



GEOHERMAL RESOURCES COUNCIL

Bulletin

REPRINT

Letter from Peru

by Susan Fox Hodgson



Letter from Peru, Part I

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The Republic of Peru

Population: 29,849,303.

Official Languages: Spanish, Quechua, Aymara.

Literacy: 89.6 percent.

Per Capita GDP: \$10,900.

GDP Growth: 6.3 percent.

Government: A constitutional republic, with 25 regions and one province, headed by President Ollanta Humala Tasso.

Total Area: 496,225 square miles.

Geographical Summary: An arid coastal strip, 10 to 100 miles wide stretching along the Pacific Ocean, supports much of the population—thanks to widespread irrigation.

The Andean mountain range rests on 27 percent of the land. The uplands are well-watered, as are the eastern slopes reaching down into the Amazon Basin, which itself covers half of Peru.

Chief Crops: Asparagus, coffee, cocoa, cotton, sugarcane, rice, potatoes, corn, and more.

Natural Resources: Copper, silver, gold, petroleum, timber, fish, and more.

Industries: Mining and refining minerals; steel and metal fabrication; petroleum extraction and refining; natural gas extraction and liquefaction; fishing and fish products; and more.

Crude Oil Reserves: 579.2 million barrels.

Electrical Production: 33.3 billion kWh.

(The information is reprinted from page 824 of *The World Almanac and Book of Facts*, 2014, published by World Almanac Books, an imprint of Infobase Learning.)

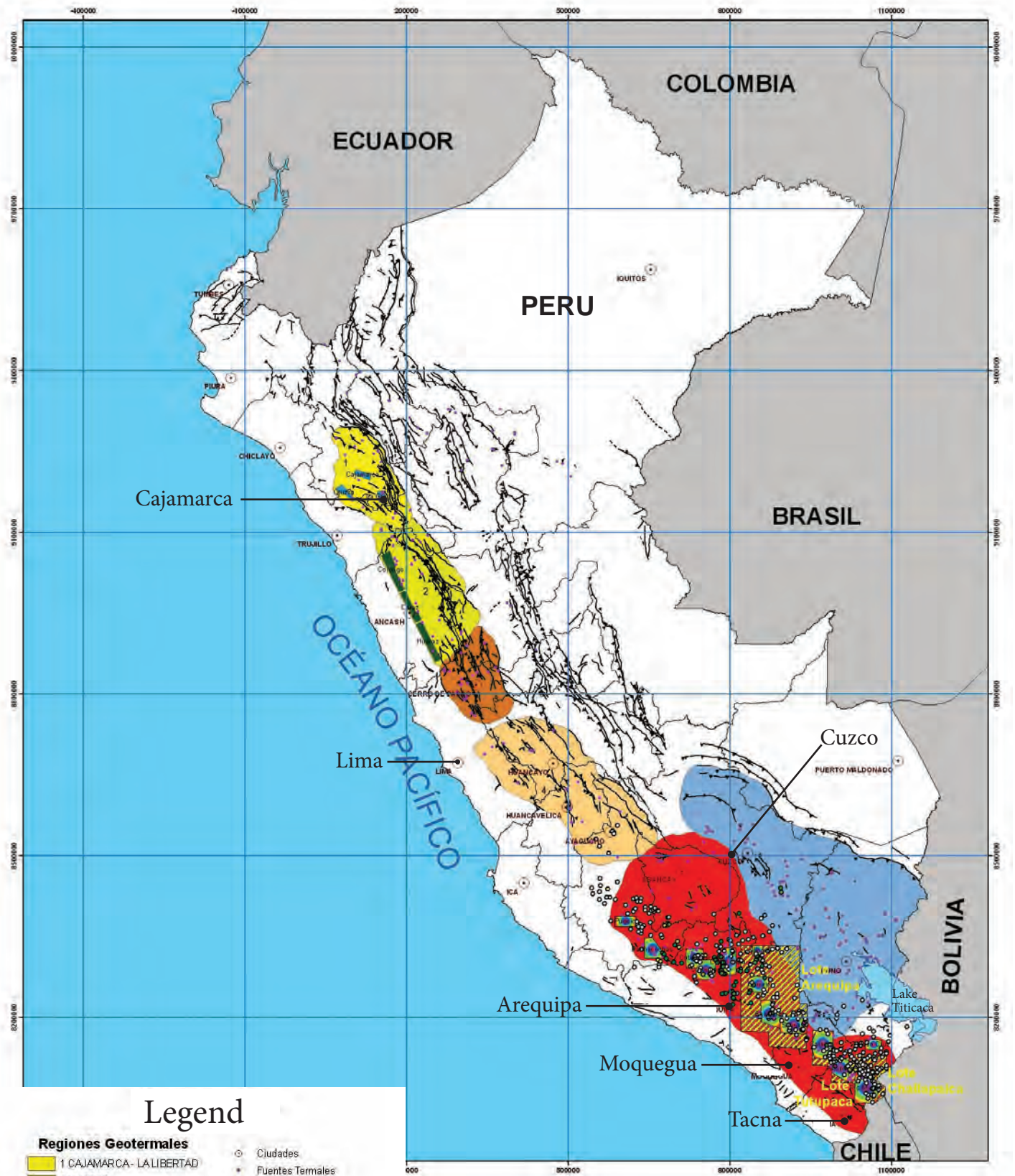
Geothermal History & Geology

Late In 1532, the thirteenth and last Inca, named Atahualpa, was staying at Cajamarca (northeast of Lima) with some of his troops. One day his runners brought back the disturbing news that a group of soldiers, led—it turned out—by the Spaniard Francisco Pizarro, had landed in Peru and were on their way.

The Spanish Chroniclers write that on hearing the news of the Spanish advance, Atahualpa left Cajamarca for a trip to the hot springs about five miles away. He said he wanted to soak in the geothermal waters and decide what to do next. Cajamarca's hot springs are still famous because of his visit, but unfortunately they offered him warmth, not wisdom.

