



GEOTHERMAL RESOURCES COUNCIL

# Bulletin

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**REPRINT**

## **Focus on Chile:**

by Susan Fox Hodgson

# Focus on Chile, Part I

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*Focus on Chile, Part I*, is the first in a series of articles and photos about Chile and Chilean geothermal development. Parts II and III will be in the next two issues of the *GRC Bulletin*. The idea for the series began last September when I was at the *Chilean International Renewable Congress* in Santiago. There I saw first-hand how the Chileans are developing geothermal energy in their country—and how important geothermal is to their energy mix.

The *GRC Bulletin* often carries short articles on geothermal activities in Chile and I reread them before visiting Santiago. But the articles are just little pieces in a big and evolving picture. They fail to show how things fit together in the Chilean geothermal world—they leave a void. Thus, the idea came to create three collections of articles offering a more detailed look at Chile, its people, and Chilean geothermal development.

Today you are reading Part I, a general introduction to Chile and Chilean geothermal. It has basic geographical, sociological, and economic information and a detailed, up-to-date picture of Chilean geothermal development written by Fernando Allendes B., President of the *Chilean Association of Geothermal Energy, ACHEGEO* ([www.achegeo.cl](http://www.achegeo.cl)). He includes facts and figures, an historical timeline, legal updates, electrical transmission data, and ideas for overcoming barriers to development.

The Tolhuaca Project is successfully underway in southern Chile and the location of wells Tolhuaca No. 3 and 4, on the flanks of the Tolhuaca volcano, has to be one of the most beautiful sites in the world. The pictures from several photographers prove it. Two shorter pieces introduce a free online-geological magazine, *Andean Geology*, and upcoming Chilean geothermal meetings.

Parts II and III will offer details on Chilean geothermal issues and geology, including interviews with the Philippine Ambassador to Chile and the U.S. Ambassador to Chile; unpublished details on the beginnings of Chilean

geothermal development, *circa* 1908; and details on how the U.S. Embassy in Chile interacts with U.S. businesses. Embassies from other countries probably offer similar programs. A few geothermal businesses in Chile will be introduced. If your company wishes to be included, let me know.

Last but not least are geothermal education and public information matters, covered in Part III. Geothermal educational projects are underway, and the Chileans have created beautiful and informative videos, logos, drawings, and explanations of geothermal energy for the general public. In 2012, the *GRC Bulletin* included the first two comics published by Energía Andina. A third comic on geothermal drilling will be in Part III—along with notes on public information materials from other sources, including the *Centro de Excelencia de Geotermia de los Andes* (Center of Geothermal Excellence in the Andes), associated with the Universidad de Chile.

Welcome to the southwestern edge of Latin America and the Chilean geothermal world.



Vicuñas in  
northern Chile.  
PHOTO COURTESY OF  
ENERGÍA ANDINA.

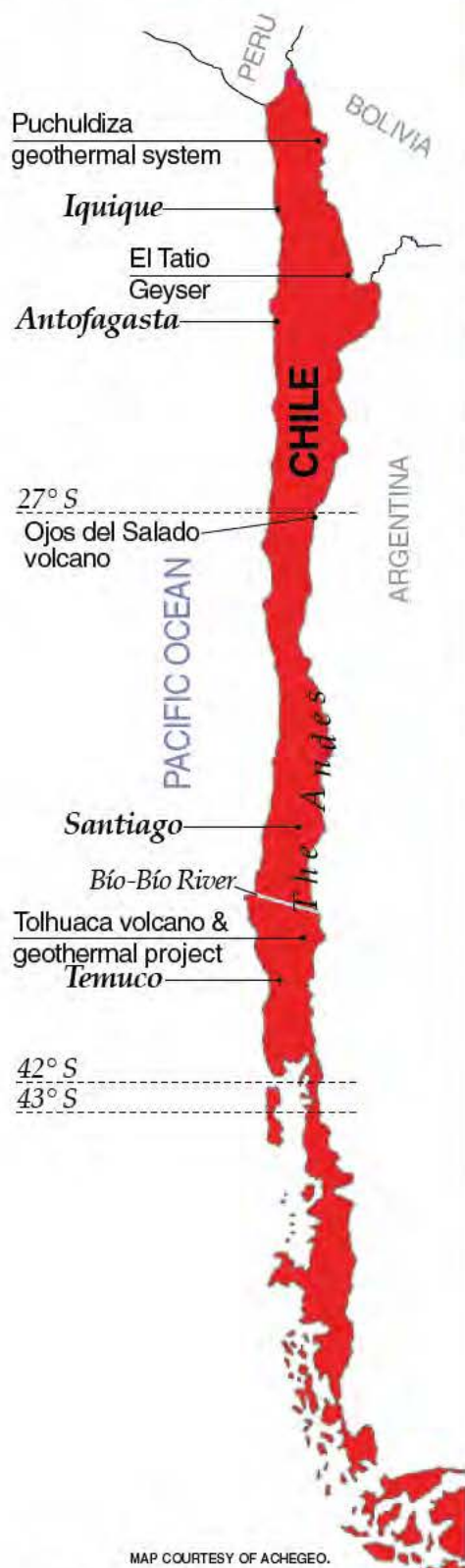
## Andean Geology

*Andean Geology*, a magazine once called *Revista Geológica de Chile*, was founded in 1974. The electronic version started in 1998 and the journal has been indexed by WOS (Web of Science) since 1993. Original and review articles are published in Spanish or English.

Major topics include the geology of South and Central America and Antarctica—particularly the Andes. The journal is published by the Chilean Servicio Nacional de Geología y Minería, with scientific collaboration by the Geological Society of Chile. The on-line journal is available free of charge and further information is at: [www.andangeology.cl](http://www.andangeology.cl).



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## Chile at a Glance

From east to west, Chile's three major physiographic features are the *Andes Mountains* ("Cordillera de los Andes"), the *intermediate depression* ("Depresión Central"), and the *coastal ranges* ("Cordillera de la Costa"). These parallel regions run almost perfectly north-south throughout the country—although not always the whole distance.

Twenty-two mountains in the Chilean Andes stand between 20,039 and 22,615 feet high. Ojos del Salado—the country's highest peak and the world's tallest, active volcano—rises to 22,615 feet.

From north to south, the *Andes Mountains* themselves can be divided into three sections, all very mountainous. These are the wide, arid plateau, known as the "altiplano," stretching from the Bolivian and northwestern Argentine borders to latitude 27° S; the narrower central Andean highlands extending southward to 42° S; and the southern Andes with many lakes and fjords.

Quaternary volcanism in Chile is restricted to the Andes Mountains (with the exception of Easter Island). In northern Chile, volcanic activity was intense during the Quaternary, and about 10 volcanoes have erupted in historical times—within the last 500 years. Many others show occasional-to-permanent hydrothermal activity. In central and southern Chile, at least 50 volcanic centers are still active, with frequent eruptions in historical times—many with permanent solfataric and/or fumarolic activities.

The *intermediate depression* begins just north of Santiago, at a place about 500 miles south of the Atacama Desert—one of the driest in the world. The *intermediate depression* continues south until submerging beneath the Corcovado Gulf near latitude 43° S—here the *coastal ranges* submerge, as well.

Chilean rivers are relatively short, flowing west out of the Andes and moving to the Pacific Ocean across the *intermediate depression* and the *coastal ranges*. The Bío-Bío River in south-central Chile is among the most important.

**Population:** 17,067,369; urban: 89.2%

**Pacific coast:** 2,650 miles

**Country width:** 100 – 250 miles, averaging about 110 miles

**Total area:** 291,933 sq. miles; land: 287,187 sq. miles

**Capital:** Santiago, 6,034,480 people

**Government:** republic, with a Senate and a Chamber of Deputies

**Head of State:** President Miguel Juan Sebastián Piñera Echeñique

**Local divisions:** 15 regions

**Budget:** \$51.8 billion

**GDP:** \$303.5 billion; GDP growth: 5.9%

**Electricity production:** 59.8 billion kWh (2010)

**Crude oil reserves:** 150 million bbl

**Chief crops:** grapes, apples, pears, onions, wheat, corn, oats, peaches, garlic

**Chief industries:** copper (largest world reserves); lithium (second largest world reserves, after Bolivia); other minerals, including molybdenum (perhaps 1/5th of the world reserves); food stuffs, iron, steel, wood and wood products

**Education:** compulsory—6 to 17 years old; literacy: 98.6%

**Sources:** Information is from *The New Encyclopædia Britannica 2005*, Vol. 3, published by Encyclopædia Britannica; *The World Almanac and Book of Facts 2013*, published by World Almanac Books; List of Mountains in Chile, Wikipedia; "Present Status of Geothermal Exploration in Chile" by Lahsen *et al.*, World Geothermal Congress 2005; and Dr. Jorge Clavero Ribes, Energía Andina, who kindly reviewed the essay.

**Note:** Facts and figures found in these and other references often differ.

# Creating a Chilean Geothermal Industry

by Fernando Allendes B., President  
Chilean Association of Geothermal Energy

*From a presentation at the Chilean International  
Renewable Congress, September 2012*

## Background

It is amazing. Over 15 percent of the world's active and dormant volcanoes are in Chile, forming an almost continuous line about 4,000 km long. As a result, over 300 geothermal areas have been identified throughout the country. The geothermal-resource potential of Chile may reach 16,000 MWe, according to preliminary estimates. Specifically by the year 2030, the geothermal-developmental potential of Chile is 2,100 MWe under a "conservative scenario" and 3,105 MWe under an "optimistic scenario," both in the context of "business as usual," according to estimates by the Comisión Asesora del Desarrollo Eléctrico, known as CADE, the Chilean advisory commission created by President Sebastián Piñera in 2011.

## History

**1908** An organization founded in the northern city of Antofagasta was first to take an interest in Chile's geothermal potential. The first exploration occurred at El Tatio, in northern Chile.

**1931** Two wells were drilled at El Tatio.

**1968** Additional surface explorations were more systematically undertaken in northern Chile at El Tatio, Puchuldiza, Pampa Lirima, and Surire. The projects were funded by the Chilean Corporación de Fomento de la Producción (Corporation in Support of Production)—known as CORFO, the United Nations, the countries of Italy and New Zealand, and the Japan International Cooperation Agency.

**1975** Feasibility studies identified El Tatio as the best prospect for development.

**1978** An international bid was proffered to develop the El Tatio site. No final decision was made for political reasons.

**1982** The Chilean Governmental Geothermal Committee was discontinued.

**1987-1989** Endesa Chile, the largest electric utility in Chile, was privatized. Endesa was created in 1943 as a subsidiary of the state-owned CORFO.

**1990** All geothermal information was transferred from CORFO to the Servicio Nacional de Geología y Minería (National Geology and Mining Service)—known as *SERNAGEOMIN*.

**2000** Law N° 19.657 concerning *Geothermal Energy Concessions* was enacted. The Ministerio de Minería (Ministry of Mining) now is responsible for managing the law and granting concessions.

**2000** Act N° 142 defined "120 probable-geothermal sources" throughout Chile.

**2004** Rules were published for the application of Law N° 19.657.

**2008** Law N° 20.257 was enacted—requiring a 10% quota from renewable, non-conventional sources of electrical generation.

**2009 January** A suggested law to modify Law N° 19.657 was submitted to the Chilean Parliament.

**2010** A new Ministerio de Energía (Ministry of Energy) was created. The responsibility of managing Law N° 19.657 was transferred to the Ministry of Energy from the Ministry of Mining.

**2010 September** A suggested law to modify Law N° 19.657 was submitted to the Chilean Parliament.

**2010** The *Centro de Excelencia de Geotermia de los Andes* (Center of Geothermal Excellence in the Andes) was created to contribute to the development of scientific knowledge. It was funded by a governmental grant awarded to the Geology Department at the Universidad de Chile.

**2012** The Ministry of Energy began reviewing the rules for Law N° 19.657 in order to improve them.

## Administrative Concessions

All Chilean geothermal resources are owned by the state. However through administrative concessions created under Law N° 19.657, Chile can grant to the private sector the right to explore and exploit geothermal resources. (Note: The Chilean process differs from countries playing a more entrepreneurial role, taking risks while developing geothermal sites.) Administrative concessions can be obtained by a *Direct Request* from a petitioner and/or by *Public Tenders* from the Ministry of Energy.

