green Power - ENAP, N. Chile), 4500 m.a.s.l., in the Atacama Desert, 100 km far away Calama city.
- Exploitation concession approved
- Probed geothermal reservoir with $T \approx 260^{\circ}\text{C}$
- Two first power units 20 MW each one, increasing up to 100 MW.
- In operation in 2018 (?)



Future power plants in Chile?

- Tolhuaca (2019), Mighty River Power
- Tinguiririca (2020), Energía Andina



Altos costos y condiciones del mercado dificultan el desarrollo de esta industria que podría aportar 3.500 MW de energía renovable al sistema. El sector busca apoyo del Estado para seguir trabajando.

Por Carolina Pizarro

Geotermia: US\$ 300 millones en compás de espera

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LATERCERA Sábado 30 de agosto de 2014

Negocios



► Proyecto de MRP Geotermia en volcán Tolhuaca, entre Biobío y La Araucanía. FOTO: MIGHTY RIVER POWER

Potential projects & the future in Chile?

Barriers: natural + legal + economical

- Not priority for STATE? (absence of oil and gas resources and high climatic dependence for hydropower!)
- Role of the **STATE** (???)
 - Geothermal projects mostly developed by private companies.
- Technical and scientific capacities in the country (but not deep drilling companies)
- High risk and high cost (some **STATE** assurances plan?; German assurances?)
- High-T geothermal areas in remote location, far away main transmission lines, altitude problems, logistic problems (infrastructure), national parks or protected areas.
- Need a specific modern legislation (new Chilean law in 2015?)
- Need a specific legislation for **direct uses**
- Indigenous communities



STATE



Tolhuaca geothermal field, Tol-4 drill hole.
© Mighty River Power

Geothermal Research in Chile (and South America): CEGA

What is CEGA?

- **FONDAP** Project funded by CONICYT during five years (2011-2015), renewable during five years more (2016-2020).
- Joint research UCH (Principal Institution) + PUC (Associated)
- Hosted in the Department of Geology (Universidad de Chile)
- Other associated departments or institutions: Geophysics, Mechanical and Civil Engineering (UCH) + UdeC
- 22 (+1) +3 (by projects) investigators + 6 (+1?) post-docs + 3 professionals (1 chemistry) + c. 30 post-graduate students (PhD & Ms Sc) and c. 30 undergraduate students