In the events that followed, Atahualpa's army was slaughtered, he was captured, and his Empire was ended—South American history had changed forever. On August 29, 1533 the Spaniards garroted Atahualpa—waiting until he had accepted the Christian faith and until they had taken the huge ransom proffered by his people for his return. The ransom filled a room, actually his cell, with intricately worked gold brought by the llama-load to Cajamarca from around the empire—a treasure worth untold millions.

View of the Calientes Geothermal area. Photo by Joe LaFleur.

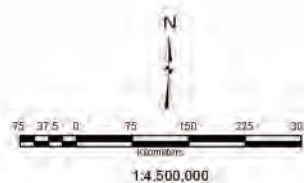


Legend

Regiones Geotermiales

- 1 CAJAMARCA - LA LIBERTAD
- 2 HUARAZ
- 3 CHURÍN
- 4 CENTRAL
- 5 EJE VOLCÁNICO SUR
- 6 CUZCO - PUNO
- Lotes Geotérmicos en la Región 1
- Lotes Geotérmicos en la Región 2
- Lotes geotérmicos en el sur
- Áreas geotérmicas en la Región 5

- Ciudades
- Fuentes Termales
- Volcán activo
- Volcán fumarólico
- Volcán latente
- Volcán dormido
- Volcán extinto
- Límites departamentales
- Falla normal
- - - Falla normal inferida
- Falla inversa
- ▲- Falla inversa inferida



Through this account and many others, we learn how the Incas, and most likely the other Indigenous peoples of Peru, valued their hot springs—over 500 have been mapped with temperatures above 20°C. But how do the modern-day Peruvians view their country's geothermal resources? "People living in and around the highland communities, and throughout the country, use geothermal hot springs for cures and for recreation—for soaking and relaxing," said Lic. Vicentina Cruz Pauccara, a geologist with the Peruvian Geological Survey (INGEMMET).



A hot spring/spa permitted by the Ministry of Tourism in southern Peru, near Yanque/Colca. PHOTO COURTESY OF INGEMMET.

What about all of the high-temperature resources? Ask Ing. Susana G. Vilca Achata, President of the Directive Council for INGEMMET. "We have to continue, to advance," she said. "We are working now on our high enthalpy resources. We want to be able to use them and we can only generate electricity from geothermal resources in two zones. But we plan to extend our studies throughout the country. Communication with the communities and everyone involved is important. We need their permission to develop our geothermal resources. To this end, we distribute a small booklet describing what geothermal development means."

"As a fundamental tool for developers, INGEMMET has drawn a geothermal map of Peru. We started our geothermal evaluations in every area by locating the geothermal manifestations, including hot springs," said Vicentina. "We've analyzed the hot spring waters and 35 of these hot springs have been certified for public bathing by the Ministry of Tourism."

INGEMMET has organized the geothermal map into six regions and Vicentina said she and other INGEMMET geologists have climbed many an Andean mountain parsing out the geothermal details. "Region five, in the south, has the most active volcanoes," she said, "and the Tacna region, also in the south, has the best development prospects. A special publication on the Tacna region is available on the INGEMMET website. "You will note," she added, "a beautiful geothermal area, called Calientes, is found here and is protected by the nation from development (see the article in the next issue)."

"Besides all of these projects," Vicentina continued, "we are beginning to make geochemical and geological studies, along with shallow studies, like analyzing the composition of geothermal discharge. We do not make geophysical studies. All of our results at INGEMMET are on the website (www.ingemmet.gob.pe), organized by geothermal region—and you can download them as a pdf files. In addition, INGEMMET is preparing an English version of the geothermal data for international users—one with more scientific terms."

The *Geothermal Map of Perú*, a paper presented at the 2010 International Congress in Bali, was written by Vicentina Cruz Pauccara and Victor Vargas, both of INGEMMET. It offers a good, basic history of Peruvian geothermal exploration and geothermal geology. A portion of the *Abstract* follows.



Geologists from INGEMMET study hot spring waters in the Pinaya-Puna area of southern Peru. PHOTO COURTESY OF INGEMMET.



Two amazing geysers at Puente Bello, in the Andes of southern Peru, east of Moquegua. PHOTO COURTESY OF INGEMMET.



An overview of the Puente Bello area. PHOTO COURTESY OF INGEMMET.

“The *Geothermal Map of Perú* geographically defines the zones where geothermal resources are found. Currently six important geothermal regions have been identified: Cajamarca—La Libertad; Callejón de Huaylas; Churín; Central; Eje Volcánico Sur, and Cuzco—Puno.

“From an analysis of bibliographical information and field studies, we concluded that in northern and central Peru, high-temperature manifestations are the results of geothermal gradients, in which the water flows across deep faults. In the southern part of the country, the geothermal manifestations are related to active volcanism. Here the hot springs are of mixed origin, with both meteoric and volcanic waters.

“Until now, most studies characterizing the geothermal resources in Peru have focused on the Eje Volcánico Sur zone, located in southern Peru where several zones have been recognized of varying geothermal importance. The zones include:

Group A—High importance—Tutupaca, Calacoa, Maure, Laguna Salinas, Chachani, and Chivay.

Group B—Medium importance—Puquio, Parinacochas, and Orcopampa.

Group C—Low importance—Catahuasi, Coropuna, Caylloma, and Mazo Cruz.”

A Peruvian Energy Overview with Miguel Cardozo

Even a strapping sentence needs extra room for all of Miguel Cardozo’s professional activities. To begin with, he is President, CEO, and Director of Alturas Minerals Corporation and the Main

Partner and General Manager of CP Group S.A.C., both headquartered in Lima. In addition, Dr. Cardozo is the General Manager for Magma Energía Geotérmica Perú SA.

He spoke to me about the state of energy in Peru—the present, the past, and the future; the good news and the not-so-good. It made for an interesting hour as we sat in his modern office, sipping water and watching the commotion outside along one of Lima’s busiest streets.

Dr. Cardozo began by saying Peru has a diversified energy matrix, with hydropower first in importance and natural gas second. Together the two produce over 95 percent of the energy in Peru. Next come oil, coal, biomass, wind, and solar.