Any Chilean person or company constituted in compliance Chilean laws can apply for a geothermal administrative concession. To request an exploration or exploitation concession, an applicant must submit personal identification; a description of the requested area; and the general, technical, and economic background of the exploration or exploitation project, stating the



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projected investments needed for the execution.

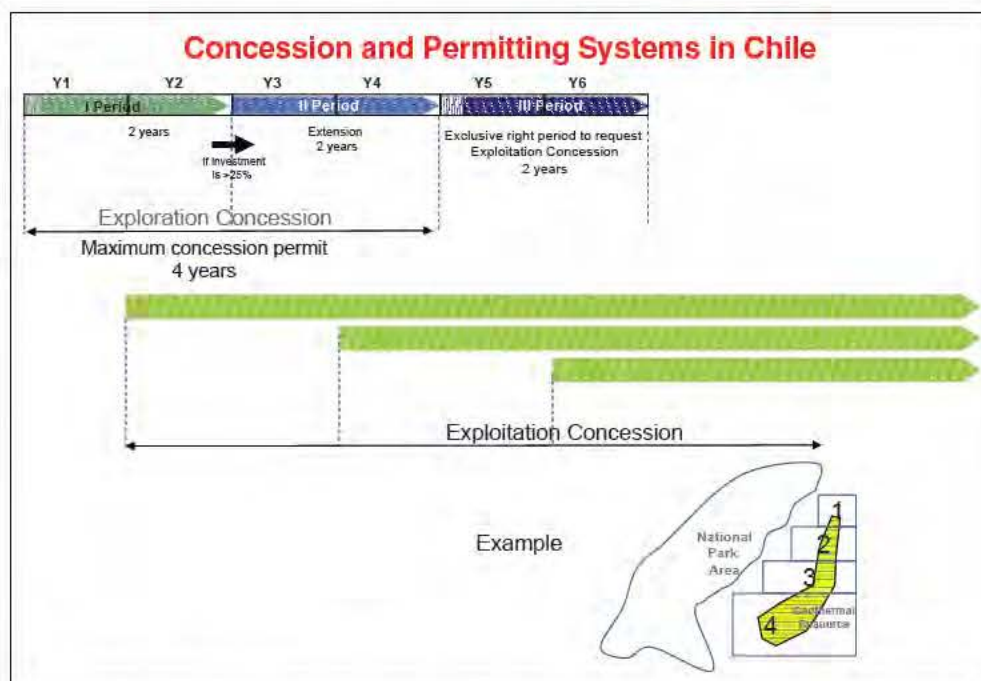
If applications overlap in a 45-day period, or overlap with one of the already defined 120 probable-geothermal sources, the application will be denied and the Ministry of Energy must call for a public bid in the near future to grant the concession. In the bidding process, the applicant, if a person, must demonstrate a minimum capital of about \$240,000 (US); if a company, about \$480,000 (US). Administrative concessions are properties and can be transferred totally or in part.

Exploration concessions are for two years with the possibility of extension for two more years if the concessioner demonstrates he or she has invested more than 25% of the committed investment amount. The investments must be made in the activities originally agreed upon. The shape of the area will be a parallelogram oriented north to south. The maximum area is up to 100,000 hectares, about 247,000 acres.

Exploitation concessions can be requested during the exploration concession phase or for up to two years after the exploration concession has expired. The duration is undefined. The shape is also a parallelogram oriented north to south, with a maximum area of 20,000 hectares, about 49,420 acres. The concessioner must pay a yearly fee (royalty) of 0.1 UTM (monthly tax unit) per hectare per year, about \$8.50 (US)—or per acre per year about \$3.50 (US).

## Electricity Regulation and Pricing

The electrical market is a “pool” and its operation is based on the minimum cost of generation. Generators sell in three markets: regulated, free, and spot. Regulated customers are those who buy from utility companies (distributors) and are clients with an installed capacity below 500 kW; between 500 kW and 2 MWe, regulation is optional. The utility companies



serving these customers must call for public tenders to fix the price and contract the energy with the generators. For free clients, there is no price regulation. They freely negotiate the tariff with the generators.

The *Energy Price* and the *Power Price* are calculated in each of the electric substations transmitting electricity. The prices are calculated every six months, in April and October. The *Energy Price* considers the demand projection for the next 10 years; the newly planned power projects by industry; and the expected *Marginal Cost*. The *Power Price* is estimated based on the capital cost of the last power unit, *i.e.* the unit which is the least expensive to build and the most expensive to operate. The *Node Price* combines the *Energy Price* and the *Power Price*.

The spot market is restricted to generators and managed by the CDEC, “Centros de Despacho Económico de Carga” (Chilean Load and Economic Delivery Centers for the Interconnected Systems). The *Energy Price* is calculated from the marginal costs of operation of the last unit in operation and the *Power Price* is sold at the *Node Power Price*.

## Law N° 20.257

Law N° 20.257, passed in 2008 and in effect in 2011, concerns the quotas for power generation based on non-conventional renewable energy. It is the only incentive for renewable-energy producers. To honor contracts signed after August 31, 2007, power generators, in their role as marketers, must demonstrate that 10% of the electricity withdrawn

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from the interconnected systems is produced from renewable sources like geothermal, small hydro (up to 20 MWe), wind, biomass, or solar. This only applies to power generators able to produce over 200 MWe. The 5% quota begun in 2012 extends until 2014—when it increases by 0.5% every year until a 10% quota is reached in 2024. If a power generator does not comply with this regulation, a fine of about \$32 (US) per MWh must be paid.

A suggested law has been submitted to the Chilean Parliament modifying Law N° 20.257 by raising the quota to 20% by the year 2020.

## Ideas to Accelerate Development

To accelerate Chilean geothermal development, natural barriers must be overcome and the regulatory framework modernized. The natural barriers include altitude, climate, vital infrastructure, water scarcity, and the distances from urban centers. Many times, the sums invested in exploration and in testing the resource are very high and the rewards are lower compared with other industries, especially when compared with the Chilean mining industry. The risk a developer assumes in exploring and testing the resource is the highest in the Chilean energy market. In Chile there is a scarcity of experienced professionals and qualified, specialized service industries. The local financial market is not well developed to help this type of project.

To overcome the natural barriers, we need to promote the favorable characteristics of Chile and the extensive opportunities it offers to the private sector to develop geothermal energy. We should promote alliances, like *joint ventures*, with experienced developers and provide incentives to encourage the arrival of qualified, experienced professionals and service businesses—and help develop Chilean professionals. At the same time, we need to stimulate the financial market with profitable projects and work with investors who are seeking this type of project because of business or ideological reasons.

We also need to overcome Chilean regulatory barriers. The fixed, 24 month duration, by law, for an exploration concession and the mechanism for

### Applications for Exploration Concessions in Process

#### Exploration Concessions in Process 79

Serviland Minergy S.A.	25
Energía Andina S.A.	10
Minera Escondida Ltda.	10
Hot Rock Chile Ltda.	8
Energy Development (EDC) Corp. Chile Ltda.	7
GGE Chile SpA.	7
Empresa Nacional de Geotermia S.A.	5
Transmark Chile SpA.	2
Colbún S.A.	2
Enel Latin América (Chile) Ltda.	1
Magma Energy Chile Ltda.	1
Marcelo Araya Núñez	1

### Status of Chilean Administrative Concessions

#### Exploration Concessions Granted and Currently in Force 69

#### Active Companies in Exploration 18

Energía Andina S.A.	16
Hot Rock Chile S.A.	12
Infinergeo SpA.	5
Ormat Andina Energía Ltda.	5
Empresa Nacional de Geotermia	4
GGE Chile SpA.	3
Minera D. Inés de Collahuasi	3
Enel Latin América (Chile) Ltda.	3
Origin Energy Chile S.A.	3
Energy Development (EDC) Corporation Chile Ltda.	3
Minera Zadiívar Ltda.	3
Colbún S.A.	2
Magma Energy Chile Ltda.	2
Minera Escondida Ltda.	1
Orandina SpA.	1
Polaris Geothermal	1
Compañía Energía Ltda.	1
Transmark Chile SpA.	1

### Exploitation Concessions in Force

#### Exploitation Concessions in Force 6

Geotérmica del Norte S.A.	Apacheta
Geotérmica del Norte S.A.	La Torta
Geotérmica del Norte S.A.	El Tatío
GGE Chile SpA.	San Gregorio ( <i>Tolhuaca Project</i> )
Compañía de Energía Ltda.	Laguna del Maule
Samuel Santa Cruz	Rollizos
<b>Application in Process for Exploitation Concessions 1</b>	
Geotérmica del Norte S.A.	Chillán

obtaining an extension—six months before its expiration and 25% of the promised investment—are not consistent with the nature of geothermal exploration activities. There are conditions of



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climate and forces of nature that change the normal development of exploration activities in ways not taken into consideration by the laws or regulations. The uncertainty of obtaining an exploitation concession lessens the incentive to drill deep wells in the exploratory phase, slowing the projects down.

How can we modernize the regulatory framework to encourage geothermal development? We should modify the regulations that govern the application of the Law N° 19.657 to lessen the administrative bureaucracy involved in the management of this industry and activate a parliamentary discussion on the improvement of the law itself. We should approve the suggested law now in parliament, changing Law N° 20.257 to incrementally raise the established *Renewable and Non-Conventional Energy Law* (ERNC) quota from 10% in the year 2024 to 20% in the year 2020. Also, mechanisms are needed to facilitate access to transmission lines, such as a better law for electrical concessions and a new law for the public electrical grid. Both initiatives are now under discussion in the Chilean Parliament. We also want to create mechanisms for purchasing commercial energy produced under ERNC at established prices, like blocks of energy, thus allowing geothermal developers to receive financing.

The Ministry of Energy needs to accelerate the delivery of exploratory concessions by direct request. We propose revising the *Administrative Requirements* prescribed for granting the extension of exploratory concessions, as well as the ones requested for granting exploitation concessions. This would provide important incentives to the geothermal industry. Financial tools need to be put in place to encourage drilling and proving geothermal resources. We should look for financial opportunities for geothermal exploration companies, offering incentives to investors.

The future of geothermal energy for electrical generation and direct use is very promising in Chile. We not only have extremely positive geological conditions, but also a very favorable geographical shape. The fact that Chile is a long and thin country, with a volcanic chain stretching from north to south, makes it possible to connect geothermal projects into the main electrical grid with

short transmission lines.

Fortunately, our previous and current governments are increasingly aware of Chile's huge geothermal potential and they are moving, even though I think they could go faster, in the right direction. The Chilean geothermal association, ACHEGEO, collaborates actively with the authorities and the Chilean people to get this done as quickly as possible.

In fact, ACHEGEO is organizing the *II International Congress on Geothermal Energy* on the 11th and 12th of April, this year, in Santiago. It will be a great opportunity to show the entire country and world the valuable contributions geothermal energy can offer Chile. There is a world of opportunities in Chile and there is no time to waste.

### Upcoming Meetings for 2013

#### **II Congreso Internacional de Geotermia, ACHEGEO 2013**

**11-12 April, Santiago, Chile**

[www.achegeo.cl/congreso2013/](http://www.achegeo.cl/congreso2013/)

facebook: [www.facebook.com/pages/](https://www.facebook.com/pages/Achegeo-AG/291517770953560)

Achegeo-AG/291517770953560

twitter: <https://twitter.com/achegeoag>

"I want to invite everyone to the congress," said Fernando Allendes B., ACHEGEO President. "At its core, the congress is a time for sharing geothermal knowledge—with each other and leading international players in the field. The congress is a major geothermal energy event in our country and we count on your participation. I hope to see you this April in Santiago."

#### **The Chilean International Renewable Energy Congress**

**3-4 September, Santiago, Chile**

[www.greenpowerconferences.com](http://www.greenpowerconferences.com)

Last year's Green Power Chilean conference in Santiago included excellent pre-conference activities. Among them were the fact-filled overviews of upcoming presentations—interviews with several key presenters were posted on the Green Power website—and a webinar with experts discussing renewable-energy developments in Chile.

#### **Geothermal Resources Council, 37th Annual Meeting & GEA Trade Show**

**29 September to 2 October, MGM Grand Hotel, Las Vegas, Nevada**

[www.geothermal.org/meet-new-html](http://www.geothermal.org/meet-new-html)

The GRC Annual Meeting and GEA Trade Show will feature international geothermal presentations, posters, discussions, and field trips. There will be time to connect with Chilean geothermal developers and learn more about their projects.



