GEOTHERMAL RESOURCES COUNCIL

Bulletin

Vol. 47, No. 2
March/April 2018

Geothermal Reservoir Engineering

Old & new methods of expanding production

The New Geothermal Generation

Interview with up-and coming geothermalist

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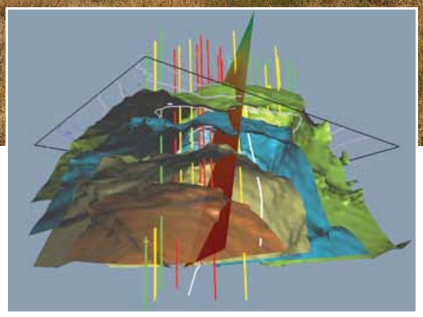

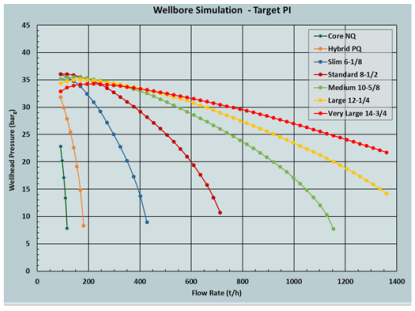

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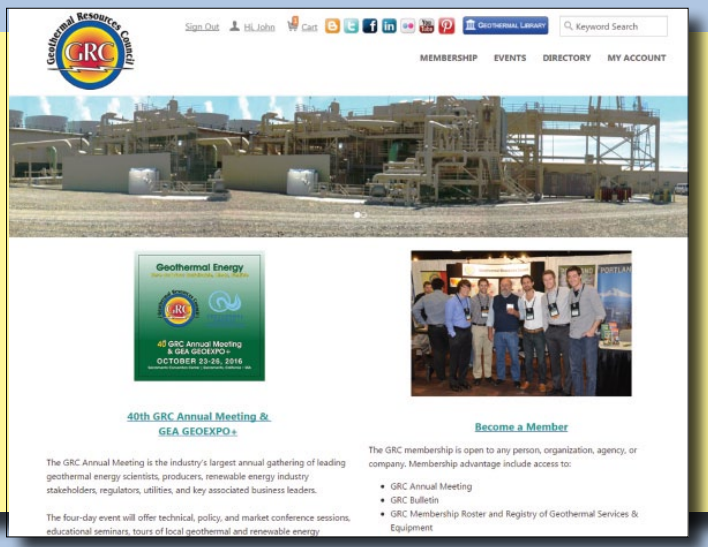
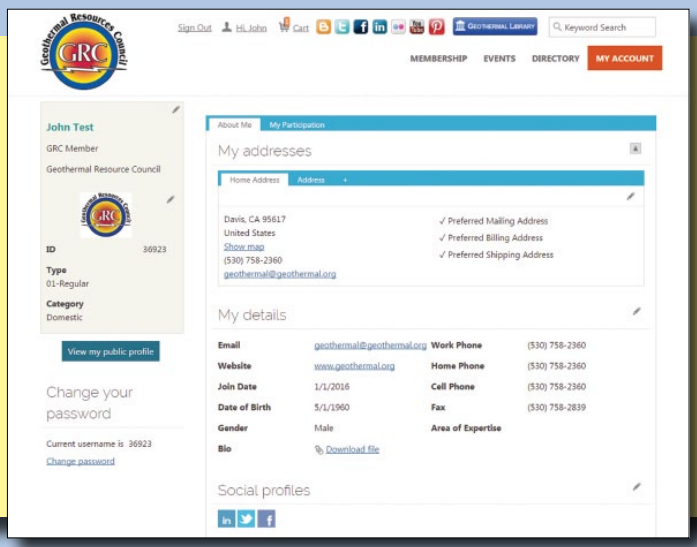
The New GRC Membership Website

www.my.geothermal.org

Highlights Include:

- **Events:** Allows you to register for GRC Events such as the GRC Annual Meeting.
- **Directory:** Allows you to search and view other GRC members' public profile. Only available to current members.
- **My Account:** Allows you view your profile, update your information, renew your membership and pay invoices.
- **Shopping Cart:** You can now pay all your dues and invoices together.





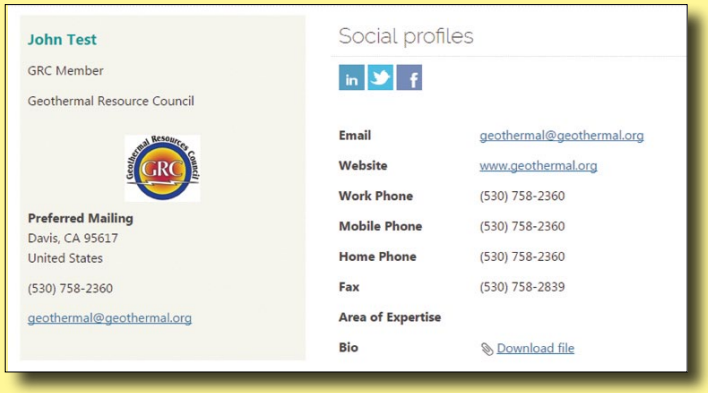
My Account:

- **Photo:** You can now upload a headshot of yourself
- **Bio:** Allows you to upload your bio or resume that can be viewed and downloaded by other GRC members.
- **Social Media Links:** You can now link your personal social media sites to your profile for other members to view.

Update Your Profile Today!

Public Profile:

- **Exclusive Access:** Restricted to current GRC Members only.
- **Advertise Your Services:** Members can find your information and download your bio/ resume.
- **Stay Connected:** Allow members to follow you on your social media links.



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Geothermal Resources Council

P.O. Box 1350
Davis, CA 95617-1350

Phone: 530-758-2360
Fax: 530-758-2839

www.geothermal.org

Office & Events Manager
Estela Smith
grc@geothermal.org

Communications Director/Editor
Ian Crawford
icrawford@geothermal.org

Membership/Office Associate
Anh Lay
alay@geothermal.org

Librarian
Brian Schmidt
bschmidt@geothermal.org

Graphic Designer/Advertising
Chi-Meng Moua
cmoua@geothermal.org

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COVER: *Flow Test at Theystareykir, Iceland*, by Bastien Poux, Pontoise, France. This picture was taken in February 2016 during a massive flow test of several wells at the Theystareykir geothermal field. Honorable Mention in the 2017 GRC Photo Contest.

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Coming Soon...

We will be publishing articles on the following subjects in forthcoming issues of the *GRC Bulletin*.

May/June
Feature article: *Geothermal/Solar-thermal Hybrid Technology*

July/August
Feature article: *Geothermal Associated with Oil & Gas Operations*

September/October
Feature article: *Field Operations/Direct Use; Preview of GRC Annual Meeting & Expo in Reno, Nevada.*

November/December
Feature article: *Geochemistry; Review of GRC Annual Meeting & Expo in Reno, Nevada.*

Let us know if you want to contribute to a particular issue. For information on advertising contact **Chi-Meng Moua** at cmoua@geothermal.org or 530.758.2360 ext. 105.

President's Message

by Maria Richards

Horizontal Flow

Geothermal projects incorporate many aspects of our human knowledge. We're not just single discipline focused. Even if we are specialists, we tend to be people with broad curiosities. Curiosity may be the thread connecting all of us in the geothermal community. In our geothermal companies, I image curiosity generating ideas which flow from desk to desk, down hallways, and then across the land via conversations and papers. As a geographer, I've participated in mapping the spread of ideas. They too reflect a distribution of flowing lines, like rivers or roads, some with abrupt stops and others that move like super highways.

This concept is on my mind because of a discussion with Dave Blackwell about the flow of water through the Columbia River and Snake River Plain basalts. In these locations, water is flowing horizontally at separated intervals, with hundreds of meters between them, and in many sections with air in those interval pores. We, as humans, don't grasp this concept easily. Water naturally flows down, gravity pulls it down, thus to have air between different formations is possible (perched aquifers exist near the surface) yet are not common and certainly not at kilometer-scale depths. Once the groundwater table is drilled into, air is not supposed to exist below it. Water's common pathways overrides our curiosity in these large basalts, and we are less likely to question the patterns seen. What fascinates me is how Earth treats the last perched layer as if it is the ground surface and from that depth on downwards the heat flow starts to rise on a gradient representative of the area. For researchers new to deep basalt hydraulics, they use the upper portion of a well temperature and state the heat flow is cold because of the isothermal pattern, thus missing the bigger picture of high heat trapped at depth.

Keeping ideas flowing is my goal, yet my next steps for the GRC and GEA (Geothermal Energy Association) unification are changing. Recently I realized, GRC's team was moving forward on one pathway while GEA's team was on another. My perspective was too tight a timeline. A newbie mistake, as this is my first unification process. The effort went from exciting and efficient to confused and frustrating over the past few months. You may have experienced that too if you were wanting to renew your membership, or join the new Policy Committee (we apologize for any inconvenience!). The good news, we are back on the same pathway to success and you will see more progress on the transition to one organization during the next months. The GRC and GEA staff both deserve kudos for working though some awkward months as they received different signals from their Board leadership and tried to piece it together and keep our organizations productive.

In the midst of all this transition, other aspects of the GRC keep moving positively forward. There are some super heroes in the geothermal community who keep volunteering! Rob Podgorney (annual meeting technical paper chair), Elaine Sison-Lebrilla and Kelly Blake (annual meeting co-chairs), and Dan Hoyer (leading our Executive Director search, we're getting closer!) are on top of my list right now. As you read this Bulletin, you're hopefully already thinking about attending the GRC Annual Meeting and Expo this fall in Reno. Fred Henderson asked for a special section within the expo for lease sales and project discussions (you're encouraged to join!). The GRC Student Committee wants you to participate in their trivia night contest – a reason to play and laugh together as we exchange knowledge across the table and room.

From storage to overlapping energy opportunities, we as a community are being given the ability to re-assess our norms and directions with renewed curiosity. It's spring! Ah, a fresh start for geothermal ideas to flow across hallways and oceans. Here's to many reasons to be curious and to delve deeper! ■

Communication from the GRC

by Ian Crawford
Director of Communications

Reserve your room now.....

https://aws.passkey.com/event/49537648/owner/7268/home

Reservations can now be made for hotel rooms for next year's GRC Annual Meeting & Expo in Reno, Nevada, USA, October 14-17, 2018

All the events and accommodation are in one location, the luxurious **Peppermill Resort Spa Casino.**

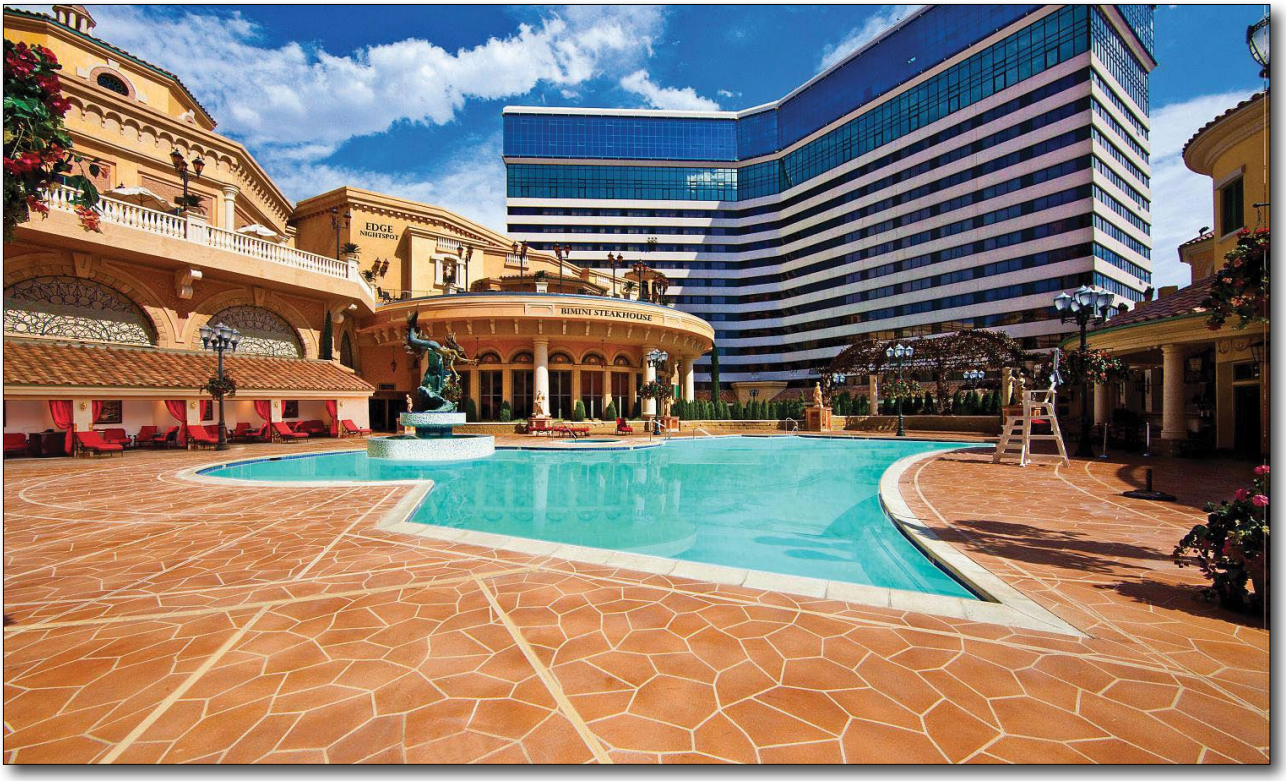
There is a choice of three room styles at discounted rates. In the **Peppermill North and West Wings** the room rates start at an affordable **$89 a night**. The award winning luxurious **Tower Rooms** offer panoramic views of the majestic Sierra Nevada mountains and are available from **$109 a night**. Top of the line are the lavish accommodations in the **Tuscan Tower** at **$149 a night. The discount ends September 19, 2018.**

Attendees can make their reservations on a secure website prepared specially for the GRC. The links are available from the GRC Annual Meeting website at: www.geothermal.org/meet-new.html

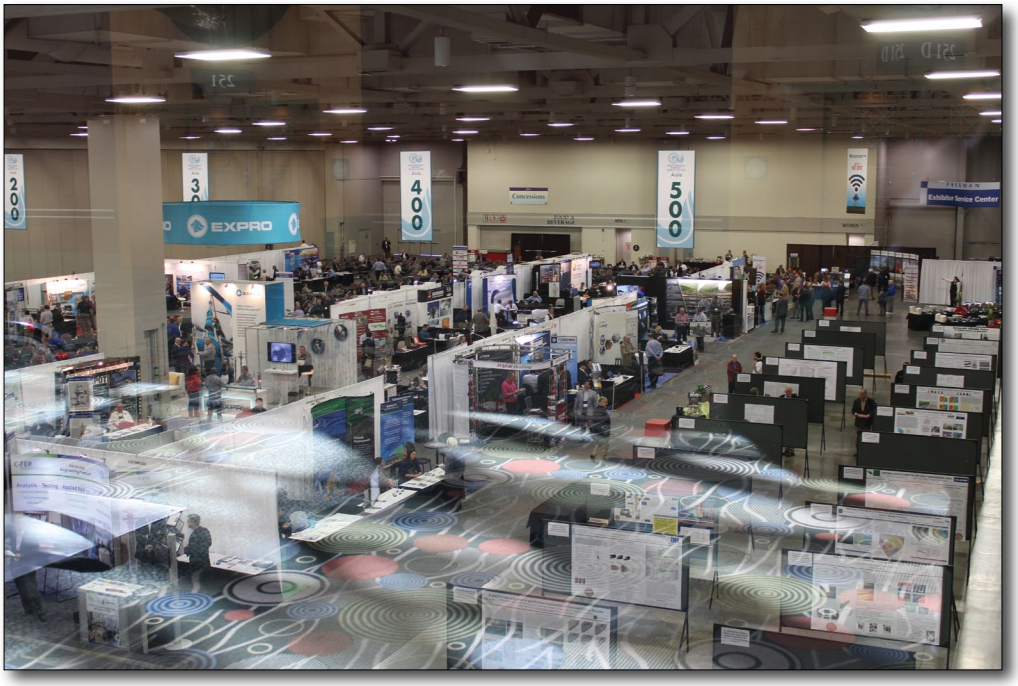
Exhibitors can Now Reserve a Booth

The 3-day expo held in conjunction with the Annual Meeting will provide ample opportunities for networking. The GRC Expo presents exhibitors with the opportunity to maximize their exposure at the largest annual geothermal energy gathering in the world.

