South America Region: Geothermal Progress

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Development of Geothermics

Economy

Legal regulation

Geothermal resources

Human resources

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from here….

Ahuachapán (El Salvador)
Outline of this talk

• Overview of South America geological and geothermal context

• Overall South America potential

• Specific projects in South America (after IRENA – NZ Geothermal Institute – CEGA May 2014 Seminar)

• Potential projects and the future

• Geothermal Research in South America: CEGA
The Andes: the largest active orogenic system developed by subduction of oceanic crust beneath a continental margin.

Developed along more than 8000 km of the Pacific margin of South America, from the Caribbean Sea in the north to the northern Scotia Ridge east of Tierra del Fuego Island in the south.

Complex segmentation history, where tectonism, magmatism and sedimentation processes changed through time and space.

The present day subduction of the oceanic Nazca and Antarctic Plates under South America Plate controls tectonism and magmatism of the Andean Margin.

Active volcanism is segmented into four main volcanic zones.

Ramos (2009)
South America geological setting

- 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.

Magmatism

Flat slabs through the Andes in Cenozoic times (from Ramos, 2009)
South America geothermal setting

- 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
- Mostly used for bathing and spa ($\approx 340$ MWt; Lund et al., 2011)
- Incipient low-T direct use in Chile ($\approx 9$ MWt)
- Geological, economical and social barriers

Heating flow in South America (from Hamza et al., 2005)
Colombia (after ISAGEN, Colombia)

T (°C) at 3 km depth

Geothermal Potential
2,210 MW
(Battocletti, 1999)

Source: SGC-UPME
Colombia

- Geothermal Projects in exploration stage

<table>
<thead>
<tr>
<th>Project</th>
<th>Location</th>
<th>Estimated Potential</th>
<th>Current stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal Project</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ruiz Volcanic Complex</td>
<td>Villamaría (Caldas), Herveo, Casabianca y Villahermosa (Tolima), Santa Rosa (Risaralda)</td>
<td>50 MW</td>
<td>Geosciences studies finished; environmental permission in progress</td>
</tr>
<tr>
<td>Geothermal Project Binacional Tufiño – Chiles – Cerro Negro</td>
<td>Cumbal (Nariño, Colombia) / Tulcán (Carchi, Ecuador)</td>
<td>138 MW</td>
<td>Ongoing geosciences studies</td>
</tr>
</tbody>
</table>
Ecuador (after INER, Ecuador)

Ecuador is located alongside more than 40 active volcanoes!

Geothermal exploration conducted by government institutions
Beate & Salgado (2012): power potential between 420 and 850 MW

Cotopaxi Volcano (5,897 m a.s.l.) viewed from Quito city.

The Geothermal Energy Association (GEA) estimated Ecuador’s geothermal potential at 1700 MWe in 1999.
Ecuador (after INER, Ecuador)

GEOTHERMAL PROJECTS

- Pre-feasibility studies (surface research)
- Ongoing Pre-feasibility studies
- Prefeasibility studies will begin soon
### Ecuador

- Currently, utilization of geothermal resources in Ecuador is restricted to bathing resorts, balneology and swimming pools.
- The total installed capacity of geothermal energy for direct heat applications in 2009 was 5 MWt (Beate & Salgado, 2005), with a slight increase over the last five years.

<table>
<thead>
<tr>
<th>Project</th>
<th>Stage</th>
<th>Potential</th>
<th>Observations</th>
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</thead>
<tbody>
<tr>
<td>Chacana Jamanco</td>
<td>Under environmental impact assessment</td>
<td>13 MW</td>
<td>Future two slim holes to 600 and 900 m depth</td>
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<tr>
<td>Chacaba Cachiyacu</td>
<td></td>
<td>39 MW</td>
<td></td>
</tr>
<tr>
<td>Chachimbiro</td>
<td>Under environmental impact assessment</td>
<td>81 MW</td>
<td>Future 1500 m depth drill?</td>
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<tr>
<td>Binacional Tufiño-Chiles-Cerro Negro</td>
<td>Exploration</td>
<td>138 MW</td>
<td>In progress</td>
</tr>
<tr>
<td>Chalpatán</td>
<td>Exploration concluded in 2013</td>
<td>Medium and Low enthalpy</td>
<td>Only surface geology</td>
</tr>
<tr>
<td>Chalupas</td>
<td>New prospect</td>
<td>238 MW</td>
<td></td>
</tr>
</tbody>
</table>
Peru (after Energy & Mines Minister)

- Highest T in the “Eje Volcánico Sur”
- Elaboration of an Strategic Plan (2009-2012) for development of Geothermics together JICA (Japan)