# Successful Wells at Tolhuaca

The successful completion of a geothermal exploratory drilling program on the northwestern flank of the Tolhuaca volcano in southern Chile was announced on August 27 by GeoGlobal Energy Chile SpA. (GGE Chile), a wholly-owned affiliate of GeoGlobal Energy LLC. A long-term flow test lasting more than 45 days at the Tolhuaca Project (also called the Curacautín Project) demonstrated the production and injection wells are able to support commercial power production, company officials said. GGE Chile has been exploring at Tolhuaca for over three years and continues project development at the site, including designing, permitting, and constructing power plants and transmission lines—with the goal of producing power as soon as 2015.

“Completion of the wells is an historic development for Chile,” said Rüdiger Trenkle, GGE Chile General Manager. “Large hydro projects are being suspended in Chile and coal projects are being delayed for environmental reasons. Geothermal energy by contrast is a clean, base load, domestic fuel source that can play a critical role in helping meet the country’s power needs.”

GGE Chile acquired access to the Tolhuaca site in January 2009 and drilled a successful exploration well in March 2009. Development of Chilean geothermal-energy reserves is a stated priority of the government. “The discovery of a proven commercial field is a game-changer for geothermal in Chile,” said Gregory Raasch, Executive Vice President and co-founder of GGE, who has spent his career leading geothermal exploration and development programs worldwide. “The project demonstrates that geothermal energy can be a significant part of the Chilean electrical system and provide clean, reliable electrical power.”

The production well Tolhuaca No. 4, pictured on the cover, was drilled to a depth of 2,303 m and produces high-temperature steam able to generate at least 13 MWe of electrical energy. The injection well, Tolhuaca No. 3, is drilled to a total depth of 2,475 m and can safely accept all of the geothermal fluids from the power operations with the highest level of environmental protection.

At the GRC 2012 Annual Meeting in Reno, Mr. Raasch said, “With five concessions, GGE Chile

was the first private geothermal-development company in Chile, applying for its first geothermal concessions in 2003. GGE Chile is working at Pulchidiza and at Alitar in Northern Chile, and in central Chile at Colimapu, Tolhuaca, and three concessions around Ranquil.

“At Tolhuaca, our primary development, we have drilled two slim holes to over 1,000 m and two production-sized wells to depths greater than 2,000 m. In well Tolhuaca No. 4, we discovered a high-temperature, high-pressure, low-gas steam reservoir. The well was extensively flow tested over a period of 38 days and is capable of producing at least 13 MWe. We expect to have the first commercial power plant in Chile on line in 2015.

“Puchuldiza, another of our projects—one with an elevation of 4,300 m, brings its own challenges. Through slim-hole drilling, we have verified a commercial resource.” (Note: At Puchuldiza, according to the GGE website, the company has acquired a 15,000-acre concession it believes to be at least similar in size and quality to the Tolhuaca resource.)

“Now, a little about the Chilean market,” Mr. Raasch continued. “The electricity law allows a developer to sell power under a long-term *Power Purchase Agreement*, to sell directly to a large-end user, or to sell into the spot market where prices are adjusted every 15 minutes based on marginal costs.

“The Chilean electric regulators have established a *Renewable Portfolio Standard* that started at 5% in 2010 and increases by ½% per year

(story continued on page 33)



The road up to the well site passes by private farms, called *fundos*. The man astride the horse is a *huaso* from a nearby fundo. Chilean huasos tend cattle and are skilled horsemen, like Argentine *gauchos*. Note the huaso's typical straw hat, called a *chupalla*, and the machete hanging by his side. PHOTO BY FERNANDO ECHAVARRIA, U.S. DEPARTMENT OF STATE AND TOLHUACA PROJECT VISITOR.





GeoGlobal Energy Chile SpA. is developing the Tolhuaca geothermal electrical-generation project in the Andes of southern Chile. The Tolhuaca No. 3 well pad and the field camp are at an elevation of 2,184 m on the northwestern flanks of the Tolhuaca volcano. The drilling rig in the photo is placed over well Tolhuaca No. 3, an injection well drilled directionally to a measured depth of 2,475 m.

Recent tests of well Tolhuaca No. 3 have confirmed the well is capable of commercial production, although it may be used initially for injection at a first-phase, 13 MWe power plant planned for 2015. The plant will be powered with steam from well Tolhuaca No. 4, the most productive geothermal well ever drilled in South America. The photo was taken from the Tolhuaca summit in mid-summer, on January 10, 2012. PHOTO BY JIM STIMAC, GEOGLOBAL ENERGY LLC.



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*Photo at right:* A view of an *Araucaria araucana* forest on the way to the well site. Often called a monkey puzzle or monkey tail tree, the *Araucaria araucana* is an evergreen growing up to 130 feet tall with a trunk 7 feet in diameter. The tree is native to central and southern Chile and western Argentina. The flat area on the left flank of the Tolhuaca volcano in the distance is a glacier moving down from the crater.

In good weather seven volcanoes can be viewed from the Tolhuaca well site. They are Llaima, Villarrica, and Lanin to the south; Lonquimay to the east; and Callaqui, Copahue, and Antuco to the north.

PHOTO BY RÖDGER TRENKLE, GGE CHILE.



*Photo below:* This hairpin turn on the way to the well site was the most difficult part of the road to build. It passes by two glacial moraines and had to be sited below and away from the glacier itself. PHOTO COURTESY OF GGE CHILE.



*Photo above:* Looking down at the camp with the well pad in the distance. PHOTO COURTESY OF GGE CHILE.



*Photo at left:* Helicopter view of the Tolhuaca No. 4 well site, the camp in the distance, and the Tolhuaca crater with the glacier in the background. PHOTO BY ARTURO ROCCO, GGE CHILE CONSTRUCTION MANAGER.





Well Tolhuaca No. 3 at sunset. PHOTO BY JIM STIMAC, GEOGLOBAL ENERGY LLC.



Protective housing surrounds a geothermal well head. PHOTO BY F. ECHAVARRIA.



Jorge Bunster Betteley, the Chilean Energy Minister visiting the Tolhuaca Project, is third from the left and speaking to the man in front of him. The gentleman in the red jacket turning toward the Energy Minister is the Governor of the 9th Chilean Region, Andrés Molina. Standing between them in the blue jacket is Rüdiger Trenkle, General Manager of GGE Chile, SpA. PHOTO COURTESY OF GGE CHILE.



Dr. Echavarria stands on a glacial moraine near the well pad. He calls the Andes a dramatic site for a geothermal project and a challenging environment for geothermal development.



The GGE Chile geosciences group and the local construction team for the Tolhuaca Project pose against the Andean skyline. Anna Colvin is on the left and Jim Stimac fourth from the left. Some of their Tolhuaca photos are in this issue. PHOTO BY R. TRENKLE, GGE CHILE.

to 10% in 2020. Failure to meet the required standard results in a 30% price penalty on any renewable-generation shortfall."

Mr. Trenkle told the host of the Chilean television program, *Agenda Económica*, GGE Chile is deciding whether to build a 70 MWe power plant now or build a smaller power plant powered by steam from well Tolhuaca No. 4. If the latter decision is made, the 13 MWe power plant, Tolhuaca Unit 1, should be operating by 2015. If a 70 MWe power plant is built instead, it will be ready for operation in 5 to 6 years. ■

# Focus on Chile, Part II

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*Focus on Chile, Part II*, begins with Chilean geologic and geothermal developmental history—including a five-star, direct-use spa and resort in the southern Andes. Next Carlos Barría Quezada, Chief of the Division of Renewable Energy for the Ministry of Energy, gives an overview of Chilean energy agencies. The Philippine and U.S. Ambassadors to Chile offer their personal perspectives on Chilean geothermal development. Company and project articles include Enel Green Power in the northern Andes and the Tolhuaca Project in the southern Andes. The section ends with recent publications, including the papers published on Chilean geothermal development in 2012 and 2013. Two upcoming meetings are noted, as well.

## Geothermal Projects & Geology in Chile<sup>1</sup>

### Geothermal Projects

“Chilean geothermal development began in 1908,” said Professor Alfredo Lahsen Azar of the University of Chile. “That year an Italian community living in the northern city of Antofagasta heard about a geothermal power plant operating in Tuscany, Italy. Since 1904 the plant had generated electricity at Larderello Geothermal Field. Impressed, the Antofagasta community formed the *Preliminary Community of El Tatio* to explore El Tatio geyser field, hoping to build a similar power plant.”

El Tatio—often called El Tatio Geothermal Field—is located in the Andean foothills northeast of Antofagasta about 4,200 m above mean sea level. Thermal manifestations scattered around a 35 km<sup>2</sup> area include boiling hot springs, mud ponds, steaming ground, some fumaroles—and most famously, about 80 active geysers. Not only is El Tatio the largest geyser field in the Southern Hemisphere, it is the third largest in the world with

about 8 percent of the world’s geysers (Glennon and Pfaff, 2003).

At El Tatio, the *Preliminary Community of El Tatio* undertook Chile’s first geothermal exploratory program. In 1921 and 1922, an Italian technical group from Larderello came and drilled two wells around 70 to 80 m deep under the direction of a Mr. Tocchi (Tocchi, 1923). No power plant was ever built and when Mr. Tocchi returned to Italy, he took with him many of the geothermal records. Later during World War II, Mr. Tocchi returned the geothermal records to Chile, mailing them to Professor Lahsen, who has them still.

Chilean developmental history shifts now to the years of 1968 to 1976, when the Chilean *Corporación de Fomento de la Producción* (CORFO) and the United Nations sponsored further exploration in the northern Andes—reviving the country’s interest in geothermal. A geological and geochemical reconnaissance was made of many hot-spring areas, along with detailed geological, geophysical, and geochemical surveys at sites including Suriri, Puchuldiza, and El Tatio. At El Tatio and Puchuldiza, a number of exploratory wells were drilled and feasibility studies for power generation were undertaken. From 1976 until 2000, a few other studies were made, as well.

From 2000 through 2003, a four-year, major geothermal-research project was carried out by the University of Chile in association with the *Empresa Nacional del Petróleo* (ENAP) and collaborating institutions in Germany, Italy, and New Zealand. The aim was to learn the geothermal potential of central and southern Chile. Detailed geological, hydro-geological, geochemical, and to a lesser extent geophysical surveys were completed in two areas where inferred-fluid temperatures were estimated to be above 250 °C.

Additional geothermal exploration in southern Chile, in the Calabozos thermal area about 250 km southeast of Santiago, was conducted by ENAP, which found a liquid-dominated system with water and gas-geothermometry temperatures between 235 °C and 300 °C.

<sup>1</sup>Information in the essay on *Geothermal Projects* is from Lahsen *et al.* unless otherwise noted.



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At the same time, *Geotérmica del Norte (GDN)*, a joint venture between *ENAP* and the *National Copper Corporation (CODELCO)*, undertook additional geothermal exploration in northern Chile. The geochemical and geophysical surveys at El Tatio Geothermal Field confirmed most previous findings. Other geothermal-exploration surveys by *GDN* led to the identification of Apacheta, a new thermal prospect located 60 km NNW of El Tatio, with estimated reservoir temperatures of  $\geq 250^{\circ}\text{C}$ .

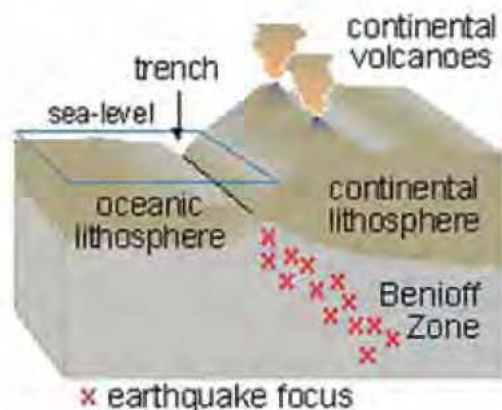
Here, the story of Chilean geothermal development moves to modern-day activities that really began in 2000 with the passage of Law N° 19.657, enacted to regulate *Geothermal Energy Concessions*. At first the Ministerio de Minería managed the concessions, but in 2010 the Ministerio de Energía was created and placed in charge.