All the essential information is available on a new website hosted by the GRC at http://my.geothermal.org/GRC/Exhibitor/GRC/Exhibitor_Portal/Exhibitor_Portal.aspx



All the events and accommodation are in one location, the luxurious Peppermill Resort Spa Casino, the only resort in the United States whose heating source is totally provided from geothermal energy produced on the immediate property.



The Expo hall in 2017. Photo by Ian Crawford.

With the international geothermal power market growing and projects currently under development in all corners of the world, the 2018 Expo will be an exciting international gathering of geothermal industry leaders, academics, financiers, policy leaders, students, and geothermal enthusiasts.

This is the event to learn about the latest developments in geothermal energy. Last year, the GRC Annual Meeting & Expo hosted more than 1,000 representatives from 35 countries. In 2018, we anticipate an even larger audience.

Exhibitors who desire a booth at the Expo should contact the GRC. Contact Anh Lay at alay@geothermal.org or (530) 758-2360 for more information.

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GRC Scholarships 2018

The Geothermal Resources Council (GRC) is announcing the following changes to the 2018 GRC Scholarship Awards:

Undergraduate Scholarship Awards:

- The number of recipients will be increased from two to three;
- Instead of a lump sum, each recipient will receive a stipend of $250 and travel expenses (up to $750) to attend the annual GRC meeting (double occupancy);
- Each recipient will be required to either present at the meeting (poster or paper such as from a senior thesis) or prepare a report for the GRC Bulletin describing what they learned from attending the meeting and how they would utilize what they learned for their educational or career path.

Graduate Scholarship Awards:

- The number of recipients will be increased from three to five;
- The amount of each award will remain $2500, but travel expenses will now be considered part of this total rather than offered separately;
- Each recipient is required to submit a paper on his/her research (or research progress) to be published in the GRC Transactions and deliver results at the meeting as either a poster or oral presentation;
- If the recipient presents in the year of the award then the full $2500 is awarded;
- If the recipient defers to present/publish the following year then $750 is withheld to cover travel expenses for when the recipient presents.

The Student Project Award will not being awarded this year to allow us to increase the number of graduate awards.

If you have any questions regarding the GRC Scholarship Awards, please contact Brian Schmidt at bschmidt@geothermal.org or (530)758-2360, ext. 104. ■

Have Your Say!

If you would like to comment on any column or article in the *GRC Bulletin* or have an opinion on a topical subject that will interest our readers, please email the editor, **Ian Crawford** at icrawford@geothermal.org or mail to Geothermal Resources Council P.O. Box 1350, Davis, CA 95617-1350.
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Inside Geothermal

The Top Geothermal Energy Cities in the World

CDP, formerly the **Carbon Disclosure Project**, runs a global disclosure system that enables companies, cities, states and regions to measure and manage their environmental impacts. From this they have compiled a list of the top renewable energy cities in the world.

City short name	Country	Geothermal (%)
Chorrera	Panama	100
León de los Aldamas	Mexico	73.86
Municipio de Mérida	Mexico	50
Akureyri	Iceland	30
Nairobi	Kenya	30
Reykjavík	Iceland	30
Kisumu	Kenya	27
Kapiti Coast	New Zealand	17
Auckland	New Zealand	16.2
Wellington	New Zealand	16
Parañaque	Philippines	13.3
Las Vegas	USA	13.15
Inje	South Korea	12
Dar es Salaam	United Republic of Tanzania	10
Nakuru	Kenya	10
Long Beach	USA	9
Santa Monica	USA	9
West Hollywood	USA	9
Reno	USA	8.67

Of the 570 plus global cities reporting to CDP, **over 100 now get at least 70% of their electricity from renewable sources** such as hydro, **geothermal**, solar and wind. The top 20 cities that source geothermal energy are topped by the city of **Chorrea** in **Panama** (can a reader explain why?!). Other more well-known geothermal cities complete the list. *Global Geothermal News.....*

NORTH AMERICA

Calpine Takeover Complete - New Owner Expects No Changes in Operations

Calpine Corporation has announced the completion of their acquisition by an affiliate of **Energy Capital Partners** and a consortium of other investors, including **Access Industries Inc.** and **Canada Pension Plan Investment Board (CPPIB).**

Tyler Reeder, a partner at Energy Capital Partners, said, "We do not expect to make any changes to the way Calpine operates its business and intend to remain focused on providing the high level of service to which Calpine's wholesale and retail customers have become accustomed."

Calpine operates 13 geothermal power plants at The Geysers, north of San Francisco, California, generating 634.1 net megawatts. *Global Geothermal News.....*

Ormat Expects to Complete Acquisition of U.S. Geothermal in 2nd Quarter

Ormat Technologies, Inc. has announced financial results for the fourth quarter and full year ended December 31, 2017. **Isaac Angel**, Chief Executive Officer, commented on the results and the imminent takeover of U.S. Geothermal Inc.

"Ormat enters 2018 in its strongest competitive position ever, with a growing portfolio of operating power plants, a robust pipeline, and new opportunities as a result of strategic M&A activity," commented Isaac Angel. "**During 2017, we added approximately 90 MW of new capacity** from our Platanares and Tungsten Mountain power plants, and our share of the Sarulla power plants, and reached a **total portfolio of approximately 800 MW**. The new power plants will contribute to our earnings growth and margin expansion in 2018 and beyond. Looking ahead, our pipeline remains strong, and **we are targeting an incremental 190-200 MW from organic growth by the end of 2020**."

"In addition, we recently announced the signing of a definitive merger agreement pursuant to which **we will acquire U.S. Geothermal Inc.**," Mr. Angel continued. "This acquisition, which **we expect to close in the second quarter of 2018**, will diversify our operations in the United States, and will create additional opportunities to expand our development pipeline. Upon closing of the transaction, we are confident that we can leverage our unique core capabilities to improve the generation and efficiency of U.S. Geothermal's operating portfolio and increase its profitability in 2019". *Global Geothermal News.....*

Golden State System Operator Promises to Do More to Promote Development of Geothermal Energy

As reported by **Sammy Roth** of the *Desert Sun*, three years ago, the **Imperial Irrigation District (IID)** sued **California Independent System**

Operator (CAISO), the nonprofit corporation that manages most of California's power grid, accusing the grid operator of stifling clean energy development in Imperial County, one of the state's poorest counties, and plotting to "crush IID out of existence." The Imperial Valley-based power provider also sued the grid operator under the California Public Records Act, demanding documents that the public utility suspected would undermine Brown's efforts to start a regional power grid.

Those lawsuits have now been settled — and both sides are pleased with the outcome.

CAISO has agreed to upgrade a power line that will allow more electricity to flow from the Imperial Valley to the rest of the state. Outside the legal settlement, **CAISO has said it will do more to promote development of geothermal energy** — a top priority for IID, which wants to see new geothermal power plants build by the southern shore of the Salton Sea. *Global Geothermal News.....*

Drilling Begins at Nevada FORGE Site

Drilling has Begun at the **Frontier Observatory for Research in Geothermal Energy (FORGE)** site at **Fallon** in **Nevada**.

Photo by **Bridget Ayling,** *Director, Great Basin Center for Geothermal Energy. Global Geothermal News.....*

Multi-Well Flow Test Confirms Resource Estimate of 25-47 MW at Nevada Geothermal Project

U.S. Geothermal Inc. has successfully completed a multi-well flow test at the recently drilled Southwest Zone wells at the **San Emidio II geothermal power project** in **Nevada**. Flowing temperature from the three wells ranged from **319°F** to **325°F**. Test results confirm a resource estimate of **25 MW (at 90% probability)** up to **47 MW (at 50% probability)**. *Global Geothermal News.....*

Reno to Further Exploit Geothermal Resources

The sometime host city for the **GRC Annual Meeting & Expo** could build a new swimming pool complex heated by the same geothermal resource as the **Peppermill Resort Spa Hotel**.

The **Reno** city council voted to move ahead in partnership with a citizen's group, Sierra Nevada Community Aquatics, to raise funding to build and operate a **USD 15-20 million dollar** facility on the site of the old **Moana pool**.

The **Moana Springs Aquatic Center** would include not only a competition sized pool, but a fitness center, an outdoor family water park area and hot springs. **The Moana site sits on an active geothermal spring** and historically hosted mineral baths. *Global Geothermal News.....*

Chinese Company Reports Successful Operation of Nevada Geothermal Power Project

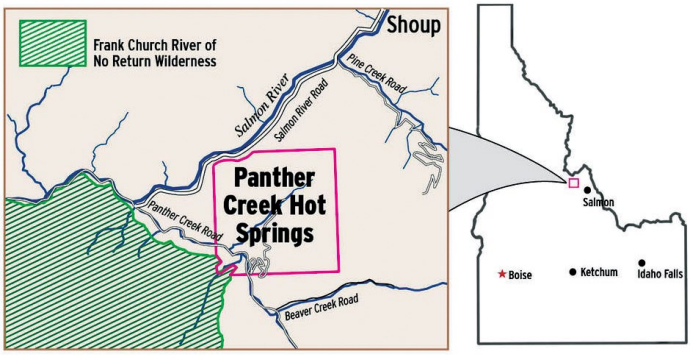
China's **Zhejiang Kaishan Compressor Co.**, has announced that the **Wabuska geothermal power plant in Lyon County, Nevada** has successively connected to the grid and is able to generate power.

According to the company, as of the first week of March, both units have been operating steadily for nearly two weeks, generating **a total of 4.4 MW power**. Following a three-month trial period, the power generation capacity can be increased by about 20 percent. *Global Geothermal News.....*

Inside Geothermal

Final Environmental Impact Statement Recommends Denying Lease for Idaho Geothermal Project

The **Salmon-Challis National Forest** is proposing to **deny a lease** to develop a geothermal power plant at **Panther Creek Hot Springs**, about 20 miles northwest of the town of **Salmon** in **Idaho**.



Ormat Technologies wants to develop the plant with an initial 10-year lease. Prior to any ground-disturbing activities, the company would have to submit additional applications. *Global Geothermal News.....*

1.2 Million Dollar Investment in Hinton Geothermal Heat Project

The **Honourable Navdeep Bains**, Minister of Innovation, Science and Economic Development and Minister responsible for Western Economic Diversification Canada (WD), has announced **CAD (Canadian Dollars) 400,000** for an engineering and design initiative to determine the viability of a Geothermal District Energy System in the **Town of Hinton, Alberta, Canada**.

The Government of Alberta and Alberta Innovates will provide a total of CAD 800,000, bringing the investment amount for the Town of Hinton's project to **CAD 1.2 million.**

The proposed system would **produce renewable geothermal heat from marginally producing oil and gas wells** to heat the town's public buildings. *Global Geothermal News.....*

Sale of Canadian Geothermal Energy Company Completed

Innergex Renewable Energy Inc. of Québec, Canada, has announced the completion of the previously disclosed acquisition of **Alterra Power Corp.** of Vancouver, British Columbia, Canada, by way of an arrangement agreement pursuant to which Innergex acquired all of the issued and outstanding common shares of Alterra for an aggregate consideration of **CAD 1.1 billion**, including the assumption of Alterra's debt.

Alterra Power has a 54% stake in the 54 MW (Net Installed Capacity) **Reykjanes (1&2) geothermal power plant** and a 54% stake in the 49 MW (Net Installed Capacity) **Svartsengi geothermal power plant** which includes a 30% stake in the **Blue Lagoon Geothermal Spa and Resort**. *Global Geothermal News.....*

Impact Documents for Saint Lucia Geothermal Resource Development Project Available

Panorama Environmental of San Francisco, California has prepared various documents pertaining to the **Saint Lucia Geothermal Resource Development Project** in the Soufrière, Choiseul, and Laborie neighborhoods.

The *Environmental and Social Impact Assessment* (ESIA), which entails a preliminary assessment of environmental and social impacts associated with the exploratory drilling phase of the project, has been completed. Also completed is a pre-feasibility study which entails initial financial, economic, legal and power systems evaluations. Follow the link to the article to access the documents: *Global Geothermal News.....*

CENTRAL & SOUTH AMERICA

Feasibility Studies Announced for Additional 105 MW of Geothermal Power Projects in Nicaragua

The executive president of the **Nicaraguan Electricity Company (ENEL), Ernesto Martínez Tiffer**, has announced the start of feasibility studies for three geothermal power projects located in the **Cosigüina Volcano, Casita- San Cristóbal** and **Mombacho Volcano** regions of Nicaragua.