He said the main concern of all Peruvian governments, since the early 1990s, has been expanding the national energy network to meet a growing demand for electrical power while keeping energy prices low. As a result, the actual energy costs in Peru are lower than in any other Latin America country and the more expensive sources of alternative-energy are scarce in Peru. Because the low prices have made energy projects less profitable, a general slowdown in new energy developments has resulted.

The good news is that the expanse of the Peruvian national grid is a great asset, not just for the country but for the energy producers themselves because power can be put online in many parts of the country. Mining companies, for one, find this helpful as they electrify mines in out- of-the-way places.

Peruvian Law for Geothermal Resources

Decreto Supremo, No 26848, July 29, 1997

The following translations are of Norma II and Norma VII from the Peruvian *Law for Geothermal Resources (Ley Orgánica de Recursos Geotérmicos)*, printed on July 29, 1997 in Lima by the periodical, *El Peruano*. (These are not official translations.) The newspaper itself was founded in 1825, as its headline reads, “by El Libertador Simón Bolívar.” Today it is the oldest newspaper published in Latin America.

Norma II: The State promotes the rational development of geothermal resources with the goal of ensuring the supply of energy needed for economic growth, the well being of the people, and the efficient diversification of energy sources in the country and proceeds prudently in developing these activities with open access and competition, according to law.

Norma VII: Geothermal activity is a public good. The state promotes investments in geothermal exploration and exploitation, as well as the rational use of these resources, while emphasizing environmental conservation.

The Peruvian Government has placed a 5 percent limit on alternative energy sources. Hydroelectric projects under 20 MWe fall into this group because they have less impact on the environment. The government does not discriminate among different renewable-energy sources. Geothermal, solar, and wind are all treated equally, even though geothermal is a 24/7 base load energy source and the others are not.

“Peru has a tremendous energy potential, especially in the south where the possibility exists of finding all sorts of energy resources,” Dr. Cardozo said. “For example New Zealand has geothermal power plants with operating costs similar to hydroelectric power plants here in Peru. There is international pressure on countries to develop alternative-energy resources. These pressures helped move Peru to create the 5 percent limit,” he said.

In Peru, the Ministry of Energy and Mines (MEM) is in charge of geothermal development. MEM has issued complex rules about the need for



Two amazing fumaroles at Quello Apacheta in southern Peru.
PHOTO COURTESY OF INGEMMET.

environmental instruments at each stage of a project; however, MEM has not yet explained what the environmental instruments must include nor has it issued environmental regulations for geothermal exploration. Presently, when Peruvian geothermal projects are in the earliest stages, MEM issues an informal permit for exploratory surface activities. As of this writing, a developer still needs a formal environmental permit before drilling can begin.

Here is the MEM timeline for geothermal projects once a lease has been secured. For Phase One, you need MEM authorization for two years of exploratory, pre-drilling work. The two years start once the letter from MEM arrives saying you can proceed with your MEM provisional environmental permit. You may now undertake surface, geophysical, and geochemical studies. Within the first year, you must get the social licenses you need from people living in the area and legal permission from the land owners allowing you to develop the property.

Once the two years are up, and before drilling if you still wish to proceed, you must submit a formal environmental document to MEM. When MEM accepts this, you have entered Phase Two and have one year to drill at least three deep wells. The geothermal authorization period may be extended for up to two years if you demonstrate to MEM



View from on high of the fumaroles at Quello Apacheta. Note how the ancient and undisturbed Inca terraces are built along both sides of the stream—and built to stay. Each terrace has its own mini-climate determined by the cardinal alignment and the elevation. Keeping the mini-climate in mind, the Incas chose where to plant each crop for maximum yield. They were brilliant agriculturists. So where does geothermal fit in? You can bet the plants chosen to grow on the lowest terraces along the steamy hot edges of the stream were the ones that flourished in hot and humid locations. PHOTO COURTESY OF INGEMMET.

the exploration work you have done has not been completed and explain why you need more time—but there will be a charge.

So what does Dr. Cardozo think about the future of Peruvian geothermal development? He says it may depend on how successfully companies, like the Philippine Energy Development Company (EDC), can develop their projects. A successful project will stand as an example, its achievements highlighted by the international press. “Personally,” he said, “I hope EDC finds a near-surface, high-energy source so the costs can be kept down.”

Peruvian Ministry of Energy and Mines

Leaving a taxi, I headed straight for the front door of the Peruvian Ministry of Energy and Mines (MEM). A short minute later, in the middle of the lawn and shrubbery, I stopped to stare. Two fluffy white llamas were vigorously munching away at the grass. *Adios* electric mowers. *Hello* conservation.

Now I must say the word “*geothermal*” is hard to find on the MEM website. This is not so very unusual, as the country itself is in the very first stages of developing geothermal resources. In fact you might call all of the people working

on geothermal development in Peru, *geothermal pioneers*.

Ing. Alcides Claros Pacheco certainly fits the bill. He is the Director of Electric Concessions for the Peruvian Ministry of Energy and Mines (MEM) and he and his division stand at the heart of the matter. He told me his office is responsible for approving requests to explore and develop geothermal resources.

“It is important to note,” he said, “that all geothermal development in Peru is in the hands of private companies, not the state. Today Peru has the potential of generating 2,800 MW of geothermal electricity. In the future we will need more electricity because of the changing climate. Every year in Peru the winters are colder and the summers are hotter. Buildings may need central heating and cooling in the future—features not so common now.

“We need courses about geothermal in our universities because today geothermal development is covered only tangentially. In MEM, we have just one person, Ing. Luis Torres Gómez, who has studied geothermal and he works for us in the Tacna region.”

“Every two years MEM sponsors an auction for renewable electrical-generation projects, like wind, solar, biomass, geothermal, wave, and hydroelectric—up to 20 MW. Nevertheless, to date geothermal energy has not been included. In 2015 we will have an auction that may include geothermal, but a decision has not been made as of yet and the date has not been set. For more information, go to the MEM website at: www.minem.gob.pe and the Peruvian Energy Regulatory Commission (OSINERGMIN) website at: www.osinergmin.gob.pe. For general information, contact Ing. Claros at: aclaros@minme.gob.pe.