## Geology

Geothermal development always depends on geology—and Chilean geology is tailor-made for geothermal electrical-generation and direct heating projects. Much of Chile's geological nature is summarized by the drawing of the Benioff zone—defined as the downward plane where oceanic plates slide beneath continental plates and where major subduction-related earthquakes occur. In fact this movement, or subduction, occurs along the entire Chilean coastline as an essentially continuous process along the Andes (Cembrano *et al.*, 2007).

The “trench” in the illustrations appears clearly as a dark-blue line on many *Google Earth* images beneath oceanic waters along the Chilean coast.

When the oceanic plates are very deep, as in the drawing, they generate



ILLUSTRATIONS COURTESY OF THE U.S. GEOLOGICAL SURVEY

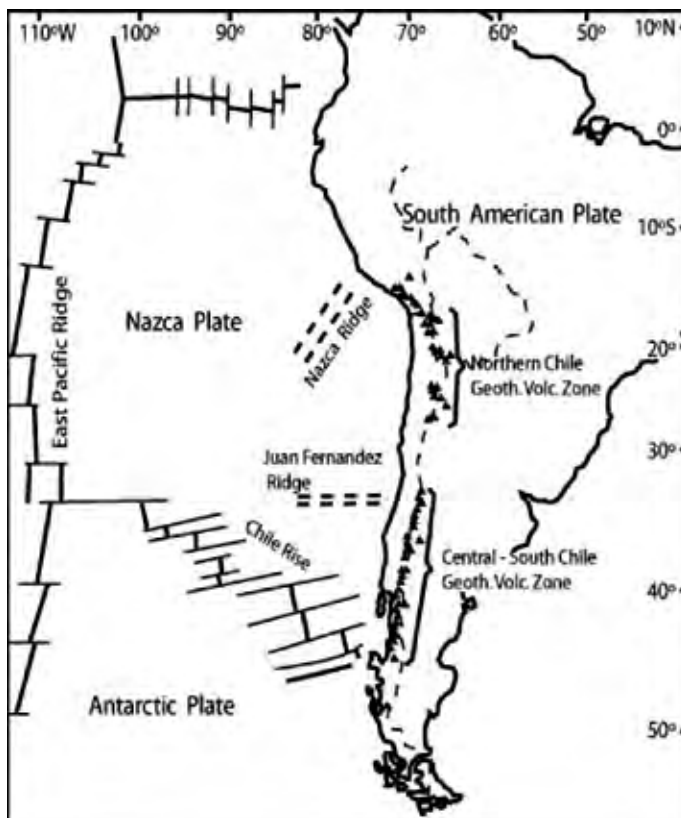


MAP COURTESY OF ACHGEO. INFORMATION BY THE GRC.



## Focus on Chile

a partial melting of the asthenosphere (the part of the upper mantle layer beneath the plates). The melted rock, called magma, can resurface and erupt, forming volcanoes. Quaternary volcanism in Chile is restricted to the Andes Mountains, with the exception of Easter Island. In northern Chile, volcanic activity has been intense during this period and about 10 volcanoes have erupted within the last 500 years. Many others show occasional-to-permanent hydrothermal activity. In central and southern Chile, at least 50 volcanic centers are still active, with frequent eruptions noted in historical times (Clavero, 2013).



The Antarctic, Nazca, and South American plates, plus the active volcanic geothermal zones in northern Chile and in central and southern Chile (Lahsen, *et al.*, 2005).

“In Chile, the Nazca and Antarctic Plates are subducted beneath the South American plate,” said Professor Lahsen. “This accounts for the seismicity, tectonism, and magmatism of the Andean margin.” Charles Darwin agreed and drew similar conclusions while visiting Chile

back in 1835. At that time, a quake, estimated at a magnitude of 8.5, struck Concepción while he was walking ashore about 200 miles to the south. The quake lasted about two minutes (he timed it) and the main shock destroyed much of Concepción in just six seconds. (This is the same area that was struck in February 2010 by an earthquake with a magnitude of 8.8.)

A few weeks later when Darwin was in Concepción walking around the devastated city, he found rocks lined with recent marine shells uplifted above the tide. Three volcanoes had erupted along the Chilean coast at about the same time as the earthquake. Darwin came to connect, correctly, the earthquakes, volcanoes, and vertical movements of the earth’s crust as part of the same great, unknown, subterranean phenomena. He wrote, “This large portion of the earth’s crust floats in a like manner on a sea of molten rock” —a manner he would come to believe true for “... the entire globe” (van Wyhe, 2010).

Besides electrical-generation projects, low-temperature geothermal projects are underway in Chile, as well. “More than 300 hot spring areas are located along the Chilean Andes, associated with Quaternary volcanism,” said Professor Lahsen. His 2005 study found three direct-heat uses: snow melting, bathing, and swimming (including balneology). The chart on the next page has information about 20 hot spring areas. The installed capacity of all the projects is 8.72 MWt; the annual energy use is 131.08 TJ/yr; and the capacity factor is 0.48.

Since 2005, more direct heat projects have been undertaken. An example is the geothermal space heating system installed between 2009 and 2011 at the five-star Termas Puyuehue Wellness & Spa Resort in the southern Andes. The project is a joint effort of several Chilean agencies and of private business. The civil engineer in charge of the project is Ricardo Bascuñán E., who offered these details.

From nearby thermal springs, waters 55 °C-to-60 °C pass to the hotel at a rate of 9 liters a second. About two liters a second of the waters are used for the hotel heating system and the rest fill thermal pools where the guests bathe. In about 50 percent of the hotel, a heat exchanger transfers heat to the hot water system and to air flowing through the ventilation system, supplying about 1.8 GWh per year. As a result, the fossil fuel needs of the hotel have dropped about 50 percent since 2011.



## Chilean Geothermal Bathing Projects (Including Balneology), Through 2004

Table data from Lahsen, *et al.*, 2005.

	Maximum Utilization			Capacity	Annual Utilization		
	Flow Rate	Temperature (°C)			Ave. Flow	Energy	Capacity
Locality	(kg/s)	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor
Mamiña	2.70	51	28	0.26	1.90	5.76	0.70
Pica	2.30	34	26	0.08	1.60	1.69	0.66
Socos	3.20	30	22	0.17	2.56	2.70	0.50
Colina	7.30	50	24	0.79	5.62	19.27	0.77
Cauquenes	2.80	45	30	0.18	1.80	3.56	0.63
El Flaco	7.00	76	45	0.91	3.60	14.72	0.51
Panimavida	1.80	32	25	0.05	1.40	1.29	0.82
Chillán	15.20	65	45	1.27	7.80	20.57	0.51
Tolhuaca	4.60	61	45	0.31	2.70	5.70	0.58
Manzanar	6.90	48	35	0.38	1.90	3.26	0.27
Huife	8.20	52	40	0.41	2.10	3.32	0.26
Minetué	2.60	41	30	0.52	1.30	3.25	0.20
San Luis	0.80	40	28	0.04	0.60	0.95	0.75
Palguín	2.90	39	28	0.12	1.80	2.61	0.69
Coñaripe	6.50	64	45	0.52	1.30	3.25	0.20
Liquiñe	13.60	46	35	0.63	3.20	4.64	0.23
Puyehue	5.00	70	45	0.52	3.40	11.21	0.68
Aguas Calientes	4.50	65	45	0.38	2.80	7.38	0.62
El Amarillo	4.20	55	40	0.26	2.00	3.95	0.48
Puyuhuapi	13.60	68	45	1.31	4.20	12.74	0.31
TOTAL				8.72		131.08	

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## Energy Agencies in Chile

by Carlos Barría Quezada  
Chief, Renewable Energy Division, Ministry of Energy

### Comisión Nacional de Energía

*Comisión Nacional de Energía* ("National Energy Commission") is a public, technical organization analyzing prices, tariffs, and technical standards for the production, generation, transportation, and distribution of energy. The

Commission's goal is to ensure ample, sure, and high-quality electrical service at the lowest cost. The Commission, through the Ministry of Energy, advises the government on how best to develop the energy sector. Since 2010, the Commission Secretary has been Juan Contreras Sepúlveda. The website has statistics on Chilean electrical matters.

### Centro de Energías Renovables

*Centro de Energías Renovables (CER)* ("Center for Renewable Energy") is an institution that strengthens the efforts of the Republic of Chile to develop non-conventional renewable energy (NCRE). *CER* promotes and facilitates the development of the NCRE industry, coordinates public and private initiatives, optimizes the potential use of NCRE resources in Chile, and helps secure an economically, environmentally, and socially sustainable energy supply. The goal of *CER* is to promote and undertake renewable-energy development, non-conventional renewable-energy projects, and supply data for energy-related decisions. Since 2011, the Commission Secretary has been María Paz de la Cruz.

In June 2009, U.S. Energy Secretary Steven Chu signed a *Memorandum of Cooperation* with the Commission Secretary Marcelo Tokman for

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further mutual renewable-energy collaboration. The memorandum establishes an institutional framework for Chile and the U.S. to broaden their range of cooperation and exchange activities, including U.S. technical expertise to support CER's operations.

At CER, Chile and the U.S. will collaborate on high-priority energy issues, like energy-efficiency technologies and developing renewable energy, including geothermal. CER will identify developments and best practices in renewable-energy technologies from around the world, sending the findings throughout Chile and the region.

CER is managed by a committee of employees from CORFO—*Corporación de Fomento de la Producción de Chile* ("Chilean Production Development Corporation")—working under the auspices of the Ministry of Energy.

## Ministerio de Energía

Since its establishment in 2010, the Chilean Ministerio de Energía ("Energy Ministry") has managed the bidding process for Chilean geothermal-exploration concessions—in conjunction with *Sernageomin* (discussed next). The Minister of Energy is Jorge Bunster Betteley.

Carlos Barriá Quezada, Head of the Ministry's Renewable Energy Division, spoke about the Ministry at the 2012 *Chilean International Renewable Energy Conference*. He said new geothermal-exploratory leases would be offered in the second round of 2013 and discussed other Ministerial geothermal-action items.

The action items include modifying laws and regulations on geothermal activities; improving concession procedures for exploration and development areas; and establishing greater judicial security for geothermal-project developers. Another item seeks to alter the outline of leased areas so they are not shaped as they are now—like parallelograms.

Another goal is to create a way to bid for blocks of renewable energy. A design and suggested final revision for the matter were prepared by the Ministry of Energy in September 2012. A bill will be submitted to the Chilean Congress in the first

## Ambassadors Assist Business

Two Ambassadors to Chile from nations thousands of miles apart spoke about their countries' participation in Chilean geothermal development. The Honorable María Consuelo Puyat-Reyes is the Ambassador to Chile from the Philippines. In September 2012, I asked for her opinion about the growing Philippine presence in the Chilean geothermal world and she said, "It is with great pride that our geothermal developers have arrived here in Chile and are contributing their knowledge. We are well prepared in geothermal and have begun geothermal exploration. I am doing everything possible to establish governmental contacts where we can explain problems.

"I hope we can continue developing geothermal resources in Chile and that a power plant will be operating before my term is over."

The Honorable Alejandro D. Wolff is the United States Ambassador to Chile. I spoke with him a month later on his visit to the University of California-Davis. He said he would "... love to see more American firms and expertise involved in the Chilean development of renewable resources, including geothermal. Renewable resources are comparatively more expensive to develop but are essential for the future energy mix of Chile."

Ambassador Wolff said the United States Embassy helps U.S. businesses in Chile in several ways. He suggests you "... sit down with our embassy sector experts, who will hook you up with the right people—rather than relying on the direct, 'cold call' approach. I suggest you contact Ms. Ellen Lenny-Pessagno, the embassy's Senior Commercial Officer in Chile, at: [Ellen.Lenny-Pessagno@trade.gov](mailto:Ellen.Lenny-Pessagno@trade.gov)."

For further information, click "Business" on the embassy website, at: [chile.usembassy.gov/](http://chile.usembassy.gov/).

half of 2013 and processing is expected in 2013.

In summary, the overriding goal of the Renewable Energy Division is to incorporate renewable energy into the electrical system in ways giving sufficient electricity and security to consumers; achieving energy independence while using clean energy; and adapting the electrical system so it can be integrated with renewable-energy.

"The *Electric Highway* initiative is key for developing renewable energy in Chile," Dr. Barriá said. "In summary, we can say construction of the second pillar for the National Energy Strategy—a move toward renewable energy—is well underway."



## Sernageomin

*Sernageomin* ("The National Geology and Mining Service") is a decentralized service that advises the Ministry of Mining.