Each power plant will have a generating capacity of **35 MW** and be **built within six years**. *Global Geothermal News.....*

Polaris Confident New Wells at Nicaragua Geothermal Project will Increase Capacity to 72 MW

Toronto-based company **Polaris Infrastructure Inc.** has reported its audited financial and operating results for the year ended December 31, 2017. Included are comments on development of the **San Jacinto geothermal project in Nicaragua.**

"We are pleased with the progress we've made this year towards our most immediate objective, being the optimization of the San Jacinto project" noted **Marc Murnaghan**, Chief Executive Officer of Polaris Infrastructure.

"We are optimistic that the wells we recently drilled, once connected, will bring us **very close to the 72 MW (net) level** we have been targeting since we initiated the 2015 recapitalization transaction." *Global Geothermal News.....*

Geothermal and other Renewable Energies to Replace Coal Plants in Chile

Drilling in the Southern Winter. Tolhuaca Volcano, Chile. Taken at sunset in late June, 2011 by **Jim Stimac**. *GRC Photo Contest 2011.*

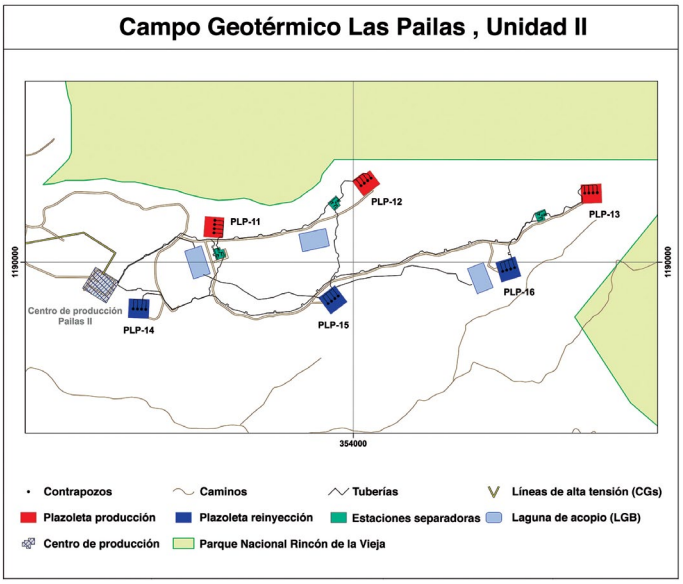
President Michelle Bachelet says Chile will not build any more coal plants without carbon capture and will start replacing existing plants with cleaner sources, including geothermal energy.

Thanks to its geographical and geological context, Chile has excellent potential for renewable energy. With 15% of the world's volcanoes and almost 10% of the world's geysers, **the country has vast geothermal potential**.

Coal and oil together generate more than half of the country's energy, with hydro providing just over 30% in 2017. *Global Geothermal News.....*

Drilling Completed for 55 MW Costa Rican Geothermal Project

The **Costa Rican Electricity Institute (ICE)** has finished drilling 21 wells to guarantee the availability of the geothermal resource at the **Las Pailas II Geothermal Plant**, in **Curubandé de Liberia, Costa Rica**. *Global Geothermal News.....*



Transmark Chile Obtains Exploration Concession for Tolhuaca Geothermal Field

The Chilean Energy Ministry has granted **Transmark Chile SpA** a Geothermal Exploration Concession in the area known as "**Peumayén**" (meaning "The Dream Place" in the local Mapudungun language) located in the **Quilaco** district of the **Biobío Region** and the **Curacautín** district of **the La Araucania Region**, southern Chile.

Flow test of Tol-4 well at Tolhuaca geothermal prospect in Southern Chile by **Silke Lohmar**. *3rd Place, 2013 GRC Photo Contest.*

Within the Peumayén Concession lies the **Tolhuaca Geothermal Field**, which has been widely studied since the early 2000's, with a full-size exploration well drilled and steam production tested to **an equivalent in power of 12 MWe.** Transmark Chile intends to conduct additional exploration studies and expand the current knowledge of the area to define the extent of the reservoir and the potential for base-load renewable power generation. *Global Geothermal News.....*

Geothermal Energy to be Included in Argentina Renewable Energy Tender

A new renewable energy tender in Argentina, Round 3 under the country's **RenovAr program**, will be held in the second half of 2018. The sale of bidding documents will start in September and the process will be finalized by the year end.

The size of Round 3 would be similar to that of Round 2, which sought 1,200 MW of capacity. **However, this time geothermal technology will be included with the participation of the 10 MW Copahue project.** As in the previous tender, there would be quotas for different regions and technologies. *Global Geothermal News.....*

AUSTRALASIA

Drilling Uncovers Hot and Active Hydraulic System in Geothermal Reservoir

In a recent scientific paper **John Townend** *et al.* published measurements made in the **Deep Fault Drilling Project** DFDP-2B borehole and studied the hydraulic properties of the **Alpine fault** in southern **New Zealand** and the damage zone surrounding it. Using downhole logging equipment and surface measurements, the scientists measured temperature, pressure, and a broad range of other geophysical parameters along the length of the borehole.

The team discovered that the rocks surrounding the Alpine Fault **are much hotter than anticipated** and are **extensively fractured**. Mud level data revealed that the hanging wall portion of the fault—the up-thrown (Pacific) side of the fault—contains an **active hydraulic system** in some areas. Scientists observed that mud levels equilibrated rapidly during the drilling, showing that some fractures in the rock surrounding the fault **can transmit large volumes of water in a matter of hours.** *Global Geothermal News.....*

Petrophysical, Geochemical, and Hydrological Evidence for Extensive Fracture-Mediated Fluid and Heat Transport in the Alpine Fault's Hanging-Wall Damage Zone, by John Townend, et al. Geochemistry, Geophysics, and Geosystems, https://doi:10.1002/2017GC007202, Volume 18, Issue 12, December 2017.

Geothermal to Power Milk Processing Plant on North Island

A group of **Maori** organizations has partnered with Japanese food company **Imanaka** to develop a milk processing plant powered by geothermal energy in **Kawerau** in the **Bay of Plenty** region on the North Island of **New Zealand**.

Kawerau industrial site (Courtesy Ngati Tuwharetoa Geothermal Assets)

The plant will be developed on land owned by **Putauaki Trust** with its principal energy supply sourced from the **Ngati Tuwharetoa Geothermal Assets** owned geothermal network. *Global Geothermal News.....*

ASIA

Geothermal Power Project to Go Ahead in Taiwan

CPC Corp., Taiwan and **Taiwan Power Co.** (Taipower) have signed a cooperation agreement to develop geothermal energy at **Renze Hot Springs** in **Yilan County**, in the east of **Taiwan**.

Under the cooperation plans, CPC would drill one or two wells near the hot spring to conduct tests, which if successful, would enable CPC to hand over the project to Taipower, which would be tasked with generating geothermal power. *Global Geothermal News.....*

ORC Geothermal Power Plant Begins Operations in Taiwan

The new ORC geothermal power plant is built with equipment from Chinese company Zhejiang Kaishan Compressor Co. (Photo courtesy Raoul Kubitschek)

Raoul Kubitschek of **Taiwan Energy Co.**, Ltd. and Ruprecht-Karls-Universität Heidelberg, Germany reports that a **30kw Organic Rankine Cycle (ORC) geothermal power plant** has started operations in **Zhiben, Taitung** on the south-east coast of Taiwan.

The power is sold to Taipower under a Feed-in Tariffs (FIT) scheme. *Global Geothermal News.....*

PGE Postpones Mount Lawu Geothermal Power Project

PT Pertamina Geothermal Energy (PGE), a subsidiary of PT Pertamina (Persero), has decided to postpone the development of the **Mount Lawu Geothermal Working Area** in Central Java. Non-technical issues are one of the main factors that affected the decision to not make the 60,030 hectares (ha) project a development priority. *Global Geothermal News.....*

Turkish Company Starts Work on 110 MW Aceh Geothermal Project

Turkish company **Hitay Holding AS** has started work on the **220 MW Gunong Geurudong geothermal project** in **Bener Meriah** in **Aceh** province, Indonesia after receiving permission from the Ministry of Energy and Mineral Resources.

According to the company, Gunong Geurudong has a huge geothermal potential of **up to 220 MW**. 110 MW will be developed in the first phase, and 110 MW in the second stage. *Global Geothermal News.....*

Location of the Gunong Geurudong geothermal power project in Aceh province on the northwest tip of Sumatra Island, Indonesia

12 MW Maibarara Geothermal Power Plant Unit II Connected to Grid

Maibarara Geothermal Inc. (MGI) has successfully commissioned a second **12 MW unit** at the **Maibarara geothermal power plant**. The facility was synchronized with the Luzon grid on March 9. *Global Geothermal News.....*

Location of the Maibarara Geothermal Power Plant on the island of Luzon in northern Philippines.

Good Potential for Geothermal Energy in Oman

A recent article, "Geothermal energy resources in Oman", explores the potential of using geothermal energy resources for electricity generation in Oman.

The temperature of **53 boreholes** in Oman **is more than 100°C**, meaning they can be used in binary geothermal plants for electricity generation. **The maximum temperature (173.68°C)** is at Petroleum Development Oman well '**Makarem-I**' located in the northern part of Oman.

The article concludes there is opportunity for Oman to explore the potential of geothermal in more detail. This will help the country to reduce its dependency on oil and gas and compete in the region towards adopting renewable energy. *Global Geothermal News.....*

"Geothermal energy resources in Oman", by Tariq Umar, MSc, CEng, MICE. https://doi.org/10.1680/jener.17.00001, *Proceedings of the Institution of Civil Engineers - Energy*. ISSN 1751-4223 | E-ISSN 1751-4231. Volume 171 Issue 1, February, 2018, pp. 37-43 - Themed issue on urban transitions to fossil-fuel-free futures.

Location of Oman on the Arabian Peninsula.

Geothermal Energy Pioneers Wins Top Award in Israel

Yehuda and **Yehudit Bronicki**, founders of **Ormat Technologies,** will be jointly awarded **the Israel Prize for Industry**, Education Minister **Naftali Bennett** has announced.

"Yehuda Bronicki, a visionary, an inventor, born in Poland who survived the Holocaust and together with his wife, Yehudit (Dita) Bronicki, one of the first businesswomen and female entrepreneurs in Israel, a pioneer in her field, jointly established the Ormat Group and made it a world leader in geothermal energy," the prize committee wrote in its decision.

The **Bronickis established Ormat in 1965** and ran the company until **they retired in 2014**. *Global Geothermal News.....*

AFRICA

Tender to Supply Drilling Rigs for Aluto Langano Geothermal Power Project

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ETHIOPIAN ELECTRIC POWER

Ethiopian Electric Power (EEP) is preparing to launch a combined tender to supply two drilling rigs and accessories and associated drilling services and maintenance services for the drilling of 8-20 wells in **Aluto, Ethiopia. Bids must be delivered on or before May 11, 2018**

- **Phase I: Supply of Two Geothermal Drilling Rigs** with all its Accessories, Heavy Machinery, Trucks & Vehicles, Drilling Consumable Materials and Base Camps in accordance with the specifications stated in the bidding document. In addition, the bidder is required to provide Directional Geothermal Drilling Equipment from its own ownership or rental bases from rental sources which will be required for directional drilling activities.
- **Phase II: Drilling Service for 8 wells** after delivering and using all the procured or supplied items in Phase I. Download the *Invitation for Bids (PDF)*. More information at *Global Geothermal News.....*

Completion of Transmission Line Helps Improve Dispatch of Geothermal Energy

Kengen's half year profit dropped from Sh4.6 billion in 2016 to Sh4 billion in the six months ending December 31st, 2017. However, at the same time the power generator saw **an increase in revenue** from Sh17.7 billion to Sh18.6 billion, an increase of 4.93 percent.

"This was due to higher energy revenues from geothermal and increased steam revenue following the completion of the **Olkaria-Suswa transmission line**," says Kengen Chief Executive **Rebecca Miano**.

Looking forward, KenGen says it's on course to complete the ongoing construction of the **158 MW Olkaria V power plant by 2019**. *Global Geothermal News.....*

Geothermal Energy to Power Nairobi - Mombasa Railway Line

Kenya Electricity Transmission Company (Ketraco) has signed a Shillings 24.2 billion (USD 239 million) contract with **China Electric Power Equipment and Technology Company (CET)** for the electrification of the **Mombasa - Nairobi** section of Kenya's Standard Gauge Railway (SGR).

Ketraco says power for the SGR will be **provided by geothermal power plants**, reducing CO_2 emissions from train operations to zero. *Global Geothermal News.....*

Drilling at Longonot Geothermal Power Project to Begin in June

African Geothermal International Limited (AGIL) will start drilling its first exploration steam well at the **140 MW Longonot geothermal power project**, located southeast of Lake Naivasha, **in June**. The firm expects to sink up to 40 wells in total. *Global Geothermal News.....*

Akira One Geothermal Project to Get European Investment Bank Loan

The **European Investment Bank (EIB)** has said a **EUR 155 million** (Sh19.5 billion) financing package for **Akiira Geothermal Ltd** to fund development of the **70 MW Akiira One Geothermal Project** at Olkaria, will be finalized soon.

Akiira Geothermal is owned by **Centum Investments** of Nairobi in conjunction with three other non-Kenyan entities, including **Ram Energy, Frontier Investment Management** and **Marine Power** of the USA. *Global Geothermal News.....*

EUROPE

First Meeting of Geo-Energy Europe Consortium

The **Geo-Energy Europe project** has created an international consortium aimed at increasing the performance & competitiveness of European **Small and Medium-sized enterprise (SME)**'s in industries involved in the use of the subsurface for energy, or "geo-energy".

The project officially started on January 1, 2018 and will initially run for 2 years. It involves 8 partners from 7 countries: **Pole Avenia** (coordinator) and **Geodeep** of France, **EGEC** of Belgium, **GEOPLAT** of Spain, **Geoenergy Celle** of Germany, **CAPES** of Hungary, **Jesder** of Turkey and **Geoscience Ireland**. *Global Geothermal News.....*

The founding members of the Geo-Energy Europe project.

GDF Latin America Wins European Geothermal Innovation Award

The European Geothermal Energy Council (EGEC) has awarded the **European Geothermal Innovation Award 2018** to the **Geothermal Development Facility (GDF) Latin America**, the first multi-donor climate initiative offering risk mitigation for surface studies and appraisal drillings during the exploration phase of geothermal projects in Latin America.