The southern axis of Peru, perhaps the most important geothermal region in the country, includes the areas around Ayacucho, Apurimac, Cuzco, Arequipa, Moquegua, and Tacna. Over 300 geothermal manifestations have been found here and more probably exist, write Victor Vargas and Vicentina Cruz of the Peruvian Geological Survey.

“The Japanese came to study geothermal in the Tacna area in 2007, and they spent a lot of time here,” said Ing. Marceline Marci Floor, MEM’s Regional Director in the Tacna region. He told me that in 2010, MEM published a list of Peruvian geothermal concessions.”

Ing. Claros soon gave me an updated list of the concessions and the names of companies leasing them. Currently, 30 concessions are leased to six different companies.

“Geothermal is a clean technology that doesn’t contaminate the environment. Geothermal concessions are often in the highest and most isolated places,” said Ing. Jesus A. Duran, MEM’s Regional Director for the Moquegua region— next to Tacna and still very much in southern Peru. “Many people are trying to use geothermal for tourism. If we can use it for electrical generation, as well, then we will be able to contribute much more to the region.”

“Geothermal is not only good and important, but interesting,” said Ing. Marci. “In our districts, it can serve the isolated and poorer communities. We want the public to accept geothermal power plants—and many people have. Here in southern Peru, people are pushing us to develop geothermal energy because they know it will help them.”

Acknowledgments

For a time, three questions stayed my plan to interview geothermal geologists, regulators, and developers in Peru. Who were these people? What were their names? Where were their phone numbers and email and street addresses?

The answers came from a congenial group of colleagues working in Peruvian geothermal development. Geologist Catherine Hickson Ph.D. set the ball rolling by putting me in touch with Geothermal Consultant Paolo Bona and Geoscience, Social Context and Communication Consultant Fernando Muñoz Carmona Ph.D.

They, in turn, introduced me to Miguel Cardozo Ph.D., Alturas Minerals Corporation, Magma Energía Geotermia Perú S.A., and CP Group S.A.C.; Ing. Alcides Claros Pacheco, Ing. Jesús A. Duran Estuco, and Ing. Marcelino Marca Flor, Ministerio de Energía y Minas; Lic. Vicentina Cruz Pauccara, Instituto Geológico Minero y Metalúrgico; and Carlos Niño Neira Ramos and David Sussman— EDC Perú Holdings S.A.C.

Muchas gracias to you all. ■





Letter from Peru, Part II

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The Startling Beauty of Calientes

The geothermal gem of Calientes is tucked 4328 m high in the Western Cordillera of the Andean mountains in southern Peru—near the small Community of Calientes. The unique and beautiful geothermal features found here are protected by the nation from geothermal development. “Presently,” says Vicentina Cruz of INGEMMET, “the Calientes Valley is located inside the *Regional Conservation Area of Vilacota-Maure (ACR-VM)*. Geothermal development is not possible here because geothermal is not listed in the *Master Plan for ACR-VM*.”

“You know, *caliente* means ‘hot’ in English,” said geothermal consultant Joe LaFleur, “and I call Calientes *The Yellowstone Park of Peru*. It is such a



Although the volcano usually associated with the Calientes geothermal area is Volcán de Candaravre, the relationship may be incorrect, geologically speaking, because the geothermal resources of Calientes may be more closely associated with other adjacent volcanic heat sources. Map courtesy of Google.

special place.” While studying geothermal geology in the area, Joe watched the crystal-clear hot waters (*las aguas calientes*) pour from countless springs into a stream flowing vigorously southwest down a small valley floor cut along a northeast-trending fault zone. He walked the edge of the stream for a few kilometers, staring with amazement at the hot springs,

fumaroles, geysers, and precipitates on display. Joe watched waterfalls of tumbling hot waters and paused astonished at a natural bridge of siliceous sinter formed from deposits of two hot springs on either side of the stream. The deposits had built up gradually—turning into a bridge where they met (*see* the introductory and the cover photos). Geologists from INGEMMET and Peruvian universities are equally fascinated by the kaleidoscope of geothermal features at Calientes and they monitor them carefully.

Joe found the hydrothermal system to be right at the surface in this incredibly beautiful area. This is why he believes producing these geothermal resources for power generation would most likely draw down the hot water table, destroying the surface manifestations—no matter how careful a developer tried to be.

In addition, he said that getting electricity out to market would be a costly task. The transmission line and access road would have to cross a large, steep-sided canyon that isolates the Calientes area from the paved roads and towns to the southwest. This is why Joe found a different geothermal prospect in the same area for his client, one much closer to the electrical grid and without the unique surface manifestations of Calientes.

Vicentina agrees with the difficulties of accessing the Calientes area and says she hopes more studies will be made to help understand and preserve the environment of her country.



The delicate wafts of hot spring steam seem out of place when seen against the vast and rigid slopes of an Andean volcano in the Calientes Geothermal area. The thermal waters at Calientes have discharge temperatures ranging from 50 °C to 87 °C, according to INGEMMET. Photo courtesy of INGEMMET.



Bunches of native grasses thrive along the many formations lining the banks of the vigorous stream of geothermal waters flowing through the Calientes area. Photo by J. LaFleur.

Climate Matters – in Lima

Beijing On November 12, 2014, Presidents Barack Obama and Xi Jinping announced a mutual, stepped-up time frame for carbon reduction in the United States and China. “The pledges provide an important boost to international efforts to reach a global deal on reducing emissions beyond 2020 at a United Nations meeting in Paris scheduled for December 2015,” *The Guardian* reported.

Strongly influencing the outcome of the Paris meeting are the commitments made by the delegates attending the United Nations COP20 conference in Lima, Peru, in early December. An overview of the conference follows.

Lima From December 9 to 15, 2014, worldwide climate change was the topic of the day in Lima. Thousands of delegates from nearly 200 nations attended forums and meetings at the COP20 Climate Conference. The six main workshops included geothermal presentations and sustainability discussions.