*Sernageomin* contributes to governmental programs by developing mining and geological policies and offering geological information to governmental agencies, private interests, and the general public. Publications, maps, geological data and advice, and technical assistance are available. *Sernageomin* regulates safety and environmental issues in the Chilean mining industry and the Nacional Director is Julio Poblete.

*El Museo Geológico del Sernageomin*, a geological museum in Santiago, is open to the public on weekdays from 9 to 1 and 3 to 4:30. The address is: Tiltil 1993, Ñuñoa, and the museum is part of *Sernageomin*'s laboratory complex.

## Cerro Pabellón Geothermal Project

by Salvatore Bernabei  
Head of Chile and Andean Countries for  
Enel Green Power

Enel S.p.A., the largest power company in Italy, operates in 40 countries—including Chile—through its renewable specialist, Enel Green Power. In the Chilean northern Andes, an Enel Green Power project is underway to generate electricity from geothermal resources. The company, through its subsidiary Geotérmica del Norte [a joint venture held by Enel Green Power (51 percent) and the Chilean National Oil Company, ENAP (49 percent)], has received an environmental license for a 50 MWe geothermal site called Cerro Pabellón. The license was granted by the Regional Government of Antofagasta in the spring of 2012.

Project feasibility studies began in 2005 at the time Enel Green Power joined Geotérmica



View of Cerro Pabellón in the winter. PHOTOS COURTESY OF ENEL S.p.A.

del Norte. Surface exploration started in 2006 with geo-structural and geochemical surveys. The geological-geochemical model took into account volcanic and stratigraphic data, structural information about the main fault systems, and chemical and isotopic data from local fumaroles and thermal springs. The geophysical surveys are from the first half of 2007, as are the aerial gravity and magnetic surveys. These allowed reconstructing the main patterns of density and magnetic-susceptibility anomalies in an area of about 300 km<sup>2</sup>.

In June 2007, a magnetotelluric survey for an area of 100 km<sup>2</sup> contributed to the creation of the first conceptual model for the Cerro Pabellón geothermal system. By the end of the year, a slim hole had been drilled to a depth of 600 m, with a final diameter of about three inches. It allowed us to confirm the stratigraphy suggested by the geological surface studies and to measure the temperature path at depth. The thermal results were extremely promising.

After these results, a deep exploration phase was launched to explore the productive layers of the Cerro Pabellón geothermal system. From August 2009 to October 2010, four wells with commercial diameters were drilled successfully. The depths of the four exploration wells range from 1,300 m to 2,000 m. The well diameters are the ones used conventionally by the geothermal industry for production and reinjection purposes.



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In 2010, well production and injection tests were undertaken to check the reservoir pressures and temperatures—and the permeability of the reservoir-rock formations. The results were promising and showed the presence of a liquid-dominated reservoir with a maximum-measured temperature of 260 °C.

In the construction phase, the drilling of an additional 13 wells has been planned to operate a 50 MWe power plant—configured as condensing units fed by the steam phase, and binary units to recover the thermal energy of the liquid phase from the pressure separators. Presently different configurations of the power plant are under evaluation as we seek to maximize efficiency and operation.

The Cerro Pabellón Project is considered as the first step in an area-wide developmental program—which will depend on the results of drilling and reservoir behavior. The number of production and injection wells may vary according to the reservoir and geological characteristics.

An *Environmental Impact Assessment* for a 73 km long, 220 kV electrical transmission line was started in August 2012.

International tenders have been launched for

drilling, turbine supply, balance of the plant, and for the transmission line. An addition of solar panels is under consideration to exploit the logistical and transmission facilities at Cerro Pabellón.

The fact that Cerro Pabellón is a geothermal-power project in itself suggests environmental care. A comprehensive monitoring plan is in effect for the local flora and fauna and for the water used at all stages of plant construction and operation. An architectural study ensures the power plant will blend harmoniously with the shapes and colors of the natural surroundings.

Enel Green Power, and the Enel Group as a whole, is very involved with the local communities. There are several corporate social-responsibility programs in place for these communities aimed at community self-development. An agricultural program will be implemented to restore indigenous irrigation techniques and to improve food safety and security. An extensive veterinary program is underway, improving the living conditions of local cattle. With the help of a Non-Governmental Organization in Tilonia, India, named Barefoot College, Enel Green Power has begun developing a rural-electrification program. Five women from three villages near Cerro Pabellón recently were sent to Tilonia for six months to attend classes at Barefoot College, learning to install and maintain solar panels. The women have just returned to their homes as “Barefoot Engineers,” ready to install solar panels in their communities.

Using our international-geothermal experience accumulated for more than a century, we are working closely with the Chilean Ministry of Energy to support the development of geothermal regulations. The Minister of Energy recently announced a draft law aimed at improving geothermal exploration and development in Chile. To increase the pace of geothermal development, the country should increase the pace of the permitting process, presently embedded in a framework more suitable for industries extracting other materials. Furthermore, it is worth mentioning how, in Chile, it



View of Cerro Pabellón in the summer.



is difficult to find geothermal drilling companies and associated services, which suggests a potential area for improvement at the operational level.

Concerning the market, and considering no familiarity with electrical generation from nonconventional renewable sources exists in Chile, it would be useful to have other forms of commercialization, like the energy auctions in Brazil and Peru. In these countries, regulators issue periodic tenders—usually once a year in Brazil and once every other year in Peru—for the long-term purchase of electricity from new renewable generators. Contracts are awarded based on the lowest electricity tariff offered and typically have a 20 year term with customary take or pay provisions. Such contracts allow bankability of projects and predictability of revenues. Usually the regulator acts as



Salvatore Bernabei, Head of Chile and Andean Countries for Enel Green Power.

procurement agent for the distribution companies that then actually sign the contracts with the generators to fulfill its regulated customer needs.

The Cerro Pabellón Project is the first real step that proves geothermal energy is industrially exploitable in Chile, in the Andean region. This will be the first commercial-scale geothermal plant in the country. It is a testimony of renewable policies, skills, and investments supporting the development of local renewable-energy sources. The local communities will benefit from direct and indirect job opportunities during plant construction and operation.

It is a pleasure for Enel Green Power to be in Chile where we can help discover and develop the valuable geothermal resources around us.



Llaima, one of Chile's largest and most active volcanoes, is a stratovolcano in the southern Andes, 663 km southeast of Santiago. With an elevation of 3,125 m, the volcano is visible from the Tolhuaca well site near the top of the Tolhuaca volcano. Llaima's frequent but moderate eruptions have been documented since 1640. Although the last major eruption occurred in 1994, an eruption on January 1, 2008, forced hundreds to evacuate nearby villages.

Llaima volcano is within the borders of Conguillio National Park, a natural area with small and spectacular lakes. The word *Conguillio* is from the Mapuche word for, "water with Arucaria seeds." The top of an *Arucaria arucana* tree appears at photo right. The trees grow to 130 feet tall with trunks 7 feet in diameter. PHOTO COURTESY OF GEOGLOBAL ENERGY CHILE S.p.A.

## Tolhuaca & Puchuldiza Updates

Ownership has changed at the Tolhuaca and Puchuldiza Geothermal Projects in the Chilean Andes. On February 15, Mighty River Power Ltd. of New Zealand announced it had reached an agreement with the Managing Partners of GeoGlobal Energy LLC to take full ownership and direct control of the geothermal investments in Chile and the U.S. (the EnergySource power-plant projects in California's Imperial Valley). The agreement, reached with the Managing Partners of GeoGlobal Energy LLC—manager of the GGE Fund where Mighty River Power is the cornerstone investor, provides for Mighty River Power to take full ownership and direct control of the GGE Fund's minority interests in EnergySource (including related entities), all of the Fund's geothermal interests in Chile (including Tolhuaca and Puchuldiza), the operating business based in Santiago, and all employees based in Chile.

Mighty River Power will transfer its ownership interest in GeoGlobal Energy to the Managing Partners and pay them \$24.8 million on final closure expected over the next few months.

Mighty River Power Chief Executive, Doug Heffernan, said, "The GGE relationship successfully provided an entry point for us into international geothermal in 2008 through the GeoGlobal Energy Fund." He said an immediate priority was integrating



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the Chilean business—including about 50 people headquartered in Santiago—into a subsidiary of Mighty River Power reporting to GM Development, Mark Trigg.

“The company sees Chile as an exciting geothermal-development prospect with sound fundamentals of high-quality resources, a stable political and legal environment, along with strong economic and electricity-demand growth. We will develop a strategic plan for the business in Chile using the knowledge of the staff in Chile and experience we have gained through the GGE relationship, and from experience gained developing a significant geothermal business in New Zealand.”

Mighty River Power’s *HY2013* document, released on February 21 and available online, includes the information.



Inca weaving, circa 1942.  
COLLECTION OF G.D. FOX.

## Papers & Publications

This complete list of current papers on Chilean geothermal development is unique and important. It allows geothermal researchers to find out the “who, what, and where” of new scientific activity by looking in one place. Plus it offers all readers a glance at what is happening in the Chilean geothermal world. Dr. Patrick Dobson kindly compiled the papers. The list of publications, though not as inclusive, is equally interesting.

The papers from the two Stanford Workshops and the GRC Annual Meeting are available in pdf format from the GRC Library, at: [www.geothermal-library.org](http://www.geothermal-library.org).

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### Stanford Workshop, 2012

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### GRC Annual Meeting, 2012

Aravena, D., Lahsen, A., 2012, “Assessment of Exploitable Geothermal Resources Using Magmatic Heat Transfer Method, Maule Region, Southern Volcanic Zone, Chile,” *Geothermal Resources Council Transactions*, v. 36, pp. 1307-1313.

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Lynne, B.Y., Morata, D., and Reich, M., 2012, “High Versus Low Altitude Hot Spring Settings and Associated Sinter Textures from El Tatio, Chile, and the Taupo Volcanic Zone, New Zealand,” *Geothermal Resources Council Transactions*, v. 36, pp. 925-929.

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Benavente, O., Gutiérrez, F., Aguilera, F., Reich, M., Tassi, F., Vaselli, O., 2012, “El sistema magmático-hidrotermal asociado al Volcan Tupungatito, Región Metropolitana, Chile,” *Actas, XIII Congreso Geológico Chileno*, pp. 423-425.

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Bustamante A., M., Wall Z., R., Lemus H., M., Vivallos C., J., 2012, “Recalificación termal de las aguas de vertiente de Los Andes – San Felipe, Región de Valparaíso,” *Actas, XIII Congreso Geológico Chileno*, pp. 565-567.

Celis, R., Reich, M., Bascuñan, R., 2012, “Caracterización geoquímica del sistema geotermal Termas de Puyehue-Aguas Calientes,” *Actas, XIII Congreso Geológico Chileno*, pp. 492-494.

Droguett, B., Morata, D., Clavero, J., Pineda, G., Morales, S., Carillo, F.J., 2012, “Mineralogía de alteración en el pozo Pte-1, campo geotermal Tinguiririca, Chile,” *Actas, XIII Congreso Geológico Chileno*, pp. 500-502.

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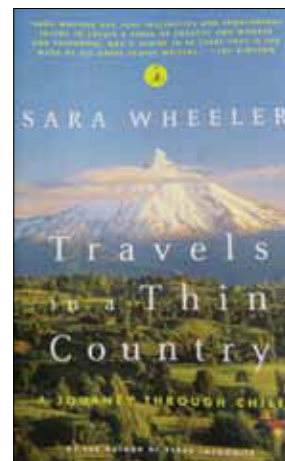
*Escenarios Energéticos Chile 2030* (Chilean Energy Scenarios 2030) is published by Fundación Chile, a non-profit, private foundation created in 1976. Foundation members are the Government of Chile and BHP Billiton-Minera-Escondido.

Energy and climate change are main foundation interests. The publication covers the energy-electrical matrix, how it impacts the economy and the environment, and the roles of renewable energy and energy efficiency. The publication may be downloaded free of charge.

*The Chile Renewables Report* is available for the *First Quarter of 2013* from Business Monitor International. Besides the report, all purchasers receive three, free, detailed quarterly updates and a monthly renewable-market update for 12 months. The report covers geothermal, wind, solar, biomass, tidal and wave energy. The cost of a report is \$1,175 and discounts may apply. Contact: [www.businessmonitor.com/dm/renewable/global](http://www.businessmonitor.com/dm/renewable/global); or call +44 (0) 20 7246 1403.