GDF is an innovative financial mechanism that fosters geothermal development in Latin America, both in South America and Central America. It has been operational for two years and is mainly **funded by the European Union and Germany**. The Lead Geothermal Project Manager is **Warren T. Dewhurst, Ph.D., P.E.**, a GRC Board member.

Ruggero Bertani, *President of EGEC, on stage with* **Christoph Sigrist** *(GDF) and the other finalists. (Courtesy EGEC)*

The other final candidates were **GPC Instrumentation Process** (France), for the design and implementation of the first sub-horizontal well in a geothermal project, a technique so far only used for oil drilling that allows the draining of more hot water over a longer length; **Politecnico di Torino** (Italy), for their system ENERTUN, that allows transforming a tunnel lining into a low enthalpy geothermal system; **PORCIÓ Ltd.** (Hungary), for the Gyopáros Production and Reinjection Geothermal System, in operation at Gyopáros Thermal Spa, and **RWTH Aachen University** (Germany), for the development of their Temperature Sensor Module (TSM) for detecting groundwater flow velocity and direction near a borehole heat exchanger. *Global Geothermal News*.....

Channel Island Company to Work with Mannvit on Innovative Geothermal Drilling Technology

Strada Energy, a geothermal project development company based in **Jersey** (a self-governing dependency of the United Kingdom), one of the Channel Islands just off the coast of Normandy, France, has entered into a services agreement with **Mannvit** of Iceland to provide engineering and other technical services for Strada's deep well geothermal district heating and electricity generation projects.

Strada Energy utilizes a patented drilling technology that claims to be able to drill deep wells in hard rock **up to 75% cheaper and faster** than conventional drilling technology. *Global Geothermal News*.....

Drilling Starts for Geothermal Resource for Cornish Open Air Pool

Drilling has begun of a **1.5km deep** geothermal well at the **Jubilee Pool** in **Penzance, Cornwall**, in south-west England. Planned to be completed by spring 2019, the development will see a section of the pool heated to 35°C by geothermal energy - becoming the first facility of its kind in Britain to make use of deep geothermal resources. *Global Geothermal News*.....

Successful Flow Test at Trias Westland Geothermal Heat Project

Geothermal waters flow into basins at the Trias Westland project (Courtesy T&A Survey Group B.V.)

Dutch company **Trias Westland** has performed a successful production test at it's direct use geothermal heat project near **Naaldwijk**, west of Rotterdam in the **Netherlands**.

Water from a **depth of 2.3 kilometers** was pumped up, the hot water flowed very smoothly into a basin and the gas in the water was flared off. Samples were taken and measurements made to determine, among other things, the pressure and temperature of the geothermal reservoir in the **Lower Cretaceous** Reservoir.

With this information the project team can start with the realization of the heat network. **The exact potential of the geothermal doublet will be known at the end of April, when the second well has been drilled and tested.**

The company **had wanted to drill down 4 kilometers** to the Triassic layer, but the temperature of the geothermal resource at that depth turned out not to be suitable for cost-effective heat recovery. *Global Geothermal News*.....

Danish Company to Help Develop German Geothermal Energy Projects

Deutsche ErdWärme and **Copenhagen Infrastructure Partners'**, on behalf of the Copenhagen Infrastructure III K/S fund, have announced that they have entered into a partnership

to develop a portfolio of geothermal energy projects in the **upper Rhine valley** of **Germany**. *Global Geothermal News*.....

Enel Green Power Withdraws From Bavarian Geothermal Project

A geothermal power plant outside **Weilheim** in **Oberbayern**, the capital of the district of **Weilheim-Schongau** in the south of **Bavaria, Germany**, will not be built.

According to **Enel Green Power** the test wells produced too little hot water for profitable power generation. *Global Geothermal News*.....

Increased Investment in Taufkirchen Geothermal Power Plant

Geothermie Taufkirchen GmbH & Co. KG has invested in the Taufkirchen geothermal power project south of Munich in southern Germany.

The company is a subsidiary of **Geysir Europe GmbH**, in which the drilling technology and geothermal energy specialist **Daldrup & Söhne AG** holds a 75.01 percent stake.

Geothermie Taufkirchen reached an agreement with **Axpo Power AG**, of Baden, Switzerland, under a share purchase agreement to acquire a 35% stake in **GeoEnergie Taufkirchen GmbH & Co. KG**, the manager of the geothermal power plant, retro-active 30th June 2017. *Global Geothermal News*.....

Daldrup & Söhne AG Gains Majority Share in Landau Geothermal Power Plant

Daldrup & Söhne AG and it's 75.01% subsidiary, **Geysir Europe GmbH**, have concluded a comprehensive settlement agreement with **Pfalzwerke AG**, **Ludwigshafen** to gain a majority share in the **Landau geothermal power plant** in the southern **Rhineland-Palatinate, Germany**. *Global Geothermal News*.....

Consortium Formed to Build 5 MW Tuscan Geothermal Power Plant

A *Development Agreement* has been signed between the Italian energy firm **Graziella Green Power** and the energy company **ENGIE**, through its subsidiaries **Storengy** and **ENGIE Italia** to build a **5 MWe net capacity binary cycle geothermal plant** in **Castelnuovo Val di Cecina** in the **Tuscany** Region of Italy. The project is set to begin in 2019. *Global Geothermal News*.....

Successful Operation of 2.2 MW Turawell Geothermal Power Project

China's **Zhejiang Kaishan Compressor Co.** reports the **Turawell geothermal power station** in **Hungary** has started operation and is generating power in good condition.

The power plant has been **operational since last November** and is able to **generate 2.2 MW power**, reaching 86 percent of the target capacity. *Global Geothermal News*.....

Greek Island Researching 5 MW Geothermal Power Plant

Location of Santorini in the Aegean Sea between mainland Greece and Turkey.

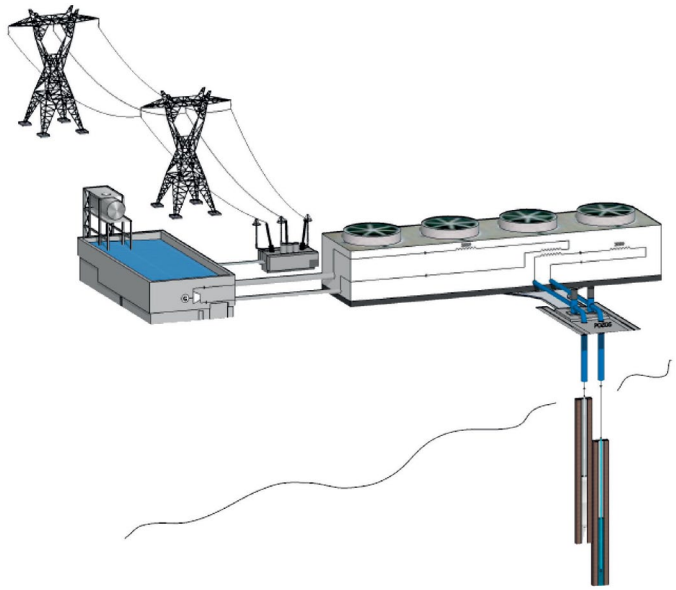
Studies by the Greek **Institute of Geology & Mineral Exploration (IGME)** have identified a low temperature geothermal field in southern **Santorini**, one of the **Cyclades** islands in the Aegean Sea and an iconic tourist destination.

According to IGME, the next step will be to conduct surface surveys and drilling to investigate the geothermal potential of the island and **the feasibility of 5 MW geothermal power plant**. *Global Geothermal News*.....

Handbooks on Potential of Geothermal Energy in the Canary Islands

Members of **Geoplat**, the Spanish Geothermal Technology Platform, and **Involcan**, the **Instituto Volcanológico de Canarias**, have helped published handbooks analyzing the potential of geothermal energy in the **Canary Islands in Spain**, as well as, the formation, technology and finance required for its correct development.

These handbooks - only available in Spanish - describe two different geothermal systems: one of high enthalpy for power production and other of medium and low enthalpy, for heating and cooling. Download the files by following the links in the article at *Global Geothermal News*.....



SCIENCE & TECHNOLOGY

"Heat Needle" Helps Produce Surface Heat Flow Map over Entire Geothermal Prospect

by Graeme Beardsmore (GRC Member), Technical Director, Hot Dry Rocks PL, Victoria, Australia

What if we could produce a surface heat flow map over an entire geothermal prospect for less than the cost of a single heat flow well? After 10 years of R&D, **Hot Dry Rocks PL** has demonstrated a tool that can do just that. We call it the **Heat Needle**.

The system works like this. We drill a one meter long rod into the ground with an off-the-shelf electric drill, and insert a set of highly sensitive and accurate thermal sensors. These sensors passively record the temperature in the top meter of the ground several times each hour for several months. When processed in the frequency domain, these

Photo courtesy Hot Dry Rocks PL.

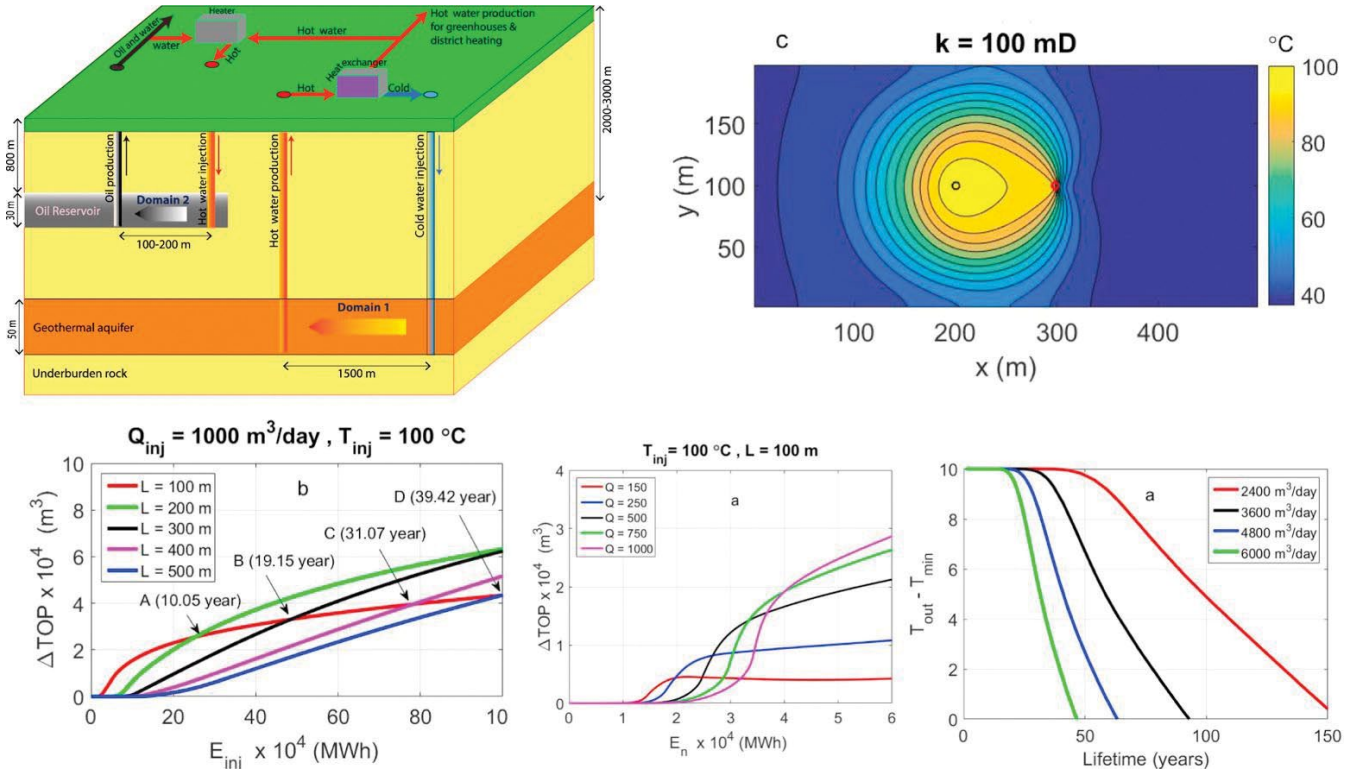
records of ground temperature tell us the thermal diffusivity of the ground to a precision of ~±1%. We also correlate our site-specific records of surface temperature against more diffuse but long-term satellite-derived records of surface temperature. That lets us extend our own surface temperature record many years into the past. *Global Geothermal News*..... ■

Combining Geothermal Energy Production and Thermal Enhanced Heavy Oil Recovery

In a recent paper, a new solution for harvesting energy simultaneously from two different sources of energy by **combining geothermal energy production and thermal enhanced heavy oil recovery** is introduced.

Numerical simulations are employed to evaluate the feasibility of generating energy from geothermal resources, both for thermally enhanced oil recovery from a heavy oil reservoir and for direct heating purposes.

The analyses suggest that the extra amount of oil produced by utilizing geothermal energy could make the geothermal business case independent and may be a viable option to reduce the overall project cost. Furthermore, the results display that



Courtesy Zaman Ziabakhsh-Ganjia et al.

the enhance oil productions are able to reduce the required subsidy for a single doublet geothermal project up to 50%. *Global Geothermal News*.....

Synergy potential for oil and geothermal energy exploitation, by Zaman Ziabakhsh-Ganjia, Hamidreza M. Nicka, Marinus E. Donselaara, David F. Bruhna. https://doi.org/10.1016/j.apenergy.2017.12.113. Applied Energy

Volume 212, 15 February 2018, Pages 1433–1447. ■

As part of an ongoing series of articles, we present the Technical Papers associated with the best presentations made at the last GRC Annual Meeting. The first featured paper is from the session on Reservoir Engineering / Reservoir Management / Modeling 2.

Temperature Recovery after Long-term Injection: Case History from Soda Lake, Nevada

James Lovekin[1], Monte Morrison[2], Greg Champneys[2], and James Morrow[1]
1 GeothermEx (A Schlumberger Company)
2 Cyrq Energy

Keywords
- injection
- thermal stimulation
- heat-up
- permeability
- temperature profiles
- pumped production

ABSTRACT

Well 25A-33 at the Soda Lake Geothermal Project illustrates the use of long-term, low-pressure injection as a means to enhance productivity in a well with potentially commercial temperatures but low initial permeability. This paper documents the recovery in temperature when the well was put on pumped production after an injection period of more than two years and a shut-in period of one year. The well's production temperature has risen from 304°F to 358°F (151°C to 181°C) over a period of 24 months. The technique of enhancing productivity by long-term injection is especially suitable for wells drilled in geothermal fields with ongoing operations, because the power plant can provide a ready source of injection water. The approach is particularly applicable for projects with pumped production wells, because the pumps give the operator the ability to set the flow rate at whatever level the formation can yield after stimulation by injection.