The conference occurred under the aegis of the UN Environment Program. COP20 itself stands for the “conference of parties” involved in the *United Nations Framework Convention on Climate Change*—the international environmental treaty negotiated in Rio de Janeiro in 1992 to “... stabilize greenhouse gas concentrations to prevent dangerous anthropogenic [human] interference with the climate system.”

Manuel Pulgar-Vidal, the Peruvian Environmental Minister, served as head of the conference. “Much of the credit for the newest internationally agreed COP20 plan—an historic commitment by all countries to cut greenhouse gas emissions—belongs to his tenacity, diplomacy, and unfailingly attentive efforts to move the UN climate framework forward,” wrote Sandy Dechert in *Clean Technica*.

Achieving this commitment was the number one goal of COP20 that *The New York Times* calls “... an agreement in which every nation commits to a domestic plan to reduce greenhouse gas emissions, along the model of the U.S.-China agreement. This is the first time all nations, rich and poor, have agreed to cut back on burning oil, gas, and coal.” But the article points out the plan will not be enacted until 2020.

Paris There is, however, another point of view to consider. Yes, the international climate change treaty to be signed in Paris this coming December won’t be binding, writes University of Chicago economist Michael Greenstone in an article published in *The New York Times* on February 15. “That’s less than ideal, but it’s still worthwhile for several important reasons. First, all treaties are essentially voluntary, short of violators being placed under severe sanctions or the threat of war. Second, the more binding the language of the treaty seems, the less likely it is that countries will make any commitment to act. And third, the only previous international treaty to reduce greenhouse gas emissions was surprisingly successful. For these reasons, the treaty to limit greenhouse gas emissions that may emerge from the December 2015 conference to take place in Paris—binding or not—is an important step forward in confronting climate change,” Dr. Greenstone concluded.

Climate Change Footnotes Only discovered in 2015 is the first ever direct observation of a link between the rising CO₂ levels from fossil fuels and the increased capacity of the atmosphere to absorb thermal radiation emitting from the earth’s surface. Scientists at the U.S. Department of Energy’s Lawrence Berkeley National Laboratory announced the discovery on February 25. The findings not only agree with theoretical predictions of the greenhouse effect due to human activity, they provide further confirmation that the calculations used for today’s climate models are on track when it comes to representing the impacts of CO₂.

The Japan Meteorological Agency has announced the year 2014 was the hottest by far in over 120 years of recordkeeping. The statement was confirmed in two separate analyses undertaken by two United States agencies—NASA and the National Oceanic and Atmospheric Administration (NOAA).

That glaciers in Peru and Chile are melting is not news to *GRC Bulletin* readers. But here is an additional note. “The glaciers in the Canadian West could shrink up to 70 percent by 2100, according to new research with implications for predicting glacier loss worldwide,” according to *The New York Times* in an article published on April 7. The research, first published in the journal *Nature*

Geoscience on April 6, combines scientific disciplines to develop what is called an unusually powerful method of predicting glacier loss, including high-resolution regional models of current glaciers and the physics of ice flow.

Developing Geothermal Energy in a Country not Your Own

by Fernando Muñoz Carmona, M.Sc. Ph.D.¹
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During my years in Peru participating in the most recent “push” for geothermal development that country is experiencing, I sensed the reality others have met there and in many other countries and contexts. For geothermal development to take off and expand to meet the needs of the people in a particular country, the expectations of stakeholders and shareholders and many other factors, elements, events, and conditions must fall into place.

Like the ingredients and steps involved in a cake recipe, a desirable geothermal project (the “cake”) follows steps with combinations of ingredients, factors, resources, sprinklings of leavening and catalyzers—all of them interacting with the “right” amounts of heat for the “right” lengths of time.

However, achieving that fabulous (geothermal) recipe has often proven to be a difficult and elusive target. Without suggesting a single magic formula for successful geothermal development, please allow me to describe, from my humble and limited perspective, some factors, actions, interactions, and their implications I have seen in geothermal developments.

It is of common knowledge that successful geothermal development is more than identifying the three key essentials for a good resource: heat, fluid, and permeability. And certainly more than the adequate management of key elements like institutions, policies, finance, and technical

development. In fact, I have learned that independent of the country where you may be, geothermal development occurs in a *supply-demand* relationship. *Supply* is the amount of a product or service, like electrical power or heat, a market can offer. *Demand*, on the other hand, refers to how much of a good or service, like electrical power or heat, a user or buyer desires. The relationship between supply and demand can reach a point where producers and consumers of geothermal resources are satisfied.

The concept of “satisfaction” implies important product or service characteristics beyond the mere concept of “quantity.” Satisfaction means that for a geothermal product or service to be offered or demanded, it needs to fulfill the expectations of those involved in the process, like geothermal companies, governmental bodies, and communities—including the people living in the vicinity of geothermal projects. As such, expectations for quality/reliability, price/affordability, and profitability in social, economic, and environmental terms should be achieved.²

From this perspective, one of recent special importance in Chile, Colombia, Hawaii, Kenya, New Zealand, Peru, and the Philippines, social satisfaction follows, leading to and reinforcing social acceptance and demand. This in turn triggers political willingness, and with it the action for the definition, application, and enforcement of adequate regulatory frameworks. Social demand, political willingness, and an adequate regulatory framework for geothermal exploration and development are very important when accessing the financial resources that can facilitate knowledge development, institutional strengthening, and institutional articulation.

Geo-technical, engineering, economic, and social knowledge access, generation, and application are crucial—not only for constantly improving geothermal development technology, facilitating better cost-profit margins, and better services and products, but also for creating a well-informed base of stakeholders and decision makers.

Access to knowledge, in turn, is facilitated by communication and education for all the

¹The author is a geoscientist with over 30 years of experience in geologic hazards/risk assessment/management and project management for resource exploration. With special emphasis on geothermal social and environmental assessment, he has worked in Chile, Colombia, Costa Rica, Guatemala, Nicaragua, and Peru. He is a former project manager for Alterra Power Corporation/Magma Energía Geotérmica Perú S.A. and lives in Scottsdale, Arizona.