*Estado de Proyectos ERNC (Energías Renovables no Convencionales)*, Enero 2013. (*The State of Non-Conventional, Renewable Energy Projects, January 2013.*) The concise report of Chilean renewable energy facts and figures is published by the Centro de Energías Renovables (CER). It is available by Googling the title.

*Travels in a Thin Country, a Journey Through Chile*, by Sara Wheeler, 1994. The book by an acclaimed British writer offers entertaining accounts of places visited, things done, and people met. Historical details appear at every turn. Still in print after almost 20 years, which says a lot, the book remains a knowledgeable and idiosyncratic guide to a long, thin, intriguing country. ■



## Upcoming Meetings for 2013

**The 2nd Chilean International Renewable Energy Congress**  
**10-11 September, Santiago, Chile**  
[www.greenpowerconferences.com/CIREC2013](http://www.greenpowerconferences.com/CIREC2013)

**Geothermal Resources Council, 37th Annual Meeting & GEA Trade Show**  
**29 September to 2 October, MGM Grand Hotel, Las Vegas, Nevada, U.S.A.**  
[www.geothermal.org/meet-new.html](http://www.geothermal.org/meet-new.html)



# Focus on Chile, Part III

by Susan Fox Hodgson  
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**F**ocus on Chile, Part III, is last in a three-part series of articles on Chilean geothermal development. In this issue, many final pieces of the Chilean geothermal puzzle fall into place. There are descriptions of projects by Alterra Power Corporation of Canada and Energía Andina S.A.; a discussion of glacier-geothermal relationships; and an overview of the ACHEGEO conference in Santiago last April.

Geothermal education and public information projects are featured—many sponsored by CEGA, the *Andean Geothermal Centre of Excellence*. A collage is included of Chilean public information pieces. Part III ends in the Andes with an adventurous geothermal *Journey Inside the Earth* (“*Rumbo al Interior de la Tierra*”).

## Alterra Power in Chile

Alterra Power Corporation of Canada has three geothermal projects in Chile. Two projects—Los Cristales south of Santiago and Tres Puntas in the Atacama Region north of Santiago—are in the early exploratory stages.

Development is further along at the Mariposa Geothermal System within the Maule Project, located about 300 km south of Santiago. The name *mariposa* was chosen because the reservoir has two lobes shaped like butterfly wings. The Maule Project includes one exploitation concession, Laguna del Maule (4,000 hectares) awarded in 2010, and one exploration concession, Pellado (100,000 hectares) awarded in 2009. Together they encompass the Mariposa Geothermal System.

The area around the system includes several large, super-imposed volcanic structures plus fumaroles and hot springs. Data suggest the presence of a magma chamber 5 to 10 km in depth, possibly the driving force for the geothermal system in the area. The area where the photo at right was taken is 2,400 m above sea level.

On acquiring the concessions, Alterra undertook geological mapping, structural analysis, water and gas chemistry analyses, and a slim-hole drilling program that ended in November 2010.

The first slim hole, completed in 2009, found a temperature of 202 °C at a depth of 650 m at the top of the reservoir. Using the exploration results, Sinclair Knight Merz has filed a report giving an inferred-resource estimate of 320 MWe available over 30 years.

Two more slim holes were drilled in 2010. Slim hole MP 02, drilled on the northern margin of the system to a depth of 897 m, has a bottom-well temperature of 193 °C. Slim hole MP 03 is drilled to a depth of 911 m below the clay cap thought to be the top of the reservoir. The bottom-well temperature is 205 °C.

Two heat sources are inferred from gas geochemistry, but the eastern side could be an outflow from the western side. The western lobe is inferred as hotter and with a higher steam content than the eastern lobe. The geologic evidence would support a younger heat source close to the most recent volcanism (the San Pedro volcano). Gas geothermometry suggests temperatures could reach 290 °C, but the range of 240 °C to 250 °C is more likely. A condensing flash power plant is planned with a capacity of 50 MWe for Phase I.

Two nearby hydroelectrical projects may offer opportunities to collaborate on transmission facilities, allowing a connection to the Central Power Grid, or Alterra may construct its own 100 km transmission line instead.



Drilling the slim hole MP 03 in the snow at the Maule Geothermal Project in 2010, 2,400 m above sea level. The seasonal snowfall exceeded 5 m.  
PHOTO COURTESY OF ALTERRA POWER



## Focus on Chile

On May 21, Alterra Power Corporation announced the completion of a Joint Venture agreement with the Energy Development Corporation (EDC) of the Philippines to develop Alterra's Mariposa Geothermal Project in Chile and three geothermal concessions held by Alterra in Peru. The agreement calls for the EDC to earn a 70 percent interest by funding 100 percent of the next \$58.3 million in project expenditures at Mariposa and \$8 million in project expenditures on the Peruvian concessions.

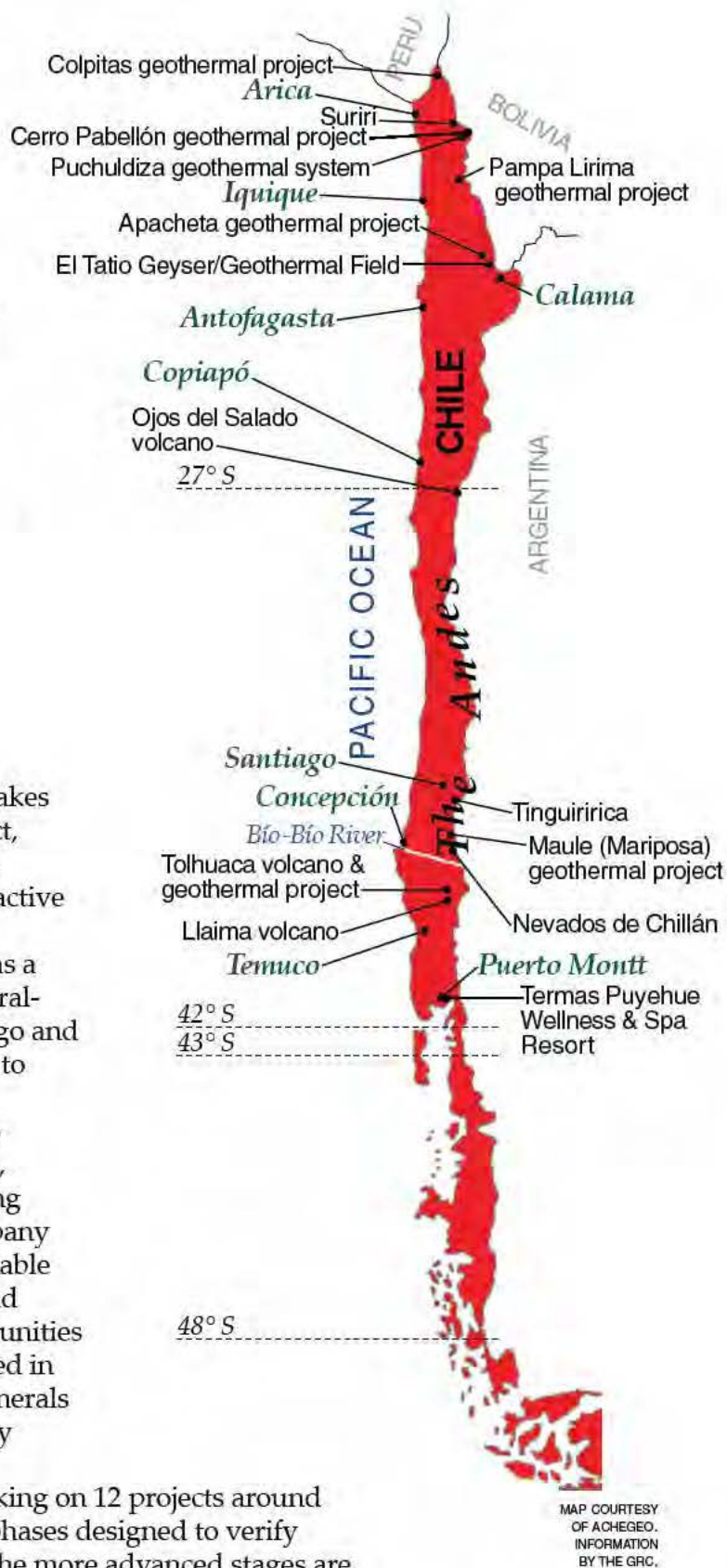
## A Look at Energía Andina

by José Manual Soffia, General Manager

Chile's location on the Pacific Ring of Fire makes it ideal for developing geothermal energy. In fact, Chile is home to about 10 percent of the world's active volcanoes. Two areas are particularly attractive in terms of geothermal resources. The northern area along the Andes, from Copiapó to Arica, has a potential estimated at least 2,000 MWe. The central-southern area, in the mountains between Santiago and Puerto Montt, has a potential estimated at 1,000 to 1,500 MWe.

Energía Andina SA, a company dedicated to exploring and developing geothermal resources, was created with the aim of becoming the leading geothermal-power generator in Chile. The company has a highly competitive, profitable, and sustainable business model, one benefitting shareholders and providing social-development projects to communities near areas where the company operates. Founded in 2008, the company is owned by Antofagasta Minerals (60 percent), a Chilean group, and Origin Energy (40 percent).

Now five years later, Energía Andina is working on 12 projects around Chile. The projects are in different exploratory phases designed to verify that exploitable resources exist. The projects in the more advanced stages are Tinguiririca, Pampa Lirima, and Colpitas (*see map*). Slim-hole wells drilled at the projects have given more precise data about the geothermal systems. In the second half of 2013, the company plans to continue this type of drilling in one or two projects located in the Atacama region of northern Chile.





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Although it is difficult to have a specific date, if all results are positive, Energía Andina could be building the first power plant sometime after 2017. Some obstacles do remain. The main difficulty is the uncertainty of finding and evaluating geothermal resources. The process requires a significant investment of venture capital, particularly in countries like Chile where no legislative incentives exist for these matters. Currently, regulations are being adjusted to streamline some of the procedures. However room remains for incorporating direct incentives to help mitigate risks in the exploration phase and for devising mechanisms other countries have used effectively to stimulate geothermal development.

The geothermal projects at Energía Andina continue moving forward, interwoven with an insistence on environmental respect and stewardship.

## ACHEGEO Comments...

"In mid-April over 435 people attended our international convention inaugurated by the Vice Minister of Energy, Sergio Del Campo," said ACHEGEO President Fernando Allendes. (ACHEGEO stands for the *Chilean Association of Geothermal Energy*.) People came to Santiago from 21 countries to discuss geothermal energy development. Meetings like this are crucial for developing a geothermal industry in Chile and Latin America. Formal discussions, business meetings, workshops, and presentations were on our agenda.

"People called a recently enacted ruling improving the application of law N°19.657 for geothermal concessions 'a great help.' We also need a financial support system for mitigating the risk of failed exploratory drilling projects. It would be helpful if geothermal energy plants could have an incentive to facilitate connections to public energy grids—eliminating costs too high for individual plants," Mr. Allendes said.

**April 29 Update:** The Renewable Energy Center of the Chilean Energy Ministry said it is accepting applications from private companies for pre-investment economic assistance with *Non-conventional Energy Projects*. The monies are for project exploration, engineering design, basic engineering, and environmental studies. More information is at: <http://cer.gob.cl/segundo-concurso-de-pre-inversion/>.



Fernando Allendes, ACHEGEO President.

**Pictured below are some of the distinguished attendees at the convention.** From left to right, they are Raul Sohr, a political scientist and writer specializing in security and energy issues; Senator Baldo Prokurica, member of the Mining and Energy Commission of the Chilean Senate; Clara Szczaranski, Dean of the Faculty of Law, Mayor University; Carlos Barria, Chief of the Renewable Energy Division, Ministry of Energy; Fernando Allendes, President of ACHEGEO; Senator Isabel Allende, President of the Mining and Energy Commission of the Chilean Senate; Deputy Carlos Vilches, President of the Mining and Energy Commission of the Chamber of Deputies; and José Manuel Soffia, General Manager of Energía Andina.





# Training and Research at the Andean Geothermal Centre of Excellence (CEGA)

by Dr. Diego Morata, Director  
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The Andean Geothermal Centre of Excellence (CEGA) is two years old, funded for five years (2011 to 2015), and renewable for five years more. A Conicyt-Fondap<sup>1</sup> project, CEGA offers scientific help for modeling geothermal reservoirs and improving geothermal knowledge in Chile and other Andean countries. CEGA works to develop geothermal as a sustainable, environmentally-friendly, and economically competitive alternative-energy source in Chile and Latin America.