1. Introduction

New geothermal wells sometimes encounter promising temperatures but insufficient permeability for commercial production. Geothermal operators have several options with such wells, including re-drilling, hydraulic fracturing, and acidizing. Each or these approaches may be appropriate in specific circumstances, but they are all fairly costly, and none of them is assured of success.

If a long-term source of injection water is available (particularly if production and injection operations are already underway at a nearby plant), a less expensive alternative may be to use the new well for injection over an extended period, with the possibility of conversion to production at a later time. Injection of cooler water (even at low rates and pressures) can induce fractures through thermal stimulation (McLean et al., 2016).

One limitation of this approach is uncertainty about how quickly production temperatures will recover after extended injection. Forecasting by numerical modeling is difficult, because formation properties are changed by the stimulation process, and the parameters that control the recovery of injected water are typically not well known. In the face of such uncertainty, case histories can provide useful insight.

The Soda Lake Geothermal Project has successfully stimulated an initially unproductive well (25A-33) by over two years of injection followed by a year-long shut-in period for heat-up. As of February 2018, 25A-33 has been on pumped production for 24 months, and its production temperature is still rising. The purpose of this paper is to document the well's improvement and the conditions that have allowed the stimulation by long-term injection to be successful.

2. Project Description

The Soda Lake Geothermal Project is located in Churchill County, Nevada, about 7 miles northwest of the City of Fallon and about 70 miles east of Reno. Geothermal exploration at Soda Lake began in the 1970s (McNitt, 1990), and drilling in the field has encompassed 23 wells and 6 re-drills (Ohren et al., 2011). The field has two binary power plants (Soda Lake 1 and 2) which have been on line since December 1987 and February 1991, respectively. These plants have a combined nameplate capacity of 23 MW gross, but they have never operated at that level due to a combination of insufficient flow and below-design temperatures. In recent years, the combined output of the two plants has averaged about 8 MW net. Cyrq Energy has operated the project since 2015 (Alterra Power, 2015) and has announced plans to replace Soda Lake 1 and 2 with a new plant to be called Soda Lake 3 (Ormat, 2016). The new plant is projected to come on line in early 2019.

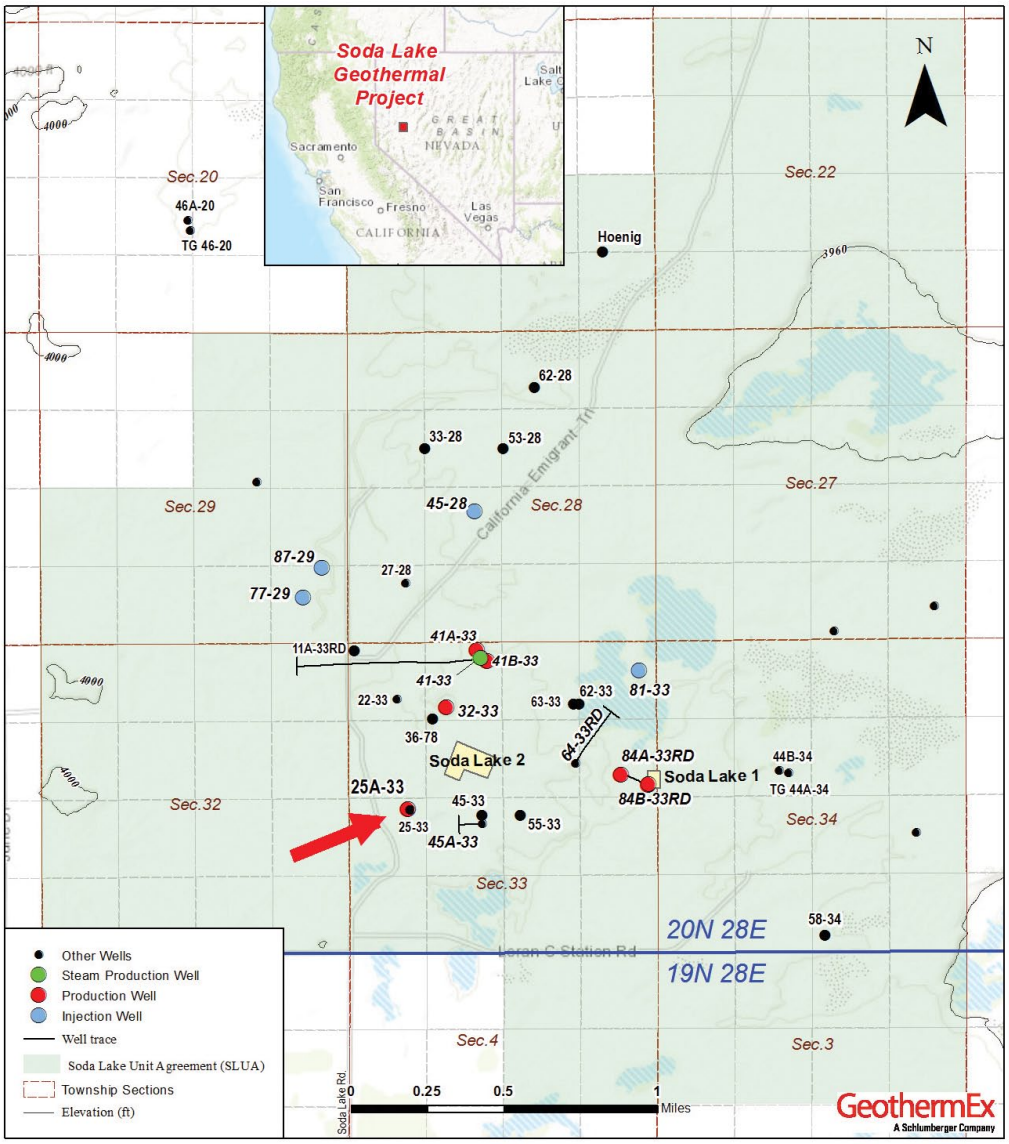


Figure 1: Well location map, Soda Lake Geothermal Project. Red arrow points to subject well (25A-33). Source: Adapted from GeothermEx (2016)

As of May 2017, the project had 6 wells equipped for pumped brine production (4 in active use), one steam production well (drawing on an induced steam cap in the reservoir), and 4 wells equipped for injection (3 in active use). The flow-weighted average temperature of the brine production wells was 325°F (163°C), with individual wells ranging from 294°F to 368°F (146°C to 187°C). Production from the steam well was used in a steam re-heat (SRH) facility to re-heat a portion of the discharge brine for recirculation through Soda Lake 2. The sum of the plant-inlet flows at both plants (including recirculation from the SRH) was about 5,800 gallons per minute (gpm) (about 370 liters/second [L/sec]).

Figure 1 shows the configuration of production and injection wells as of May 2017, as well as the location of the two existing plants. Well 25A-33 is located at the southwest margin of the wellfield. The nearest active well to 25A-33 is producer 32-33, about 0.3 miles (about 0.5 kilometers) away.

Figure 2 shows the history of production temperatures since the start of plant operations. From 1994 to 2010, production temperatures declined by about 17°F (9°C). Several operational changes in 2010-2011 brought the temperature decline under control. Average production temperatures remained stable at about 329°F (165°C) from 2011 to 2015. In 2015, one of the hotter wells (41B-33) went offline because of a pump failure, and the coolest well (41A-33) increased its production rate after a pump repair. As a result,

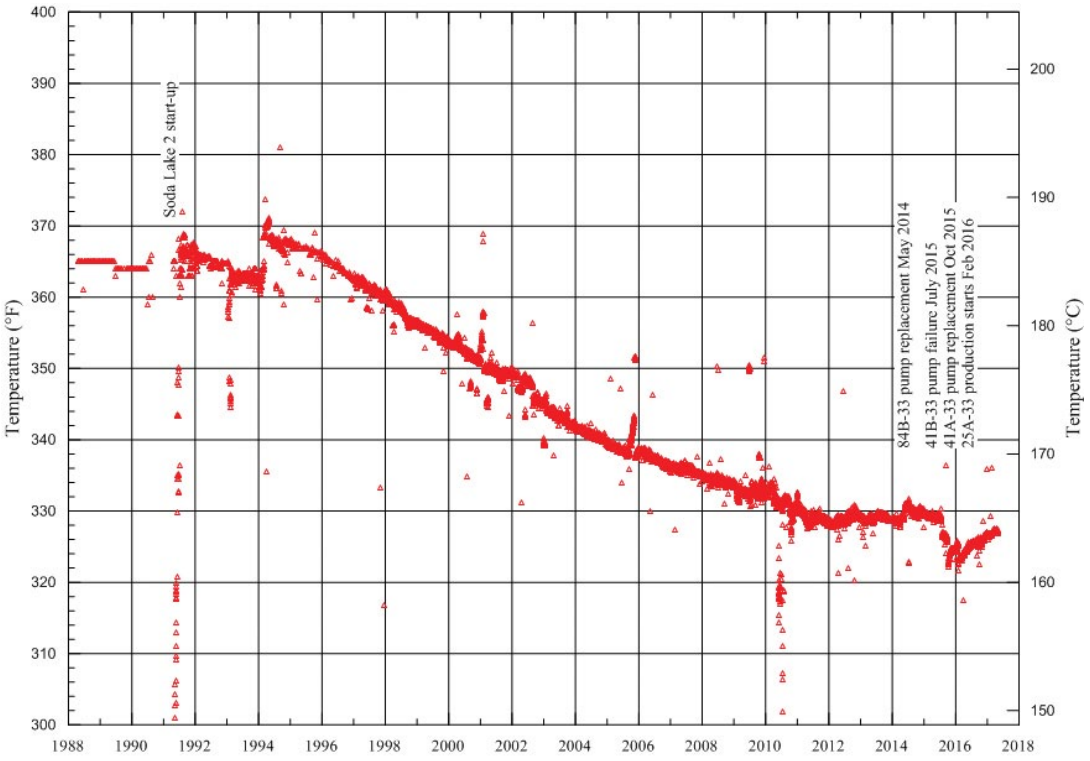


Figure 2: Flow-weighted average temperature of production wells at Soda Lake Geothermal Project

the average production temperature dropped to about 323°F (162°C) by the end of 2015. The rise in average production temperature since February 2016 has resulted from the 25A-33 heat-up.

3. Stimulation of 25A-33

When well 25A-33 was drilled in 2010, it had one of the highest temperatures ever measured at Soda Lake: 391°F (199°C) at a depth of 4,983 feet (1,519 meters) (Ohren et al., 2011). It was also one of the least permeable wells in the field, based on tests within the first few months of completion (Benoit, 2014). Table 1 summarizes the history of the attempts to improve the well's permeability and establish commercial production. These included injection tests at a range of pressures, detonation of explosive charges (deflagration), and repeated air lifts through 2 $^{7}/_{8}$ inch tubing. At injection pressures up to 400 psig (28 barg), the well took only about 150 gpm (25 L/sec). At the pressure of the plant's injection system ("system pressure," equal to about 140 psig [about 10 barg]), the well took little or no water (Ohren and Benoit, 2012). After a workover to remove bridges and install a 7-inch slotted liner, the well took just 7 gpm (0.4 L/sec) at system pressure. The deflagration on 1 February 2011 induced little improvement on its own: immediately after deflagration, the well took just 30 to 40 gpm (1.9 to 2.5 L/sec) at system pressure. However, during injection over 5 days after deflagration, the well's injection rate rose to about 600 gpm (38 L/sec) at system pressure. Benoit (2014) estimated the well's Injectivity Index to be about 1.9 gpm/psi (1.7 L/sec per bar) at that point, based on a pressure fall-off test. Three air-lifts over the following four months induced production of 300-400 gpm (19-25 L/sec), but flow from the well was never self-sustaining. The operator at the time (Alterra Power) decided to undertake long-term injection at system pressure, in hopes the well's permeability would improve over time.

A series of temperature surveys conducted in 25A-33 provides useful insight into the well's evolution (Figure 3). An early survey conducted through drill pipe just hours after circulation (14 August 2010) shows the well cooled by drilling, with the hint of cross-flow behind pipe based on isothermal temperatures over an interval from about 3,900 to about 4,300 feet Measured Depth (ft MD). By 26 August 2010, the temperature profile began to show a zone just above 5,000 ft MD as a significant inflection point, and a month later (24 September 2010), this was the zone that recorded the hottest temperature in the well (391°F [199°C]). The temperature reversal below this point suggests that this zone was the locus of a deep thermal plume that controlled the overall temperature profile of the well. A survey after a week of injection post-deflagration (8 February 2011) showed virtually all the injection water leaving the well just below 5,000 ft MD. Two surveys during the heat-up after this short-term injection

(Continued on page 26)