²Modified from statements in the sixth geothermal item appearing in the article on page 35: *Peruvian Geothermal Literature on the Internet*.

stakeholders involved, starting with geothermal developers. Here communication, in addition to being a means for informing (in multiple directions), is a means for transforming the very same reality created with the contribution of geothermal development.

The supply-demand relationship for geothermal development operates at corporate, international, national, regional, and local levels. Both supply and demand drive and are driven and modeled by economic, social, cultural, political, regulatory, financial and financial market, geological, meteorological, biological, and environmental conditions that may act as dampers or catalyzers. Examples of *dampers* are the lack of financial and human resources and regulations. Examples of *catalyzers* are the oil crises in Italy and the Philippines of the 1970s; the Nicaraguan political goal of energy independence; and the 2011 tsunami and the Fukushima Daiichi nuclear disaster in Japan.

Without considering this list of attributes as exhaustive and just by combining these variables (the geographical levels and conditions) in a 5x11 matrix, as shown in **Table 1**, we can see the huge number of combinations for particular conditions and particular geographical contexts that influence and affect the geothermal development process—at *particularly opportune or inopportune times*—or *at times of no particular consequence* (yes, another variable!).

Table 1. Matrix of Influence with some conditions and contexts that influence and are influenced by geothermal development.

	Environmental	Biological	Meteorological	Geological	Financial Markets	Financial	Regulatory	Political	Cultural	Social	Economic
Corporate											
International											
National											
Regional											
Local											

How do corporate decisions looking for better returns for their shareholders prompt investment shifts that affect geothermal development commitments? How do power struggles and trade

strategies between countries affect the access to and management of commodities (energy) and other resources modifying the international economic and financial markets, making it more difficult or easier to access funds for development? How do these conditions affect national, regional, and local contexts? How do natural events, like geology and weather, modify access, generation, and distribution of energy resources at different geographical scales? How do social, cultural, political, and environmental conditions, again at different geographical scales, affect geothermal development? This is a sample of the many questions the matrix helps to pose and that the geothermal industry needs to address constantly while contemplating and implementing different scenarios for exploration and development of geothermal resources.

Independent of the country where geothermal development takes place, there will always be something that can hamper, derail, or—the opposite—accelerate a particular geothermal development process. In any scenario, it is very important for the geothermal industry to understand and, more importantly, as much as possible engage actively in the construction of the aforementioned conditions at the different geographical levels.

There are no magic formulas, but it will help the geothermal industry be aware of its surroundings and to be active participants in the construction of a project. The geothermal industry needs to work both the supply and demand sides of the geothermal development equation, applying business models that constantly react and anticipate, adapting and intervening to new challenging and changing conditions that always emerge, especially in a country that is not your own.

Acknowledgement

The author thanks Jim Combs for his valuable comments on the article.

The Peruvian Geological Society

So there I was one sunny afternoon, strolling through a pleasant Lima neighborhood by the ocean, when I saw it. Right in front of me stood a large Elizabethan house with a gate and a shiny

brass plaque elegantly engraved: *La Sociedad Geológica del Perú*. Plainly there was nothing to do but press the buzzer, go inside, and ask for an appointment.



The Elizabethan façade of the Peruvian Geological Society. Photo by S. Hodgson.

The appointment was kindly granted by Dr. César Muñoz Pineda, the President of the society's Council of Directors. He spoke with me at length about the society, which he said was founded in 1924 and has over 1,000 members. The non-profit, scientific organization is comprised mostly of geologists but also includes people working in related areas, like paleontology, hydrology, mining, and petroleum.

"Geothermal" may be a new specialization in Peru, but the geological society offers geothermal developers prime information: inside the walls of this Elizabethan house, the society runs the largest geological library in the country. "Many library items are available on the Internet at no cost to members, but nonmembers must pay," said Dr. Muñoz. All readers of the *GRC Bulletin* are welcome to join the society. For more information, email the society at: sgp@sgp.org.pe. The Internet address is: www.sgp.org.pe.

The society also distributes geological information throughout Peru—focusing on schools and institutions involved with geologic hazards. It supports scientific and technological investigations, sponsors an annual congress and other geological seminars and meetings, and publishes annual bulletins plus other publications. So the next time you're visiting in Lima, why not take a minute to look at the society's website and catch an event while you're in town?

Peruvian Geothermal Literature on the Internet

More information about geothermal Peru is found on the websites of agencies and companies mentioned in *Letter from Peru, Parts I and II*. In addition, you can Google the titles listed below to download papers and publications.

1. *Caracterización y Evaluación del Potencial Geotérmico de la Región Moquegua*, Lima, Perú 2014, Vicentina Cruz Pauccara, Víctor Vargas Rodríguez, and Lourdes Cacya Dueñas, Boletín N° 58, INGEMMET.

2. *Caracterización y Evaluación del Potencial Geotérmico de la Región Tacna*, Lima, Perú 2013, Vicentina Cruz Pauccara, Víctor Vargas Rodríguez, and Lourdes Cacya Dueñas, Boletín N° 56 Serie C, INGEMMET.

3. *Estudio Geotérmico del Campo Calientes*, Lima, Perú 2012, Víctor Vargas Rodríguez, Vicentina Cruz Pauccara, Yanet Antayhua Vera, Marco Rivera Porras, and Lourdes Cacya Dueñas, Boletín N° 48 Serie C, INGEMMET.

Comment: The three geothermal publications, noted above and written in Spanish, offer only a small sample of the geothermal information available under the auspices of INGEMMET, the Peruvian Geological Survey. The agency's publications are well written and clearly illustrated. For a complete list, visit the INGEMMET website.

4. *Development of Geothermal Energy and Factors that Affect its Utilization in Peru*, March 2014, Alcides Meraias Claros Pacheco, Dirección de Concesiones Eléctricas, Dirección General de Electricidad, Ministerio de Energía y Minas del Perú.

Quote: "To develop geothermal energy, we have established the granting of licenses for the exploration of geothermal resources and the granting of concessions for the exploitation of these resources."