Pools of water collect every spring at El Tatio Geyser Field.  
PHOTOS COURTESY OF CEGA.

How? By creating, improving, and communicating scientific knowledge about geothermal resources in Chile and the Andes; by training and encouraging top undergraduate and graduate students to advance basic and applied research in geothermal energy in academia and industry; by creating a new “in-house laboratory culture” (not yet available) for generating results in state-of-the-art facilities in Chile; by promoting collaborative-geothermal research among CEGA,

<sup>1</sup>Conicyt is the Chilean National Science Foundation program.  
Fondap is a Conicyt program supporting projects in priority areas.



Dr. Valiya M. Hamza (photo right) on a field trip with CEGA geologist Mauricio Muñoz. They are measuring water temperatures at wells throughout the Metropolitan Region of Chile. Earlier in his career, Dr. Hamza discovered an underground river flowing beneath the Amazon.

academic institutions, and industry; by identifying, evaluating, and developing new and emerging technologies for geothermal assessment and exploration; by increasing public awareness of geothermal energy; and by promoting geothermal as a renewable and clean alternative energy.

All this reinforces one foremost goal: building a framework for focused and collaborative geothermal projects in six research areas: Magmatic Systems, Heat-Water-Rock Interactions, Fluid Geochemistry, Reservoir Architecture & Geofluid Dynamics, Structure, Tectonics & Geophysics, and Surficial Processes & Environment.

Academic training is key. This means educating undergraduate, graduate, and post-doctoral students in all geothermal areas; encouraging graduate students to work in different national and international laboratories for interdisciplinary experience; participating in CEGA short courses, conference meetings, and workshops; and becoming a leading international student training center for geothermal-resource development in Latin America.

On an organizational chart, CEGA sits in the Department of Geology at the University of Chile, but it remains involved in geo-science and engineering programs at other Chilean universities. CEGA investigators work on research projects with about 40 students at the undergraduate, master, and doctorate levels.

What is studied? Examples include low-enthalpy processes (heat-flow mapping in the Santiago and Talca basins of central Chile) and



Graduate students Oscar Benavente and Constanza Nicolau sample geothermal waters with Dr. Dobson (photo right).



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high-enthalpy situations (alteration patterns in active and fossil geothermal fields; the mineralogy and geochemistry of silica sinters; structural controls on geothermal systems; gas geochemistry in selected geothermal areas; the dynamics of



Graduate student Constanza Nicolau (foreground) collects sinter samples at El Tatio Geothermal Field.

magmatic chambers; new isotopic systems in geothermal research; and geophysical surveys in active and fossil geothermal fields).

Several analytical instruments are available in CEGA laboratories. Students undertake water and rock analyses, mineral characterization, radiogenic dating, gas geochemistry (lab in progress), and geophysical surveys. All these help promote collaborative research with industry and with national and international centers—and they help improve geothermal training and research in Chile.

Current collaborative projects are underway at Lawrence Berkeley National Laboratory (U.S.), the Institute of Earth Science and Engineering and University of Auckland (New Zealand), Karlsruhe Institute of Technology and the International Geothermal Center (Germany), and Italian universities in Florence and Bologna. Study topics include helium isotopes in geothermal systems, gas geochemistry, silica sinter, structural control, and geophysical surveys of geothermal fields. The collaborations help students, researchers, and the people of Chile understand and facilitate geothermal development in the Andes of Latin America.

## CEGA/LBNL Collaboration

Dr. Patrick Dobson, of the Lawrence Berkeley National Laboratory (LBNL), traveled to Chile at the end of 2012 as a Fulbright Specialist in association with CEGA, the Andean Geothermal Centre of Excellence, at the University of Chile in Santiago. A collaborative effort between LBNL's geothermal program and CEGA was undertaken—a study of the variations in helium isotope ratios at geothermal hot springs and fumaroles throughout the Andes.

Dr. Dobson helped Chilean graduate students studying geothermal geochemistry and numerical modeling to increase their practical and theoretical skills. The students in the photograph at right are from the University of Chile on a visit to the Olla de Mote thermal area at the Nevados de Chillán—a group of stratovolcanoes in southern Chile.

The class was led by Professor Alfredo Lahsen and Dr. Juan Rojas; Dr. Dobson gave a guest lecture on geothermal exploration methods.



PHOTO BY P. DOBSON.



## Glaciers & Geothermal

Glaciers can become part of Chilean geothermal projects just by being nearby—like the glacier at the Tolhuaca Geothermal Project in the southern Andes in the photo below.

“There are five major glaciers in the vicinity of the Tolhuaca Project,” said Sergio Iriarte, Geology Manager of the Tolhuaca Geothermal Project. “The one closest to the project area (Pemehue) is about 2 km away from the site of the future geothermal power plant and cooling towers—and about 350 m above them. According to the environmental impact study, submitted by GeoGlobal Energy Chile SpA. (now MRP Geotermia Chile Ltda.), an atmospheric model has established that no element created by the project could affect the integrity of glaciers at the summit of the Tolhuaca volcano. For example, the particulate and temperature changes due to plant construction and operation will have negligible effects on the glacier because of the distance between them.

“Mighty River Power has committed to undertake glacial studies and monitoring before and during power plant construction and operation. Unfortunately the glaciers in this sector have followed the trend of most parts of mountain glaciers in Chile—they have been retreating and shrinking at accelerated speeds.”

Many glaciers in Chile are studied by scientists at the Laboratorio de Glaciología (“Glaciology Laboratory”) in the Universidad de Chile ([www.glaciologia.cl](http://www.glaciologia.cl)). The melting of glacier Jorge Montt (48°20’S), a main glacier in the Southern Patagonian ice field, is the topic of a 2012 paper by Rivera *et. al*. The glacier receded 19.5 km between 1898 and 2011, the greatest terminal retreat observed in Patagonia in the past century.



Summertime helicopter view of the Tolhuaca No. 4 well site, the camp in the distance, and the Tolhuaca crater with the glacier in the background. PHOTO BY ARTURO ROCO, GGE CHILE CONSTRUCTION MANAGER.

## Books & Journals for CEGA

At the end of 2012, several boxes of geothermal books and journals were mailed from California to the CEGA library in Santiago. The books include two GRC donations: a copy of *Stories from a Heated Earth* and a CD of the papers presented at the 2012 GRC Annual Meeting (see photo). The scientists at the Earth Sciences Division, Lawrence Berkeley National Laboratory, donated nearly complete sets of the *GRC Transactions* and *GRC Bulletins*.

The U.S. Department of State shipped all the materials to CEGA under the auspices of Dr. Fernando Echavarria in Washington, D.C., and Pablo Valdez at the U.S. Embassy in Santiago.



PHOTO BY S. OTERO, CEGA.

## More Chilean Publications

*ThinkGeoEnergy/Piensa en Geotermia* is a weekly geothermal online newsletter written in Spanish and available free of charge. Latin American news is featured, but not exclusively. To subscribe, visit: <http://piensageotermia.com>.

*Piensa en Geotermia* is sponsored by Scientific Drilling International. When asked about the decision to sponsor the newsletter, Patrick Hanson of Scientific Drilling said, “We recognize the void the newsletter fills in the geothermal world. Our newsletter sponsorship has brought us increased visibility in the growing Latin American geothermal marketplace. We’ve seen a dramatic increase in website traffic and web or social media inquiries throughout all of Latin America because of this.”

**Dr. Patrick Dobson sends the following citation.**

Sánchez, P., Pérez-Flores, P., Arancibia, G., Cembrano, J., Reich, M., 2013, “Crustal deformation effects on the chemical evolution of geothermal systems: the intra-arc Liquiñe-Ofqui fault system, Southern Andes,” *International Geology Review*, DOI:10.1080/00206814.2013.775731.



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### *These citations come from the CEGA website.*

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- Diego Saide, Rocío Núñez, Diego Carrasco, Arancibia, G., Cembrano, J., Pérez Flores, P., Santibáñez Boric, I., 2013, "Vinculación entre volcanismo y deformación tectónica en los Andes del Sur," 13, *Revista de Investigación de Pregardo, Facultad de Ingeniería, Pontificia Universidad Católica de Chile N°3*, in press.
- Le Roux, J.P., 2012, "Analysis of interfering co-linear, fully developed deepwater waves," *International Journal of Oceanography*, ID 314064, 8 p.
- Oppikofer, T., Hermanns, R.L., Redfield, T., Sepúlveda, S.A., Duhart, P., Bascuñán, I., 2013, "Morphologic description of the Punta Cola rock avalanche and associated minor rockslides caused by the 21 April 2007 Aysén earthquake (Patagonia, southern Chile)," *Revista Asociación Geológica Argentina, Special Issue*.

### ***Dr. Patrick Muffler notes four early publications on Chilean geothermal exploratory activities prepared at the New Zealand Department of Scientific and Industrial Research. An historical context for the papers is found in Professor Lahsen's history of Chilean geothermal development, published in the March/April GRC Bulletin.***

- Ellis, A.J., 1969, "Survey for geothermal development in northern Chile: Preliminary geochemistry report, El Tatio Geothermal Field, Antofagasta Province."
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## Walking the Talk on Geothermal

by Sofía Otero  
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"Geo what?" This is, more or less, the starting point for geothermal outreach in Chile. The general public knows so little that when you want to talk about geothermal, you literally need to start from the ground. Geothermal is the least known, most ignored, yet most abundant and widespread renewable-energy resource in our country. And it gets worse.

It might not be scientifically proven, but experience tells us a true and sad fact: ask anyone

on a Chilean street what first pops to mind on hearing the word *geothermal* (let's suppose you are lucky enough to find someone who already knows what geothermal is...) and the person will mention the El Tatio incident of 2009, referring to an unfortunate and accidental activation of a fumarole in El Tatio Geyser Field during tests at a nearby exploratory well. Most of the press claimed it an ecological disaster, even though this was proven not technically true. Nevertheless that was how the word *geothermal* reached a mass Chilean audience for the first time. It was not a fortunate debut.

But this tough scenario for geothermal outreach only encourages us. The Andean Geothermal Centre of Excellence (CEGA) is the only research center uniquely devoted to geothermal research in Chile, and one of its main objectives is to increase public awareness and promote geothermal resources as a clean, sustainable, and possible energy alternative for Chile. How? Mainly by creating materials and organizing activities to disseminate information on geothermal energy to children, political decision-makers, and everyone else in between.

"Geothermal" is a topic surrounded by misconceptions. Providing accurate information to target audiences through many activities and materials is the best way to address negative attitudes toward geothermal. How should this information be? Simple. The "less is more" commandment comes first. We aim to communicate just a few concepts in the materials and activities we develop and we want to teach these concepts to our public. In a nutshell: what is geothermal and how does it work? Simple to say, but to keep it simple is not simple at all. There is a big temptation to saturate the public with information. They know so little and there are so many things we want to tell them about geothermal! However we are at such a preliminary stage in terms of geothermal outreach in Chile that we must focus on uprooting myths and building solid information from the base with a few basic facts.

Knowing your audience is the key to outreach success. Every product must match a specific public and have a clear objective. Our main outreach goals at CEGA are to educate: battling prejudgments and providing accurate information; creating bonds with different groups (educational, media, governmental) to boost outreach efforts—crucial to bringing geothermal closer to the community; and maintaining communication with our audiences by



developing a dialogue allowing us to monitor the impacts of outreach efforts. Within the framework of these objectives—which in summary are to educate, engage, and cultivate relationships in simple, clear, and informative ways—we have developed many different materials and activities in our first two years as a center.



*Young children looking at computer tablets watch CEGA videos on geothermal energy during National Explore Science and Technology Week. PHOTOS COURTESY OF CEGA.*

We have created two videos in both English and Spanish: “What is Geothermal?” and “Geothermal Direct Uses,” seen at: [www.cea.ing.uchile.cl/cea/index.php/en/videos](http://www.cea.ing.uchile.cl/cea/index.php/en/videos). Using concrete and direct language, the animated videos aim to define in 150 seconds or less what geothermal is, how it is produced, and how people and industries use it. We hope to release two new videos this year, one on geothermal myths and one explaining how geothermal power plants operate.