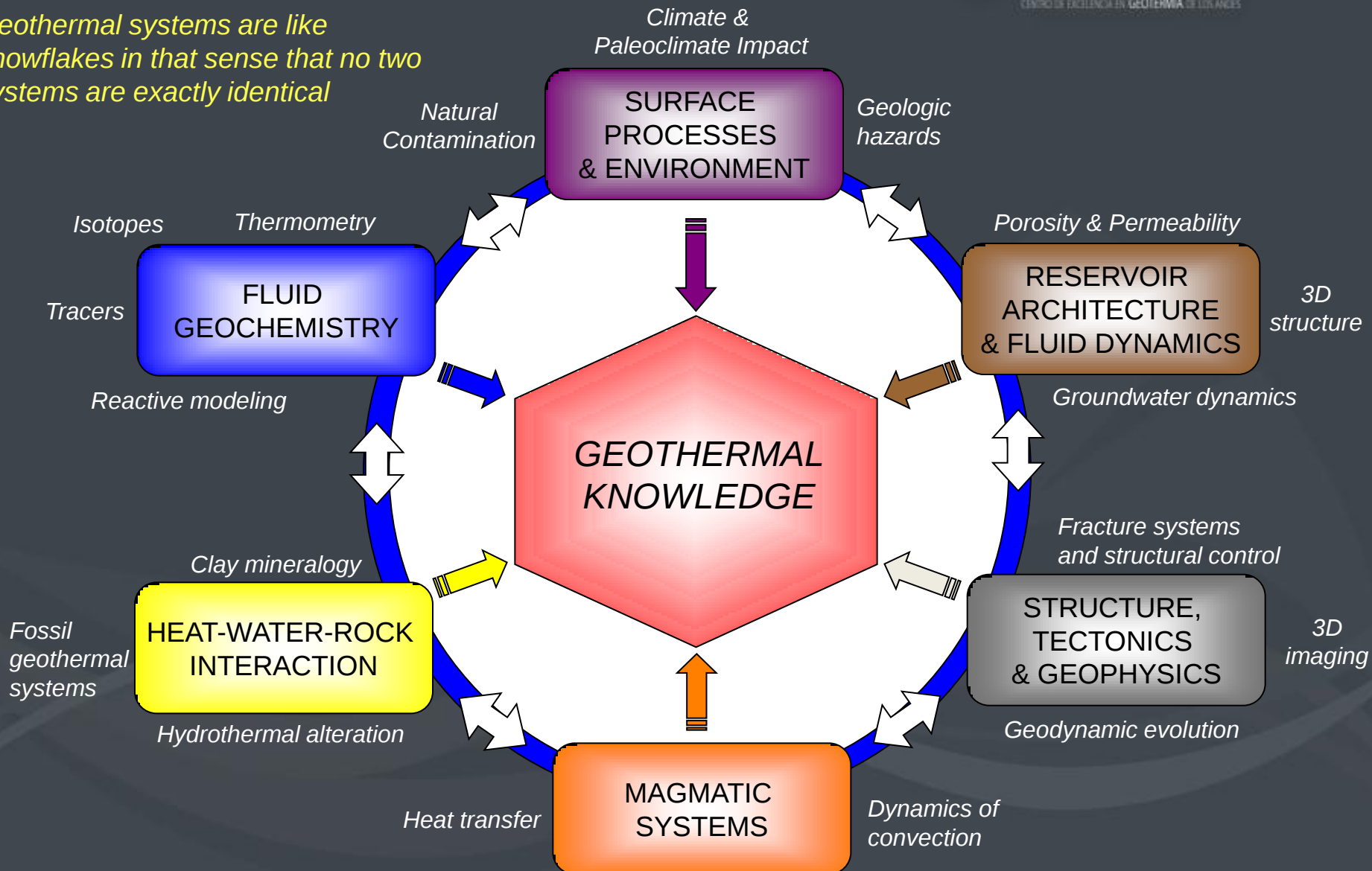
CEGA's Main Goals



- Generate and communicate scientific knowledge
- Form highly trained scientists and technicians
- Establish a state-of-the art, multi-user analytical facility
- Promote collaborative research with other academic institutions and the private sector
- Develop new and emerging methodologies for improving geothermal assessment and exploration
- Increase public awareness and promote geothermal resources as a renewable, clean alternative energy

Research lines

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



CEGA's analytical facilities

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

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



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

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



Conclusions

- Chile:

- geothermal country
- need to explore medium and low-enthalphy systems
- need one state as a principal actor in the geothermal development
- need to enhance the international cooperation in R & D
- good opportunities electricity independence
- “pilot country” in South America



First geothermal
power plant!!