5. *Geothermal Activity in South America: Bolivia, Chile, Colombia, Ecuador, and Peru*, February 2013, by Ingimar G. Haraldsson, United Nations University Geothermal Training Programme.

Quote: "Most of the studies to date have been focused on Eje Volcanic Sur, which has more than 300 volcanic centers and more than 300 surface manifestations from hot springs to fumaroles."

6. Geothermal Development in Peru: Opportunities, Concepts, Actions, Results and Recommendations, September 2014, by Fernando Muñoz Carmona, Catherine Hickson Ph.D., Vicentia Cruz, Instituto Geológico Minero y Metalúrgico del Perú, Melissa Mendoza, Ministerio de Energía y Minas del Perú, Miguel Cardozo Ph.D., ExploAndes S.A.C. General Manager, Ursula De la Mata, ENEL Green Power Chile y Países Andinos, and Paolo Bona, Geothermal Consultant.

Quote: “The paper is divided into five sections. The first discusses some of the opportunities Peru currently offers for geothermal development. The second describes the main factors shaping current geothermal development in Peru. The third presents concepts and actions that can improve current geothermal development in Peru. The fourth summarizes the achievements accomplished by the geothermal sector in Peru after applying the concepts and actions described in the document. The last section offers conclusions and recommendations for promoting Peruvian geothermal development.”

7. Geothermal Map of Perú, April 2010, by Victor Vargus & Vicentia Cruz, Instituto Geológico Minero y Metalúrgico del Perú (INGEMMET).

Quote: “We re-defined the boundaries of the six geothermal regions in Peru and the boundaries of their sub-divisions. The geothermal map will be a useful tool for defining the high-priority sites that could be the most promising while at the same time supporting the development of Peruvian geothermal resources.

Geothermal Museums at a Glance

Museo Andres Del Castillo This elegant museum, one I found purely by accident, is located in a restored house in downtown Lima called the Casa Belén, built in the mid-nineteenth century and home to many notable Peruvian figures. Not only can you explore Casa Belén itself, wandering through the well-proportioned rooms and a white marble patio and colonnade, you can stop and admire display after display of mineral crystals, Chancay ceramics, prehispanic textiles—plus a gallery full of historical and restoration facts.

I personally went right for the minerals, which are as beautifully trimmed and artfully



Quartz crystals on display at the Museo Andres Del Castillo. Photo by S. Hodgson.

displayed as any I've seen. Although the samples were collected from just a few mines and do not represent all the mineral wealth of Peru, they are well worth a visit. Most striking are the hundreds of quartz crystals shimmering in the lighted glass cases. Unforgettable.

A small gift shop offers a few geological souvenirs

and the museum address is: Jirón De la Unión 1030 – Lima 1. The website is: www.madc.com.pe.

Museo de la Electricidad de Barranco The displays in this intimate museum tell the story of electrical generation in Peru. The museum itself is in Barranco, the bohemian area of Lima just south of Miraflores. Barranco is famous for art galleries, musical events, restaurants, coffee houses—and visits by drowsy tourists on warm Sunday afternoons.

The museum was opened by Electrolima S.A. in August 1994 at a time when the company was being replaced, in part, by Luz del Sur, Edelnor, and Edegel S.A. In fact Electrolima founded the museum to preserve its own role in the history of Peruvian electrification. In 1998, the year Electrolima was totally deactivated, care of the museum was transferred to Electroperú S.A.

On entering the museum, you find yourself in a patio full of electrical generation machinery you are free to touch and explore. Displays in the next room explain Peruvian energy sources and the many pioneers who developed them.

The history of Peruvian electrification and the story of Lima's electric streetcars (no longer used) come next. After these, a display asks visitors to use electricity judiciously and to value alternative-energy sources. Of course geothermal *per se* is not mentioned, but it will be someday when Peru's first geothermal power plant goes on line somewhere in the Andean Range.



The museum is open every day, free of charge, from 9 to 5. To end your visit, why not grab a ride down the street in the renovated electric streetcar? The cheerful conductor charges about 25 cents for a short, roundtrip excursion. The museum address is: Avenida Pedro de Osma 105, Barranco, Lima. Send emails to: museoelectri@speedy.com.pe.

CHILEAN UPDATE

EDC to Drill in Chile

The Energy Development Corporation (EDC), of the Lopez Group in the Philippines, has begun its first major drilling campaign at the Mariposa Geothermal Prospect in Southern Chile, *The Manila Times* reported on May 6. Over the last few years, *GRC Bulletin* readers have learned about this geothermal prospect 250 km south of Santiago.

EDC President and COO Richard B. Tantoco said the company is on track to drill two to three wells by the fourth quarter of 2015. He added that EDC has begun drilling the first 50 m of the wells. "The installation of the anchor casing in the top hole sections of the well will reduce the time it takes to drill the full three-kilometer wells. This critical because we have only five months of the Chilean summer in which to work, starting in October," he said. "The company continues to invest in infrastructure for the Mariposa project," he added, "and has budgeted \$58 million for exploratory drilling activities." In 2013, EDC acquired a 70 percent stake in the Mariposa Project from Alterra Power Corporation of Canada.

EDC officials said the company is earmarking P3.8 billion for geothermal exploration projects in

Latin America, with the bulk of the amount allotted for the Mariposa prospect in Chile, *Manila Standard Today* reported on May 6. EDC has stakes in five concessions and has filed 19 applications in Chile and Peru.

Power Plants on Order

Ormat Technologies, Inc. announced on May 7 that its wholly owned subsidiary, Orandina I S.p.A., has signed a \$98.8 million engineering, procurement, and construction (EPC) contract to construct a binary geothermal project in Chile. Under the EPC contract, Ormat will provide two, air-cooled ORMAT® energy converters for a high-enthalpy reservoir. The project is scheduled to be completed by mid-2017.