Table 1: Chronology of Soda Lake 25A-33

Date	Activity	Comment
27 Jun - 17 Aug 2010	Drilling	Drilled to total depth of 5,989 ft. Well was side-tracked at 3,905 ft to get around "drillable" packer that proved to be non-drillable.
14 Aug 2010	Static TP log	Logged during completion, just hours after last circulation. Low injectivity noted (24 bbl/hr = 17 gpm).
26 Aug - 24 Sep 2010	Static TP logs	3 suveys during heat-up, conducted inside 2-7/8" tubing hung at 5,720 ft. Survey on 24 Sep 2010 showed 390.8°F at 4,943 ft, with reversal below.
28 Sep 2010	Injection test	Could not get water down 2-7/8" tubing (later found to be plugged). Well took 150 gpm down annulus (outside 2-7/8" tubing) at 400 psig.
4-5 Oct 2010	Tubing removed	Removal of 2-7/8" tubing (bottom plugged w/ mud and pipe dope). Injection attempted, but well took little or no water at pressure of plant's injection system (about 140 psig).
1-8 Dec 2010	Install 7" liner	Cleaned out bridges to 5,957 ft. 4-hour injection test after clean-out: 81-132 gpm at 350-750 psig. 7" liner installed with slots in 4 intervals between 4,120 ft and 4,979 ft. After liner installation, well took just 7 gpm at injection-system pressure of 140 psig.
1 Feb 2011	Deflagration	Charges detonated at 3 depths between 4,150 ft and 4,910 ft. Injection capacity immediately after deflagration was 30-40 gpm at injection-system pressure.
2-22 Feb 2011	Injection test	In first 5 days of test, injection rose to over 600 gpm at injection-system pressure. Maximum injection after 2 weeks was about 750 gpm at 120 psig. TP log during injection on 8 Feb 2011 showed virtually all water leaving well at about 5,000 ft. 2-hour fall-off test on 8 Feb 2011 showed Injectivity Index of 1.9 gpm/psi (Benoit, 2014).
3 Mar 2011	Install tubing	2-7/8" tubing set at 2,021 ft for air-lifting.
16 Mar - 27 Jun 2011	Three air-lifts	Flow 300-400 gpm while lifting. Flow was never self-sustaining. Static TP surveys 4 Apr and 25 May show residual cooling from Feb 2011 injection, with minimum temperature between about 4,980 ft and 5,000 ft. Productivity Index estimated at 0.5 gpm/psi from air lift on 4 Apr 2011 (Benoit, 2014).
11 Feb 2012	Tubing removed	Preparation for long-term injection.
2 Jul 2012	Start long-term injection	Injection started at around 300 gpm and rose to around 750 gpm at injection-system pressure over 2 months. From July 2012 to Feb 2015, injection was generally 200-300 gpm, with occasional higher spikes at times of plant operational needs.
27 Feb 2014	Static TPS log & injectivity test	Log shows minimum temperature of 206°F in main permeable zone around 5,000 ft after 18 months of injection (Jul 2012 - Dec 2013). Well had been shut in for 2 months prior to this survey. Injectivity Index estimated at 8.6 gpm/psi (Benoit, 2014).
13 Aug 2014	Injection peak	The "Aha" moment (per Dale Smith at Soda Lake): 25A-33 took 1,800 gpm over 4 hours at a WHP of 21 psig.
9 Feb 2015	End of injection	
1-3 Apr 2015	Air lift	Static survey on 1 Apr (before airlift) shows 212°F in main permeable zone around 5,000 ft. Flowing survey on same day after start of air lifting shows zone at 5,000 ft heated to 232°F. Air lifted 2.5 days through 2-7/8" tubing hung at 1,974 ft. Productivity Index estimated at < 9.3 gpm/psi (Benoit, 2015).
3-11 Jun 2015	Air lift	Static survey on 3 June (before airlift) shows 252°F in main permeable zone around 5,000 ft. Productivity Index estimated at about 6 gpm/psi from 4-day build-up (Benoit, 2015).
4 Feb 2016	Start pumped production	Initial production temperature 304°F. Temperature rose by 10°F in first day, then about 1°F/week for first 2 months. One year after start-up, temperature was rising about 1°F/month, reaching 358°F by Feb 2018. Production has been kept constant at about 1,000 gpm.

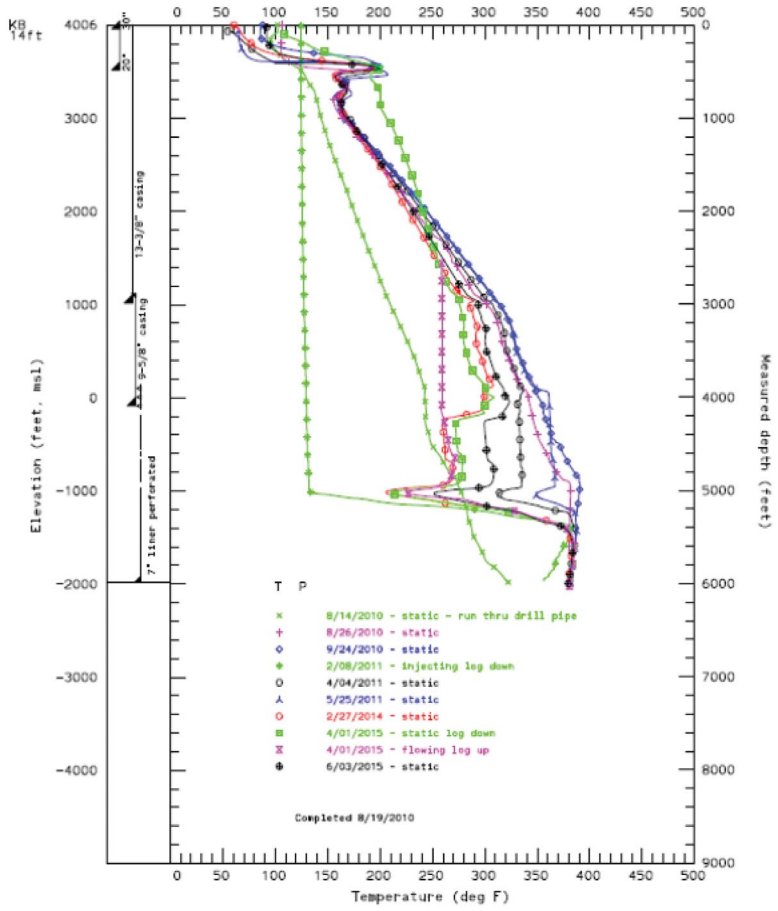


Figure 3: Selected temperature profiles, Soda Lake 25A-33

test (11 April and 25 May 2011) showed the most residual cooling in the zone at around 5,000 ft MD (reflecting the fact that it had taken most of the injection), with an isothermal section extending back up the well to about 3,900 ft MD (the inflection point in the survey of 14 August 2010). Thus, there appeared to be two or more zones with some permeability in the interval between 3,900 and 5,000 ft MD (with the deeper zone clearly dominant), even though early testing indicated that the permeability of these zones was quite low.

Alterra Power started long-term injection into 25A-33 on 2 July 2012. At system pressure, the well initially took little or no water. Using high-pressure Griffin pumps, a flow rate of about 175 gpm (11 L/sec) was established. The injection rate increased over several days at decreasing wellhead pressures. The Griffin pumps were removed on 10 July 2012, and the well took about 300 gpm (19 L/sec) at system pressure. Over the next two months,

(Continued from page 24)

injection at system pressure rose to about 750 gpm (47 L/sec). Between July 2012 and February 2015, injection was generally in the range of 200 to 300 gpm (13-19 L/sec), with occasional higher spikes at times of plant operational needs.

Eighteen months into the stimulation, Alterra Power stopped injection into 25A-33 for two months to assess the well's improvement. A static survey after the two-month heat-up (27 February 2014) showed a temperature of 206°F (97°C) in the zone at 5,000 ft MD. An injectivity test showed the Injectivity Index had risen to about 8.6 gpm/psi (7.9 L/sec per bar) – over four-fold improvement since the injectivity test of February 2011 (Benoit, 2014). This was encouraging, and injection continued at the same low rates and pressures as before the 2 month heat-up. The "Aha moment" of insight into the well's improvement came on 13 August 2014, when the well took 1,800 gpm (114 L/sec) over four hours at a wellhead pressure of just 21 psig (1.4 barg) (Dale Smith, personal communication).

Cyrq Energy stopped injection into 25A-33 on 9 February 2015. A static temperature survey on 1 April 2015 showed a temperature of 212°F (100°C) in the zone at 5,000 ft MD, and a flowing survey during air-lifting on the same day showed this zone's temperature rising to 232°F (111°C). A static survey 2 months later (3 June 2015) showed the zone had heated to 252°F (122°C). A 1-week airlift in June 2015 yielded flow at about 650 gpm (41 L/sec), and a 4-day build-up following the air-lift indicated a Productivity Index of 6.2 gpm/psi (5.7 L/sec per bar) (Benoit, 2015).

4. Temperature Recovery of 25A-33

Well 25A-33 started pumped production on 4 February 2016. On the first day, the production temperature rose from 304°F (151°C) to 314°F (157°C). Figure 4 shows the shape of the temperature recovery curve through February 2018. In early May 2017, a recalibration of the temperature gauge for 25A-33 showed a production temperature of 351°F (177°C), 3.0°F (1.7°C) higher than before the calibration. The rate of drift out

(Continued on page 28)

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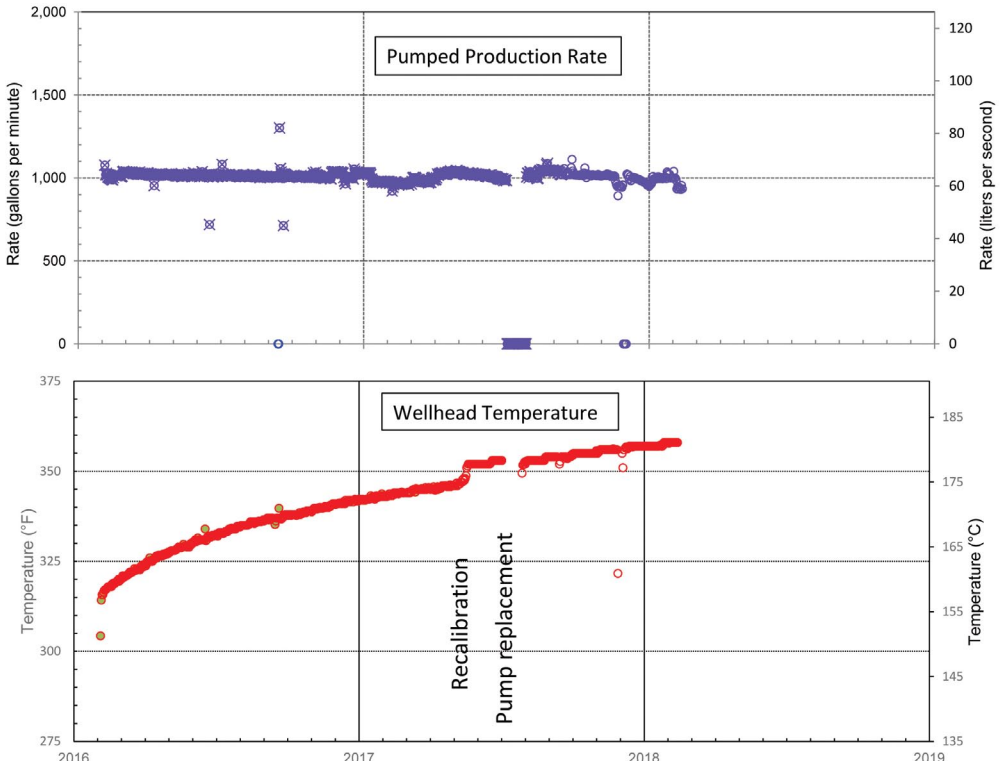

Figure 4: Temperature recovery of Soda Lake 25A-33 under pumped production after extended injection

(Continued from page 26

helped open a path for injected water to reconnect to permeability that existed before damage by drilling. Most of the improvement in permeability appears to have come from the injection itself: the first big rise in injection rates occurred over 5 days of injection after deflagration. Considering that the improvement in permeability seems to have been focused on the hottest part of the well, it seems likely that the mechanism of this improvement is thermal stimulation; that is, fracturing induced by the temperature contrast between cool injection water and high formation temperatures. As injection is prolonged, the thermal stimulation would affect a larger and larger volume of the formation around the well. Other mechanisms of permeability enhancement may also be at play, such as the flushing of drilling mud and cuttings away from the well, or the shearing of fractures that are favorably oriented within the stress field. In any case, it is worthwhile to note that the stimulation of 25A 33 was accomplished with relatively low injection pressures (that is, system pressures of about 140 psig [about 10 barg]), without the need for elaborate intervention procedures.

of calibration is unknown, so Figure 4 presents the data through the date of recalibration as originally reported (the shape of the curve should be essentially unchanged). As of 13 February 2018, the production temperature of 25A 33 has reached 358°F (181°C). Cyrq Energy has limited the production rate of 25A-33 to about 1,000 gpm (63 L/sec) in order to minimize interference with adjacent production well 32 33, which produces at a higher temperature (368°F [187°C]). When 25A-33 eventually stabilizes in temperature, the optimal balance of flow rates between these two wells will be re-assessed.

5. Discussion

The shape of the temperature profiles in Figure 3 suggests that the rise in production temperatures at 25A-33 is driven primarily by temperature recovery in the main permeable zone at about 5,000 ft MD. This zone appears to have been a pre-existing conduit for a deep thermal plume that emplaced heat in this portion of the reservoir, even though no significant loss of circulation was noticed at this depth during drilling. It is unclear whether deflagration made much of a contribution to the improvement in the well's permeability, though it is possible that the shock of deflagration

The time required for the stimulation of 25A-33 (over two years of injection followed by a year of shut-in, plus over a year for temperature recovery) is in a sense a hidden cost, since potential revenue was being foregone. On the other hand, 25A 33 provided value as an injector during the stimulation period, and the stimulation by injection avoided the cost of additional drilling, with its attendant risks. It is also possible that, with a clearer idea of the potential for a favorable outcome, the time allotted for the stimulation and heat-up could be shortened in application to other wells.

6. Conclusion

The temperature recovery at Soda Lake 25A-33 is useful as an example of the time required for temperature recovery after stimulation by extended injection at low rates and pressures. The continuing rise in production temperatures over a period of two years shows that the full benefit of this stimulation technique does not come quickly – but the potential benefit is real. This stimulation technique is especially suitable for wells drilled in geothermal fields with ongoing operations, because the power plant can provide a ready source of injection water. The approach is particularly applicable for projects with pumped production wells, because the pumps give the operator the ability to set the flow rate at whatever level the formation can yield after stimulation by injection.

7. Acknowledgement

The authors wish to express thanks to Cyrq Energy for permission to publish this paper. Amber Falconer Thomas provided valuable assistance with the map of well locations.

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Corporate Focus

The GRC would like to highlight our partners in the industry with a regular series of articles featuring our company colleagues. We thank our friends in the corporate sector for their ongoing support.

The authors of this issue's Technical paper come from two stalwart GRC company members: **GeothermEx (A Schlumberger Company)** and **Cyrq Energy.**

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GeothermEx - A Schlumberger Company,

A U.S. corporation, GeothermEx has been in business since 1973, specializing exclusively in providing consulting, operational and training services in the exploration, development, assessment and valuation of geothermal energy. They are recognized worldwide as leading experts in geothermal energy.

GeothermEx
A Schlumberger Company

The staff consists of specialists in geosciences (geology, geochemistry, geophysics, hydrology), engineering (drilling, well testing, reservoir, production, power plant, chemical), computer science and economic analysis. All technical staff members have advanced degrees and lengthy geothermal experience (average 20 years), with several members having more than 25 years in the geothermal industry.