To address the negative image of geothermal development in northern Chile, we approached two local and influential groups. One is an association of tour guides who each year take thousands of tourists to see the geysers at El Tatio. To update their knowledge of geothermal manifestations and to combat misconceptions, an interactive workshop was held.

A second workshop was organized in an Aymaran community in the city of Calama, in northern Chile. The Aymarans are an indigenous Andean people. The workshop was led by two social leaders known as the “El Tatio Grandmothers.” In 2009, they walked for nine days from the Antofagasta Region to La Moneda, the Presidential palace in Santiago, protesting against geothermal development at El Tatio. The workshop was a joint venture with Dr. Suzanne Pierce, a researcher from the Center for International Energy and Environmental Policy, University of Texas.

At both workshops, we gained geothermal supporters and dispelled prejudices about geothermal as an energy alternative in Chile. We offered advice on how to promote scientific tourism and basic scientific information for use in this regard.

CEGA has designed an interactive activity for science fairs. Creating a geothermal display is not without its challenges. How do you design a hands-on



*An interactive workshop for tour guides was held at El Tatio Geyser Field in northern Chile.*

experience for kids—considering the soul of geothermal is (very) hot water? Finally we came up with a large magnetic and detachable graphic illustrating geothermal uses. People can manipulate it safely and also view geothermal photo galleries and videos on touchable computer screens.

Our low-enthalpy experimental kit goes out on tours. Basically the kit is a set of acrylic containers with openings at six levels where thermometers and conductivity meters are inserted and measurements made. The containers, filled with sediments and water, sit on a steel platform heated by a small burner, thus recreating a slice of the underground. This helps explain the basic concepts, like

geothermal gradient, conductivity, permeability, Chilean geothermal conditions, and how geothermal exploration works.

We have developed a summer school on “Geology and Geothermal” for high school students and teachers. The curriculum includes



*A young student at a science fair learns how the earth is heated.*

theoretical classes and a two-day field trip at Cajón del Maipo in the Chilean Metropolitan Region. Here students undertake field work—sampling rocks, water, and steam in geothermal areas. We hope the school continues for a long time.

Putting CEGA on Facebook has led us to a dynamic audience. With multimedia tools, we seek audience interaction and



## Focus on Chile



At the CEGA booth, geologist Dr. Valentina Flores and graduate student Alida Pérez speak with young visitors at the First Engineering and Science Festival (FCFM UChile). They are explaining how temperature and conductivity are measured in a heated slice of sediment with and without water.

participation. With over 500 followers, we have almost quadrupled the size of our community in one year. Through Facebook, we offer geothermal information not necessarily related to CEGA's work but helpful in creating geothermal awareness.

Yes, it is true that we prefer to do things rather than talk about them; however, dialogue is vital and we at CEGA talk in several ways. We chat in science cafés, leading informal and friendly discussions about geothermal. We speak at vocational conferences for high school and undergraduate students learning about "green energy," and we organize seminars to discuss geothermal pros and cons.

Most CEGA outreach activities are designed by a special unit at the center devoted to geothermal communication and dissemination. However none of the events and materials could be developed without the commitment and motivation of CEGA



Dr. Morata talks about geothermal energy with high school students.

researchers and students offering their time and ideas to take the world of geothermal from the depths up to the surface.

### Upcoming Meetings for 2013

**GeoPower LatAm**  
13-14 November 2013 (*tentative date*)  
Santiago Marriott, Santiago, Chile  
[www.greenpowerconferences.com](http://www.greenpowerconferences.com)

**Geothermal Resources Council, 37th Annual Meeting & GEA Trade Show**  
29 September to 2 October,  
MGM Grand Hotel, Las Vegas, Nevada, U.S.A.  
[www.geothermal.org/meet-new.html](http://www.geothermal.org/meet-new.html)

## The Who, What, & How

by Susan Fox Hodgson

Every public-information project begins with choosing an audience, what to say, and how to say it. Narrowly defined audiences are the best, and there are many—children, the general public, the media, geothermal companies, stockholders, legislators, regulators, utilities, communities near geothermal developments, environmental organizations, etc. A one-size-fits-all approach doesn't work well.

For many years, I've created and written geothermal public information. The experience has led to these comments on the role of public information in Chile as geothermal energy resources are developed throughout the country.

As geothermal development in Chile increases, so does geothermal public visibility. Positive public opinion is critical to geothermal developers. Positive opinions form when people understand what geothermal development means, what it offers, and what safeguards are in place. Companies, universities, foundations, and governmental, professional, and environmental organizations—all play a role in the arena of nontechnical public information. Their voices should be an expected part of the public dialogue.

Most nontechnical public information is prepared for children and adults knowing little about geothermal energy. Sometimes information reaches "semi-technical" status when more (but not all) details are needed, like company brochures designed to attract clients.

Find and study other public information pieces as you create your own. The best have built-in ways of measuring effectiveness. Does a brochure do what you want? If not, use what you learn from the first edition to improve the second.

Materials published in more than one language stand out and suggest a global outlook. When different languages are used, I suggest asking a native speaker of each one—someone with an editorial background—to proofread, as all languages are tricky.

Through the years, I've found each country's geothermal publications to have intrinsic qualities easy to enjoy but difficult to articulate—and Chilean materials fit the bill. The photo on the next page offers a brief introduction to Chilean public information, which I admire for its content;



artwork—including the layout and paper; and pure originality. The pieces pictured are just ones I happen to have—several are taken from display tables at Green Power's 1st *Chilean International Renewable Energy Congress* last September. The items in *no way* begin to represent the large amount of Chilean geothermal public information available or the many organizations producing it. No online materials are included—and the amount of geothermal information on the Internet is staggering.

If there are other geothermal public information pieces you would like noted, send me an email and ask for a mention in an upcoming issue of the *GRC Bulletin*.

Here are the Internet addresses for the organizations producing the pieces in the collage.

- **CEGA**, the Andean Geothermal Centre of Excellence, [www.cega.ing.uchile.cl](http://www.cega.ing.uchile.cl).
- **"Chile,"** the two booklets pictured in the first row by ProChile, [www.prochile.gob.cl](http://www.prochile.gob.cl).
- **"Clean Energy,"** [www.cleanenergymag.com.ar](http://www.cleanenergymag.com.ar).
- **"El Costo Nivelado de Energía y el Futuro de**



**la Energía Renovable no Convencional en Chile: derribando algunos mitos,"** by the National Resources Defense Council, [www.nrdc.org](http://www.nrdc.org).

- **Estrella International Energy Services Ltd.,** [www.estrellasp.com](http://www.estrellasp.com).
- **GeoThermHydro**, comprised of the Icelandic GeoSurvey (ÍSOR), [www.geothermal.is](http://www.geothermal.is); & Verkís, [www.verkis.com](http://www.verkis.com).
- **Less Carbon**, [www.lesscarbon.com](http://www.lesscarbon.com).
- **Renovalab Fundación**, [www.renovallab.cl](http://www.renovallab.cl).
- **"Rumbo al Interior de la Tierra"** and the booklet to the right of the calendar are by Energía Andina, [www.energiandina.cl](http://www.energiandina.cl).
- **Scientific Drilling International**, [www.scientificdrilling.com](http://www.scientificdrilling.com).
- **Teranov-Kidova** and the **Geothermal Resource Group** are companies working together, [www.teranov.com](http://www.teranov.com) & [www.geothermalresourcegroup.com](http://www.geothermalresourcegroup.com).
- **The green volcano**, with eruptions and *Arucaria arucana* trees near the peaks reaching out like hands, is part of a mural installed at a Santiago metro station.
- **Transelec**, [www.transelec.cl](http://www.transelec.cl).
- **Volcán Paríacota** is by the Government of Chile, CONICYT, and FONDECYT.
- **ZAPATA—Zapata Engineering**, [www.zapatainc.com](http://www.zapatainc.com).

Turn the page for a *Rumbo al Interior de la Tierra* ("Journey Inside the Earth") with two Aymaran children and their llama. This comic, the third in a series by Energía Andina, explains geophysical testing and slim hole drilling to young Juan and Anita in clear, nontechnical language. José M. Soffia, General Manager of Energía Andina, said the Aymaran people near the geothermal lease are not expected to use much of the electricity that is generated. However if they wish, the company will help them use geothermal waters and energy to heat their buildings and greenhouses, dry llama meat, and develop tourism.

All three comics are available free of charge. Energía Andina offers the international-geothermal community permission to reprint and distribute them tailored to other languages and geothermal situations. The company asks only to be notified by anyone "editing" the comics—and to receive copies of the "foreign" editions. The comics are on the Energía Andina website. For more information, contact Patricia Armingol at: [parmingol@energiandina.cl](mailto:parmingol@energiandina.cl). ■



# RUMBO AL INTERIOR DE LA TIERRA







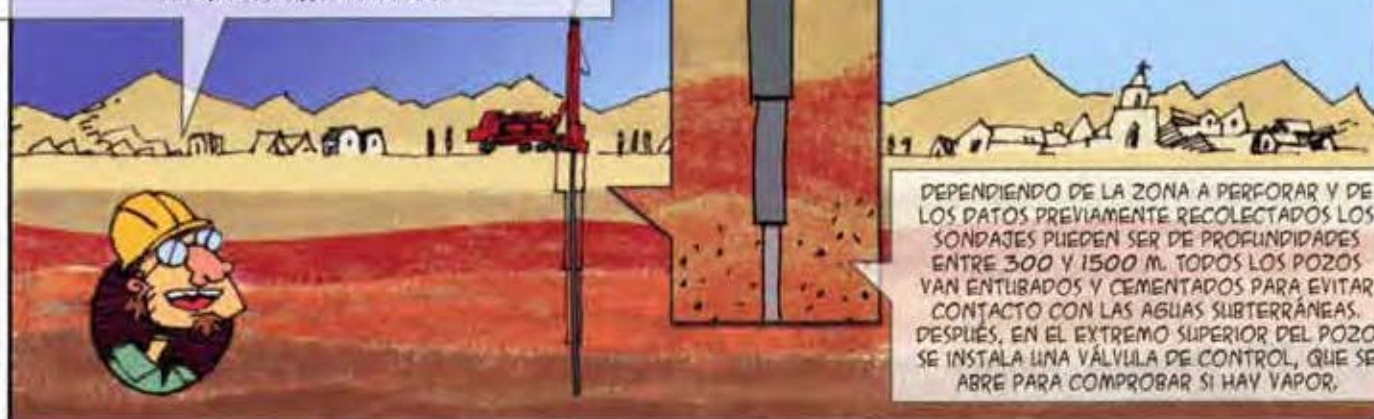








LA MÁQUINA PERFORA UN PRIMER TRAMO SACANDO EL MATERIAL TRITURADO O CORTANDO TESTIGOS. LUEGO ESE TRAMO SE REVISTE CON UNA TUBERÍA Y SE CEMENTA. SE REPITE EL PROCESO PROFUNDIZANDO OTRO TRAMO CON UN DIÁMETRO MENOR Y ASÍ SUCESIVAMENTE LUNOS DOS TRAMOS MÁS. EL MATERIAL EXTRAÍDO SE ANALIZA PARA ESTUDIAR LAS CARACTERÍSTICAS DE LAS ROCAS ENCONTRADAS Y SE MIDE LA TEMPERATURA QUE HAY A DIFERENTES PROFUNDIDADES.



DEPENDIENDO DE LA ZONA A PERFORAR Y DE LOS DATOS PREVIAMENTE RECOLECTADOS LOS SONDAJES PUEDEN SER DE PROFUNDIDADES ENTRE 300 Y 1500 M. TODOS LOS POZOS VAN ENTUBADOS Y CEMENTADOS PARA EVITAR CONTACTO CON LAS AGUAS SUBTERRÁNEAS. DESPUÉS, EN EL EXTREMO SUPERIOR DEL POZO SE INSTALA UNA VÁLVULA DE CONTROL, QUE SE ABRE PARA COMPROBAR SI HAY VAPOR.

LUNOS MESES DESPUÉS,  
CUANDO YA TERMINARON  
LA PERFORACIÓN.

¡ESTEBAN, TENEMOS QUE CONTARLE A NUESTROS  
AMIGOS Y VECINOS QUE CORROBORAMOS NUESTRO  
MODELO GEOTÉRMICO!

¡AL PARECER DESCUBRIMOS  
ENERGÍA GEOTÉRMICA!  
¡VAMOS A CONTARLES!



FIN