Mighty River Power Leaves Chile

Mighty River Power of New Zealand (MRP) is exiting its geothermal interests in Chile and Germany, the *Fairfax New Zealand Ltd.* reported on December 16, 2014 and the *GRC Bulletin* in January/February 2015. "We are very clear about Mighty River Power's strategy and direction that we outlined to our shareholders last month—the current strategic focus is on incremental consumer-focused growth options, including smart meter deployment and data services," said MRP Chief Executive Fraser Whinery. "Geothermal remains a core capability for Mighty River Power and indeed New Zealand." The company will sell its Chilean and German assets.

In addition MRP will not invest more development capital in the United States, where it has an interest in a 50 MWe operating plant in California's Imperial Valley and a minority stake in a geothermal development company. However the company said it will keep its stake in operating the U.S. interests.

Chilean Renewables

Legislation The tasks listed in the new, Chilean energy agenda were divided into three parts by the Chilean Government, reported Francisco Rojas in *Thinkgeoenergy* on January 9. The first part covers geothermal development, the second legal frameworks for transmission systems, and the third increases in energy efficiency. Work and consultations have begun on parts two and three

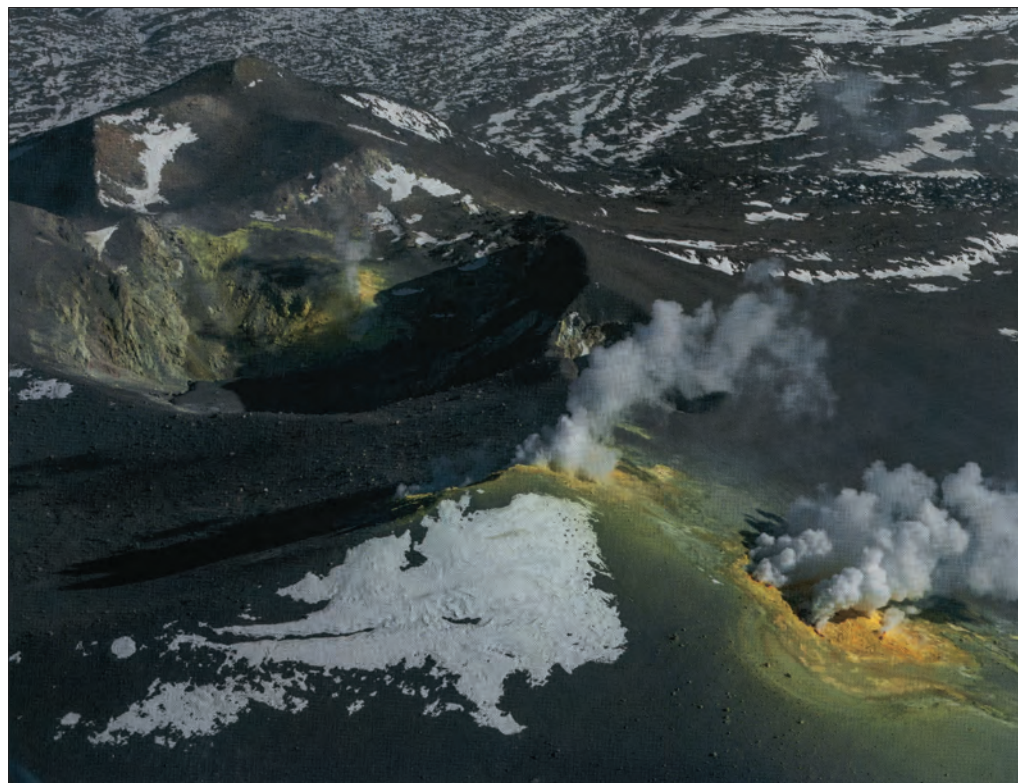
and the legislative process is scheduled to begin in the second and fourth quarters of 2015. As for part one, legislative actions are scheduled to begin in late 2015.

Maps On April 13, SERNAGEOMIN, the Chilean National Service of Geology and Mining, announced it has identified 14 areas with high geothermal potential in Region X, named Los Lagos. The region is in southern Chile and ends just where the Chilean western shoreline turns into many tiny islands. SERNAGEOMIN Director, Rodrigo Alvarez, added that the agency is preparing geothermal maps of the Los Rios and La Arucania regions.

On March 13 the Chilean Minister of Mines, Aurora Williams, announced SERNAGEOMIN has published 30 basic maps of Northern Chile. The maps include information about geology, geophysics, and geochemistry and will help promote mining, geothermal, and hydrogeological exploration.

Win a Book!

Do you remember *Stories from a Heated Earth*, the large red book published 15 years ago by the IGA and GRC full of geothermal myth and legends from around the world? A few copies still are available from the GRC office, free of charge.



Inspired by this volume, a Chilean writer has just finished her own book of Chilean geothermal myths, legends, and accounts, published by the Chilean Centro de Excelencia en Geotermia de los Andes, better known as CEGA. Written in Spanish by Sofía Otero, the book is titled, *La Tierra de Fuego* or *Land of Fire*.

A promotional video for *La Tierra de Fuego* is found at: <http://vimeo.com/114944277>. The Spanish text is at: http://issuu.com/cega_uchile/docs/latierradefuego.

How can you get a copy? Well....the book isn't for sale because it is funded by grants mandating free distribution to Chilean public libraries and NGOs. But a chance remains. If you would like to win one of the two copies of *La Tierra de Fuego* donated by Sofía to the GRC, **email your request to Ian Crawford by June 30, 2015**, and ask him

to enter your name in the drawing. His email address is: ICrawford@geothermal.org. A photo and translated text from the book follow.

An aerial view of the Lastarria Volcanic Complex. Note the huge deposits of sulfur rimming the smoking craters. The complex is part of the Andean mountain range in Northern Chile, along the Argentine border. About 12 km long, 10 km wide, and 18,691 feet high, the Lastarria Complex is famous for its unique and exotic sulfur deposits. Beautiful, abundant, and pure, the deposits remain almost untouched. Experts are seeking special protection for Lastarria, calling the sulfur deposits an exceptional geological patrimony. Photo by Guy Wenborne; reprinted with permission. Text by Sofía Otero, CEGA. ■