Marcelo Camargo is the President of GeothermEx. Other notable figures include **Jim Lovekin** (Field Operations Manager) and **Ann Robertson-Tait** (Business Development Manager/ Senior Geologist), all of whom are on the GRC Board of Directors.

In 2010, the company was acquired by Schlumberger, one of the world's leading providers of technology for reservoir characterization, drilling, production, and processing to the oil and gas industry, with principal offices in Paris, Houston, London and The Hague.

GeothermEx has a main office in Richmond, California. However, it also has an international presence in Ankara, Turkey and Jakarta, Indonesia. More information on the company can be found at http://www.geothermex.com/.

GeothermEx will be exhibiting at the GRC Annual Meeting & Expo, from 14-17 October at the Peppermill Resort Spa Casino, Reno, Nevada, USA.

Cyrq Energy

Headquartered in Salt Lake City, Utah, Cyrq Energy is a leader in renewable energy technology with geothermal, solar and storage facilities generating energy and under development in California, New Mexico, Utah, Oregon, Nevada, as well as Africa.

Cyrq

Cyrq has over a decade of experience in the development of clean, efficient renewable energy facilities with the goal of becoming a leading global developer and provider of renewable energy. The CEO is **Nick Goodman**.

The company's geothermal energy assets include Lightning Dock in New Mexico, Soda Lake and Patua in Nevada and Thermo in Utah.

More information on the company can be found at https://www.cyrqenergy.com/ ■
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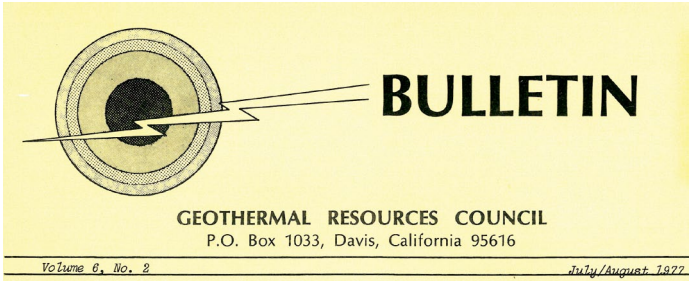
Geothermal History in the Making

by Ian Crawford, Director of Communications

In 2020, the Geothermal Resources Council, the GRC, will be celebrating its 50-year anniversary. Our association was established in 1970 "to encourage development of geothermal resources worldwide." To mark our golden anniversary we are running a series of articles from the GRC Bulletin looking back on the history of geothermal energy around the world over these past decades.

We start with an article from 41 years ago that is a distant echo of current developments in geothermal energy research.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Volume 6, No. 2 July/August 1977

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LASL Scientists Report Geothermal Breakthrough

Los Alamos, New Mexico, June 7, 1977 -- Scientists at the Los Alamos (N.M.) Scientific Laboratory (LASL) have recorded a significant breakthrough in the quest for geothermal energy. They have created a man-made geothermal well system 2 miles deep near the Valles Caldera in the Jemez Mountains of New Mexico by producing a fracture system in hot granite. The achievement is a major step in the Energy, Research and Development Administration's (ERDA) hot, dry rock geothermal energy program.

LASL Director Dr. Harold M. Agnew said in the past week 2 bore holes drilled into the west flank of the Valles Caldera, 20 air miles west of Los Alamos, were properly connected as evidenced by a significant flow of water between the two. The water flashed to steam as it was diverted to a nearby holding pond. Temperatures of 130 C (265 F) were recorded after 20 hours of pumping. Based on preliminary measurements of water flow, over 92 per cent of the water injected into one hole will be recovered in the second hole after a month of operation. This recovery level is anticipated to increase with time. Testing will also show whether the initial heat transfer rate is maintained or falls off with time.

"This is a major step in the program," Dr. Agnew says. "We have proven that we can create a geothermal well using adaptations of oil field drilling techniques without the use of explosives, that we can recover the water in order to ultimately create a pressurized hot water system suitable for generation of electricity and other industrial and domestic uses, and that we are ready for the next step in the study."

LASL's system involves 2 holes drilled almost 2 miles deep that are separated at the surface by about 250 feet. Water under high pressure is utilized in a process known as hydraulic fracturing, to create a system of cracks in the hot granite bedrock, thus exposing a large heat-exchange surface of rock with a temperature of about 400°F. Cold water was pumped down the hole at 900 to 1000 psi (pounds per square inch) pressure. It circulated through the crack system, was heated, and flowed from the second hole at a temperature of 265°F. Back pressure was applied to the second hole to keep the water from boiling until pressure was released at the surface.

Such a system would be capable of driving a 10-MWe (megawatt electric) power plant. Although LASL does not plan to construct a power plant, Dr. Robert Brownlee, head of the Laboratory's Geosciences Division, says a utility company is discussing with ERDA the possibility of harnessing such a plant to an enlarged LASL system. Brownlee describes the potential of hot, dry rock geothermal energy as "enormous."

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Whatever happened to the Los Alamos program? What happened with the development of geothermal energy in New Mexico? How important was this research in hot, dry rock geothermal energy? Bring us up-to date with your answers. We will publish your thoughts as a Letter to the Editor in the next Bulletin. Contact Ian Crawford at icrawford@geothermal.org. ■
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Panoramic view of Norris Geyser Basin, Yellowstone. **Joe Moore**, *2015*

Adventures Within the Geothermal Community:

A Q & A with Cary Lindsey, a past GRC Scholarship Awardee

by members of the GRC Student Committee:
Jon Golla (University of New Mexico, USA),
Kevin Fan (University of British Columbia, Canada),
& Racine Basant (University of West Indies, Trinidad & Tobago)

In this feature, we interview Cary R. Lindsey, a PhD candidate in the Department of Geological Sciences at the University of Idaho and a self-proclaimed 'hockey mom' of three. As an undergraduate student at Mississippi State University, Cary attended the National Geothermal Academy in Reno, Nevada, USA in 2012. Her current research involves application of geostatistics and exploratory statistics to heat transfer in and exploration of geothermal systems. She has been a prolific member of the GRC, having attended Annual Meetings since 2012 and presented various papers, highlighting her past work in Oktibbeha County, Mississippi and Yellowstone National Park. Furthermore, Cary is a recipient of a 2015 GRC Graduate Scholarship award.

GRC: How were you introduced to geothermal science?

Cary R. Lindsey (CL): I think I've told this story from both angles. I'm not sure if geothermal brought me to geology or if geology brought me to geothermal, but they both kind of happened at the same time. I went back to college as a non-traditional student. I was actually a psychology major. I was a little intimidated by the intense math and science courses. So a couple of years after, I met a professor who really encouraged me to rethink that and consider a different direction. I looked into environmental science programs and somewhere along there, I happened to read an article about a geothermal energy project, and that was pretty exciting. I was also looking at a geology program. Somehow, I ended up switching my major to geology after my second year - I finished my two years of community college and transferred to Mississippi State to pursue a degree in Professional Geology. I wanted to do an undergraduate research project with my Honors college. I knew I wanted to do something geothermal, but no one at my university had known anything about geothermal energy. It was kind of a meteorology department [and] a few oil and gas guys there, but certainly no geothermal or heat transfer going on.

GRC: How did you work around this lack of geothermal expertise at your school?

CL: I started Google-ing which universities were doing what. I found Southern Methodist University's geothermal lab (this was right after David Blackwell had completed the Google Earth geothermal overlay project). I called Maria Richards and Cathy Chickering and just asked for some help - some direction, as to what I could do. We talk about what could be done for Mississippi and how the map could be improved for the area. I [also] talked to Dave Blackwell about it. They gave me some directions that kind of sent me off. I ended up visiting those guys at Southern Methodist at one of their first Power Plays conferences. Met all their students and all the professors. They just took me under their wing for my last two years at Mississippi State and the rest was soon to be history.

GRC: Did your undergraduate background in psychology play any role in that?

CL: First off, being involved in geothermal is not always the easiest path to pursue. The industry is up and it's down. It's recreating itself, so you have to have a certain type of spirit to push through in geothermal. You can't just do science, you can't just do energy, you can't just do policy - you have to be able to do all three of them. You have to be able to work with people, and know how to talk with them, how to understand and deliver what they want to them. I think a little bit of psychology helps sometimes when you're trying to get your way or get your point across with people. That goes with any industry, but I like to use it in this one.

GRC: It seems like most of your research is rooted in statistics. Could you tell us a little more about it?

CL: Right now, my research project is in Yellowstone - certainly not an area we're ever going to develop for geothermal. Because of that, it's a really cool place to work - it's pristine, it hasn't been developed, so you can just go in there and see how the natural system reacts. I use geostatistics to look at [spatial] trends in temperature mostly and fracture networks and things like that. I think that can lead to better exploration, more economic exploration, and better reservoir characterization if we understand what's happening because the near surface has so many clues as to what's happening in the deeper subsurface. For me, geostatistics was a natural progression of my interests because it wasn't something that I was first interested in when I came to the University of Idaho. I just found it when I was here - my advisor teaches a course in geostatistics. Then, you start tying in spatial analysis with GIS. I really think it's just the direction that a lot of us should be looking into. You saw with the Play Fairway analysis - there's a lot of spatial statistics involved with that. And even when we start producing these systems, it really matters that we're monitoring them so that we're sustainably producing these systems. Using some of the tools that we use with spatial analysis in the shallow subsurface lends itself to monitoring these systems once we start producing them.

GRC: Let's talk about your GRC Award. Congratulations on receiving it. What have you been doing since then? How has it helped with your career track?

CL: One of the things with awards like these is that it means a lot to get them. Personally, it meant a lot to get it, because it's [from] your peers, the people in the industry that you want to be in, who are saying: "Hey, you have an idea we're interested in". It's not the National Science Foundation, it's not some random group of folks in a random building, but it's people whose opinions you really care about. So even just receiving the award does something for you. And of course, being able to write a scholarship application and get it funded means something for your CV. It means you can present an idea in such a way that people understand the value in it.

But it also gave me the opportunity to look at a pretty interesting project that I had in the back of my head. It ended up not being exactly what I wrote it to be, but it ended up being a pretty interesting one nonetheless. We looked at this field area in Yellowstone called Porcupine Geyser. It was labeled as a 'geyser', but nobody's actually seen that behavior - except for a couple of drunk guys back in the 80s. So nobody actually knows whether it's a geyser or not. For all intents and purposes, it's a hot spring. We dropped these loggers, which are what I wrote my grant proposal for. I wanted some of these U-12, stainless steel temperature probes. These can handle hot springs, [since] they have a rubber seal on them, so you can drop them in on a hot spring and they can log temperatures for a really, really long time. We tie these up with some pear cord and drop them in hot springs. I was looking for hot spring response to earthquakes or shorter seismic activity. We didn't happen to see any of that.

On the very last day I had this logger in, all of a sudden, the temperature of this logger dropped by 45 degrees and it recovered almost [instantaneously]. We argued about what had happened to it. Had somebody stumbled across it and pulled it out then dropped it back in? Had there actually been an event causing such a drastic temperature change in the spring? Another student, an undergraduate at the time, worked with me and we developed an analytical model to plot what that

temperature recovery would have actually looked like had somebody actually pulled it out and dropped it back in. What we found was that the [modeled and empirical] curves did not match. We were able to disprove that somebody had pulled it out and dropped it back in. We don't know what happened. We were not able to explain for the amount of temperature drop what happened. That was a really nice opportunity to do something that wasn't what I was doing everyday - it didn't have anything to do with mapping heat flow. [The experience] made me develop an analytical model, which I thought was really hard to get for a long time. And I got a conference presentation out of it -

I presented the results at the GSA in Denver. None of that would have happened without the GRC scholarship.

GRC: What's the most exciting thing you've witnessed while on a geothermal field outing?

CL: A few years ago, I went to a workshop - it was a near-surface geophysics workshop for hydrology that was hosted by CUAHSI (Consortium of Universities for the Advancement of Hydrologic Science, Inc.) - great workshop if you ever have the chance to go to it. I found out through Iris Pascal at New Mexico Tech that you can actually just borrow seismic refraction equipment for free. All you have to do is pay for the shipping, and if you have an NSF grant you get priority. We borrowed some seismic refraction, some geophones. They even sent us the source, the thumper that you attach to a truck. Of course, we didn't use that for our fieldwork, but we did

use it to teach a class on. We took the stuff out to the Alvord Basin in Southeast Oregon, and we were going to do a seismic survey over this stepover in a fault. We were trying to look at the fluid breakthrough in this relay ramp, so we were running this seismic line, and our source was a sledgehammer and a big steel plate. We'd put that plate down and swing the sledgehammer about 8 times, and then move a few metres down the line and do it again. We had some graduate and undergraduate students and my advisor out there. I was sitting, running the computer, and recording our work.

One of the undergraduates was swinging the hammer at the time. He got about a third of the way down the line we were working on, and when he swung the hammer and hit that plate, we could feel it probably 30 metres away. You could feel it move through the ground, like the ground was hollow underneath us. And everybody just stopped and looked up, and we were like "We're on top of the fluid, on top of this massive spring or something". We had everybody move away. Since I was the graduate student on the project, Jerry looked at me and said "Okay, let's finish this". He swung the sledgehammer down the next 2 stops, which is all we needed to finish that line. I just sat there hoping the next swing of the sledgehammer didn't break us through and send us down into some massive geothermal cavern. It was a great story to tell [for] later - we probably weren't in any major danger, and I think if we were we would have stopped and done the line somewhere else. It was pretty weird to feel that, but also awesome to think of all the implications. When we looked back at the survey data, we weren't over empty caverns. We probably were right over the main upflow zone through that relay ramp, so it was pretty cool to see that in the results of our survey.

GRC: Gosh, death by geophysics, wouldn't that be something?

CL: Right? *Laughs* How we all want to go right?

GRC: How have you promoted your work?

A. I go to the geology conferences because I am a geologist and because it is also important to have a presence at those events. There are GSA (Geological Society of America) and AGU (American Geophysical Union) to consider, although they're not specifically geothermal. I've presented at the National Park sections about my Yellowstone work. I've also presented in specific sessions that are geared towards geothermal. I went to Power Plays during my first year. Stanford is phenomenal, but also intense. Roland Horne is a great host for that event. Of course, GRC is the best geothermal one out there. I think we should have more student presence at GRC. We should really open the doors to GRC for local universities where the Meeting is hosted. GRC is our community, and it's my favorite.