Fuentes termales de Calientes - Tacna
**Peru**

**Geothermal Areas and Power Stimulation**

- Five main geothermal areas
- Power potential estimation (following Strategic Plan) of **2860 MW**

*Source: Plan Maestro de Geotermia – Perú 2012*
Peru

**Exploration developed by private companies**
*(being EDC the most active)*

**Solicitudes de Empresas Geotérmicas**

Currently 463 expedientes (May 2014)

**Solicitudes (%)**

- MAGMA: 46.7%
- EDC: 13.6%
- GGE: 20.1%
- ECO ENERGY: 9.1%
- ENEL GREEN: 0.2%
- EMX GEOTHERMAL: 0.0%

*Source: Ministry of Mines and Energy, Peru*
Bolivia

- At present, electricity power supply supported by gas (70%) and Hydro (30%)

- By 2025, 70% Renewable and 30% gas

- More than 70 identified geothermal areas

- Geothermal exploration mostly focused at Salar de Empexa and Laguna Colorada

- In Laguna Colorada-Campo Sol de Mañana, four wells drilled suggest a power potential of 350 MW

- Supporting by a JICA/ Jetro West Jec feasibility study (2008) to develop a 50 MW power plant (2018, twp 25 MW units) increasing up to 100 MW (May 6th 2014, La Razón, Bolivia; Empresa Nacional de Electricidad, Bolivia)
Argentina

• High-T geothermal exploration in Tuzgle, Los despoblados (San Juna), Domuyo and Copahue

• Low-T explored for direct uses (307.47 MWt, Lund et al 2011)

• More advance studies in Copahue (ADI-NQN) and Los Despoblados (Geotermia Andina)

• Copahue: first Andean power plant (0.76 MW, abandoned by 1995), with an estimated potential of 100 MW

• Domuyo: currently used for district heating & spa
Chile

Abundant high-T geothermal resources

Close relationship high-T geothermal areas with active volcanism
Chilean Geothermal potential

“Aone of the largest undeveloped geothermal prospects of the world” (Lahsen et al. 2005)
Exploration concessions in Chile

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<tr>
<th></th>
<th>N</th>
<th></th>
<th>N</th>
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</thead>
<tbody>
<tr>
<td><strong>Active geothermal concessions</strong></td>
<td></td>
<td><strong>New geothermal concessions pending</strong></td>
<td></td>
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<tr>
<td>Exploration</td>
<td>75</td>
<td>Exploration</td>
<td>56</td>
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<tr>
<td>Exploitation</td>
<td>8</td>
<td>Exploitation</td>
<td>20</td>
</tr>
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</table>

Source: Ministry of Energy, Chile & ACHEGEO, May 2014
Power resources estimations (after Chilean Geothermal Council)

More advanced projects

● Slim holes

Potencial Proyectos Geotérmico en Chile

<table>
<thead>
<tr>
<th>PROYECTO</th>
<th>Mínimo</th>
<th>Máximo</th>
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<tbody>
<tr>
<td>TACORA</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>COLPITAS</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>POLLOQUE 1</td>
<td>70</td>
<td>140</td>
</tr>
<tr>
<td>POLLOQUE 2</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>LICANCURA III</td>
<td>70</td>
<td>140</td>
</tr>
<tr>
<td>PICHLUDEZA</td>
<td>30</td>
<td>100</td>
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<tr>
<td>PAMPA LIRIMA</td>
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<td>APACHETA</td>
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<tr>
<td>EL TATIO</td>
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<td>250</td>
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<td>SAN ALBERTO</td>
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<td>100</td>
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<td>TUYAJO</td>
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<td>170</td>
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<td>TINGUIRIRICA</td>
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<td>CALABOZO</td>
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<td>200</td>
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<tr>
<td>LAGUNA DELMAULE</td>
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<td>200</td>
</tr>
<tr>
<td>CHILIAN</td>
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<td>100</td>
</tr>
<tr>
<td>CALLAQUI</td>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>TOHUACA</td>
<td>40</td>
<td>150</td>
</tr>
</tbody>
</table>

Total (MW)

1000 2440

Potencial en Chile 3500 MW considering other projects under explored that could be developed in 20 years.
**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 $T \approx 260^\circ$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

Source: La Tercera, August 30th 2014
Potential projects & the future?

**Barriers:** natural + legal + economical

- Not priority for some countries (abundant hydropower or oil and gas)
- Role of the **STATE** but not in Chile!! Geothermal projects mostly developed by private companies.
- Limited technical and scientific capacities (but not in Chile!)
- High risk and high cost (some state assurances plan?)
- 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 in some countries
- Need a specific legislation for direct uses
- Indigenous communities

© Mighty River Power
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
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