www.cega.ing.uchile.cl



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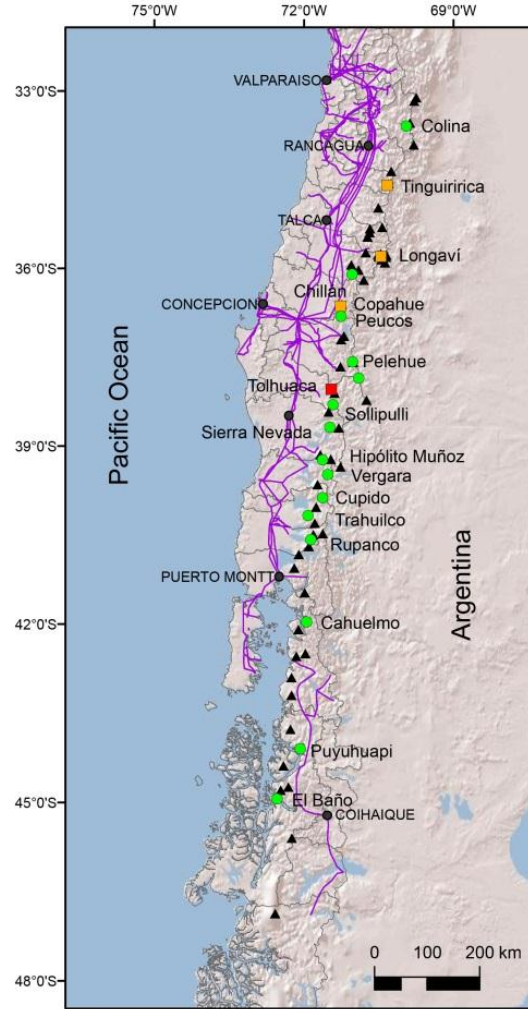
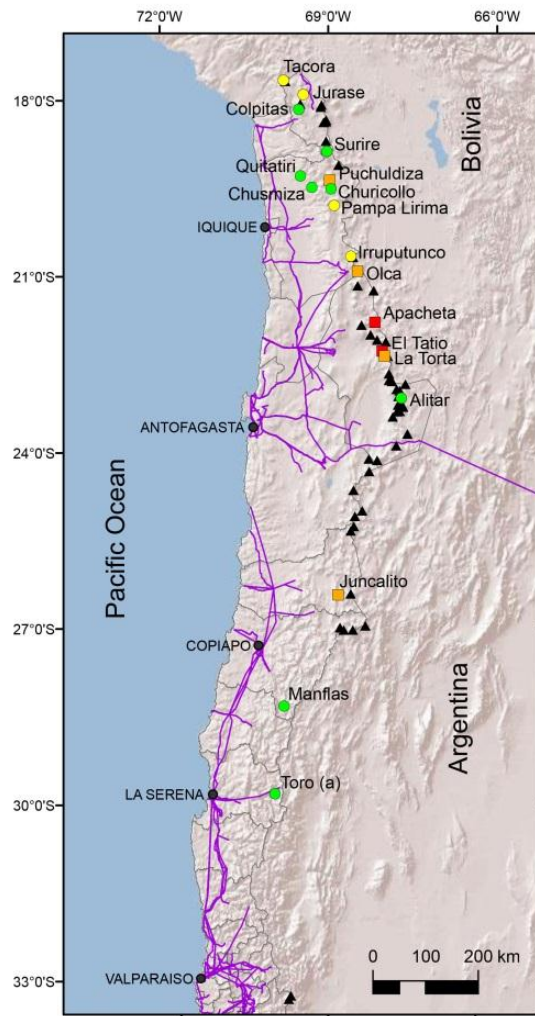
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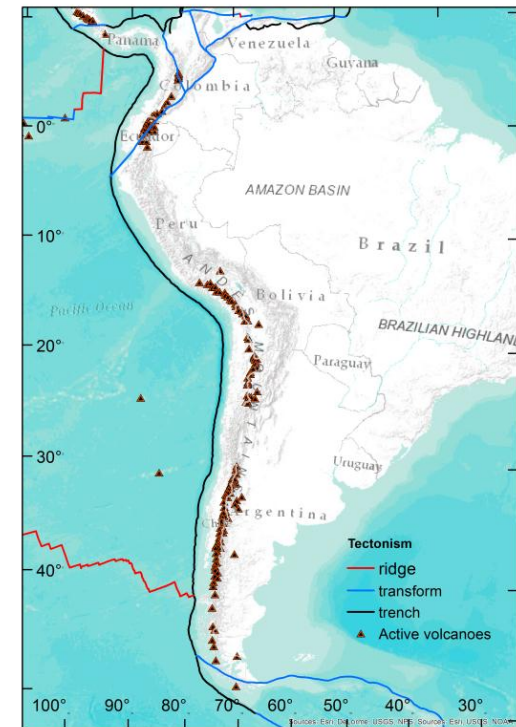
Gobierno de Chile

Chile



- Legend**
- Geothermal resources**
- Indicated
 - Inferred
 - Highly probable resource
 - Area of interest
- Geographic information**
- ▲ Active volcano
 - Regional capital
 - Electric transmission line

**Close relationship
high-T geothermal
areas with active
volcanism**



Abundant high-T geothermal resources