GRC: As your candidacy is nearing completion, what are your plans for the future?

CL: I see myself continuing my research. While it is exciting that I am graduating in a couple of months, I still have a book full of ideas, with things I've jotted down and thought: "Oh, I could do this with cluster analysis"; "I could do this in Yellowstone."; "Wouldn't it be cool to work with an undergraduate and have them go through some statistical process?". This is just the beginning for me. Whether I end up in the industry or...I'm looking at universities, liberal arts colleges, community colleges. Wherever I go, I will certainly continue my research. Now that I've spent so much time with writing, I'm actually enjoying the process. Hopefully, I'll also be able to mentor other students. I love working with undergraduates. I love statistics, geostatistics, and data. I'll mention the National Geothermal Data System - there is so much stuff out there for free. We could just go grab it and do these really cool models and use exploratory statistics with it. That's certainly something I look forward to doing.

GRC: Given your previous response, how would you envision yourself as a mentor?

CL: I have some alternate visions as to what's that going to be like. I kind of imagine myself being this really quirky geology professor who wears big chunky necklaces and sensible shoes and makes all of her students do a lot of statistics. I imagine exposing my students to a side of science they all wouldn't get to, especially in a two-year college. I want people to understand that science isn't just

what happens in the classroom - it's about being creative, being a thinker, stepping up outside the box and trying something that maybe no one has done before or doing something in a different way that people have not tried before. Really, I just want to encourage people to find what it is they care about and to find what excites them. If that's geothermally related, then great. If it's statistics or generally just science or if it's not, I just want them to feel like they can talk to me about what excites them and guide them on how they could do it at a four-year university or alternatively, how they could do it with an associate's degree. I just want to offer people a way to their path because I think there were so many people who helped me find what it was for me. I would not be here if my adviser at Mississippi State had not managed to scrape up enough money to pay me 10-15 hours a week to do a research project or if the folks at SMU had not been able to encourage me to do undergraduate research. Personally, it's just about offering some advice at the right moment or being able to go eat a brownie and cry in my coffee in my office while they're having a hard time in class like Calculus 3. Whatever issue it is, I just want to be there for my student.

GRC: Finally, do you have any advice to give to future GRC scholarship applicants?

CL: I really think that it's important that you understand the scope of your project. You can only do so much. You need to tailor your proposal to the organization and to the amount of money that they are funding. If they want results back from you at a certain time, be sure you can accomplish what you say you can accomplish in that given time. Make it easy to read. Be really clear in what you're going to do. Fill the application out correctly. A lot of applications get tossed out, simply because people did not follow the rules, so write a really nice succinct proposal, do it right, and submit it on time. The GRC get quite a few applicants, but they don't get a thousand. You just have to put your neck out there and be willing to apply for them. Just because somebody tells you no, it does not mean your work is not valid. It just means that they had other things they wanted to fund that day. Just keep trying and go to the next place. Try again next year. Take the feedback to heart and make the adjustments and understand that everybody wants you to succeed. Nobody is out to crash your dreams or anything. Also, talk to other people who have been successful with it, and see what works for them.

We thank Cary for participating in this interview. We hope to extend this work to future Bulletins, either in interview Q & A format (like this one) or as a more detailed profile of other past GRC scholarship winners or of any professional or academic in the geothermal industry. If you'd like to nominate anyone (even yourself!) to be featured in future editions, please contact Anh Lay at alay@geothermal.org.

The Geothermal Resources Council (GRC) has announced the 2018 GRC Scholarship Awards:

- **Three (3) GRC Undergraduate Scholarship Awards** – to be eligible for one of these awards, the candidate must be a third or fourth year undergraduate at an accredited academic institution at the time of the award (Fall 2018). The award will consist of a $250 stipend and travel expenses to attend the GRC Annual Meeting. Each recipient will be required to either present at the meeting (poster or paper such as from a senior thesis) or prepare a report for the GRC Bulletin describing what they learned from attending the meeting and how they would utilize what they learned for their educational or career path.
- **Five (5) GRC Graduate Scholarship Awards of $2500** – to be eligible for one of these awards, the candidate must be enrolled in a graduate-level program at an accredited academic institution at the time of the award (Fall 2018). Each recipient is required to submit a paper on his/her research (or research progress) to be published in the GRC Transactions and deliver results at the meeting as either a poster or oral presentation. If the recipient presents in the year of the award then the full $2500 is awarded; if the recipient defers to present/publish the following year then $750 is withheld to cover travel expenses for when the recipient presents.

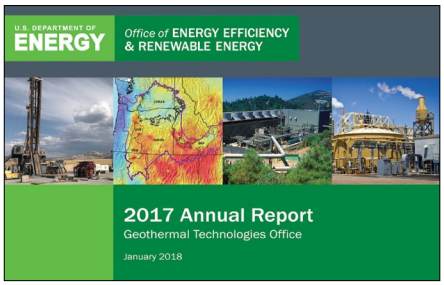
More information on the GRC Website at: https://geothermal.org/students.html#scholarships

If you have any questions regarding the GRC Scholarship Awards, please contact Brian Schmidt at bschmidt@geothermal.org or (530)758-2360, ext. 104. ■

Publications, Websites, Videos & Maps

by Ian Crawford

Annual Report from the Geothermal Technologies Office



The U.S. Geothermal Technologies Office (GTO) announces the release of its 2017 *Annual Report* recognizing advances in transformative, high-risk/high-reward science and engineering from GTO's portfolio.

The 2017 issue highlights project successes and continued efforts in all of our program areas – Enhanced Geothermal Systems (EGS), Hydrothermal, Low Temperature & Co-produced Resources, and Systems Analysis – which are flanked by useful tools, resources, and links to more information. Highlights include FORGE and EGS Collab advancements, projects reducing geothermal costs and risks, advancements in technology research and development, and the launch of GTO's Deep Direct-Use efforts. *Download the GTO 2017 Annual Report.....*

New Scientific Journal for Geothermal Energy Studies

A new scientific journal for geothermal energy studies might be of interest our readers. The purpose of the *International Journal of Terrestrial Heat Flow and Applied Geothermics* (IJTHFA) is to provide a forum for publication of results of high-quality research work dealing with recent advances in field measurement of terrestrial heat flow, regional and global geothermal data analysis, model studies of heat transfer in the Earth's interior and practical applications of geothermal studies. *More Information.....*

(Thanks to GRC Member Marcelo Lippmann, Staff Scientist (retired) at Lawrence Berkeley National Laboratory for the submission.)

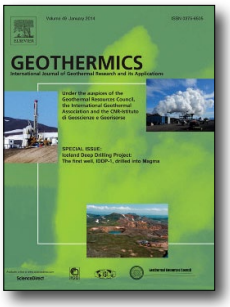
Geothermal Energy Offers a Competitive Advantage

The International Renewable Energy Agency (IRENA) has released a report *Renewable Power Generation Costs in 2017* which argues that renewable energy has emerged as an increasingly competitive way to meet new power generation needs. This comprehensive cost report highlights the latest trends for each of the main renewable power technologies, based on the latest cost and auction price data from projects around the world.

2017's average levelized cost of electricity from utility-scale renewables fell to within the range of fossil fuels for almost all sources. *Download Renewable Power Generation Costs in 2017.....*

Geothermics

Through affiliation with the **International Geothermal Association (IGA)** the GRC offers a discount to the professional journal *Geothermics*, which publishes articles on the theory, exploration techniques and all aspects of utilizing geothermal resources.



Current, past as well as upcoming articles in *Geothermics* can be found by going to: http://www.elsevier.com/locate/geothermics

Members can contact the publisher Elsevier at: JournalsCustomerServiceEMEA@elsevier.com in order to subscribe to the journal. Upon request Elsevier will send a *proforma* invoice to the member e-mail ID.

Members can make their payment via bank transfer, fax their card details or call Elsevier with the information provided in their invoice.

The discounted price details for IGA/GRC members is $285. ■

In Memoriam

Harry J. Olson
1931-2018

Harry Olson *(second from left) together with friends from the geothermal energy industry (from left to right)* ***Fred Henderson***, ***Paul Morgan*** *and* ***Dave Blackwell****.*

Long time GRC Member and past Board President Harry J. Olson passed away at his home in Denver, Colorado on 16 March 2018 after a long illness. He is survived by his wife Connie, his son Douglas and daughter Kris.

Harry was born on 13 July 1931. He received his PhD in mineral science from the University of Arizona in 1968, with a dissertation focused on geologic mapping along the South Fork of the Payette River in central Idaho, an area of many hot springs. Starting in the early 1970s, he managed the geothermal program for American Metals Climax Corporation (AMAX) and was the lead scientist and project manager for many of their exploration efforts in the western US. From the mid-1980s to the early 1990s, he spearheaded the program of drilling scientific observation holes in the Kilauea East Rift Zone of Hawaii, under the aegis of the Hawaii Natural Energy Institute at the University of Hawaii at Manoa. He was a strong advocate for the use of geothermal energy, particularly in island nations.

Harry was a GRC member for 40 years (1973-2013). He became president of the GRC Board in 1985, presiding over the expansion of the organization to more than 1,000 members. Harry leaves a deep legacy with the GRC and within the geothermal industry. Many in academia and industry benefited from his knowledge, enthusiasm and expertise. He gave some of us our first geothermal jobs and fostered many careers by encouraging academic institutions to support geothermal research and provide financial support through graduate assistantships.

The GRC recognized him as a true pioneer in the geothermal industry by presenting him with the Joseph W. Aidlin Award in 1990.

For all who knew him, he is fondly remembered and will be sorely missed. A thanksgiving/celebration event in his memory is planned for Tuesday, 3 April 2018, from 2 to 4 pm. The event will be at the Village at Belmar, 7825 West Alameda Avenue, Lakewood, Colorado.

Thanks to ***Jim Lovekin*** *and* ***Gene Suemnicht****, with kind input from* ***Dave Blackwell****,* ***Paul Morgan****, and* ***Fred Henderson III.***

Robert L. "Bob" Wright
1927-2018

The United States geothermal industry has lost another of its founders.

Robert L. "Bob" Wright, age 90, passed away due to cancer on February 22, 2018. Bob was a classical "old time" land man who could charm almost any landowner into signing a fair agreement. He had an amazing ability to use the English language in an unsparingly witty and colorful manner. A meeting, a meal, or a phone call with Bob was always punctuated with raucous laughter.

Bob graduated from Spencer Iowa High School in 1945 and served in the U. S. Navy during WWII in the Pacific and Atlantic. He graduated from

University of Iowa in 1951 and was immediately hired by the Denver exploration office of Phillips Petroleum as a land man. He worked for Phillips Petroleum for 35 years in the western states, first in the oil and gas and mining industries before entering the geothermal industry in the early 1970s. His signature geothermal accomplishment with Phillips was the negotiation of the geothermal lease with the Southern Pacific Railroad, by far the largest private landholder in Nevada at the time. This lease agreement led to the discovery of the Desert Peak and Rye Patch geothermal fields. Bob also negotiated the leases in Phillips other discoveries at the Steamboat, Soda Lake, and Roosevelt fields. Phillips' lease positions and unit agreements were remarkably free of later litigation, in large part due to Bob's integrity.

Bob served as chairman of the Western Oil & Gas Association Geothermal Committee; on the Board of Directors of the Geothermal Resource Council (1984-1986); president of the Intermountain Oil Scouts Association; member of the American Association of Professional Landmen; and, as a long-time member of the Willow Creek Country Club, Salt Lake City, where he enjoyed swimming and playing golf with family and friends.

After retirement from Phillips, Bob was a busy consultant for three more decades to many oil and gas, mining, and geothermal companies and he maintained his own portfolio of oil and gas and geothermal leases.

Bob is survived by his wife and love of his life, Katherine Reid Wright of 60 years and daughter Barbara Ann Wright. He was always proud of his daughter's accomplishments.

Bob was a kind man. His humor, kindness and generosity will be greatly missed by his family, friends, and colleagues.

Bob was buried in the family plot at Riverside Cemetery, Spencer, Iowa. ■

Transitions

Bastien Poux has joined the Dewhurst Group as Senior Geoscientist for Geothermal Exploration and Development.

GRC Board Member **Kate Young** is the new NREL Geothermal Energy Laboratory Program Manager.

Geothermal energy industry veteran **Randy W. Keller** has joined lithium extraction company MGX Minerals Inc. as Vice President of Business Development. ■

Calendar of Events

DESTRESS Mid-Term Conference
5 April, Glasgow, United Kingdom
www.destress-h2020.eu/en/stay-informed/news-and-events/bsds-blog/Join-our-Mid-Term-Conference-in-Glasgow/

Geothermal Cross Over Technology Workshop Part II (AAPG and IGA)
17-18 April, Utrecht, Netherlands
www.eiseverywhere.com/ehome/275855/homegeothermal/

25th Annual Congress of the Mexican Geothermal Association
18-20 April, Morelia, Michoacán, México
www.geotermia.org.mx/geotermia/?page_id=1131

5th Expo Geothermal
19-21 April, İzmir, Turkey
http://demosfuar.com.tr/fair/2

Iceland Geothermal Conference 2018
24-26 April, Reykjavik, Iceland
www.igc.is

Resources for Future Generations
16-21 June, Vancouver Convention Center, Vancouver, BC, Canada
http://rfg2018.org/

Grand Renewable Energy 2018 - International Conference and Exhibition
17-22 June, 2018, Yokohama, Japan
www.grand-re2018.org/english/index.html

ICEM18 - the Eighteenth International Conference of Experimental Mechanics (EuraSEM) Session on "Experimental Methods in Geothermal Engineering"
1-5 July, Brussels, Belgium
www.icem18.org/

Geothermal Energy: From Potential to Implementation (Cranfield University)
11-13 July, The Geological Society, London, U.K.
www.cranfield.ac.uk/Courses/Short/Energy%20And%20Power/Geothermal%20Energy

GEOHEAT International Geothermal Conference
4-7 September, Petropavlovsk-Kamchatsky, Russian Federation
https://pbs.twimg.com/media/DLsAdQDW0AAxWj9.jpg

6th Indonesia International Geothermal Convention and Exhibition (IIGCE)
5-8 September 2018, Jakarta Convention Center, Indonesia
http://www.iigce.com/

GRC Annual Meeting & Expo
14-17 October, Reno, Nevada, USA
www.geothermal.org/meet-new.html

6th National Geothermal Congress - Polish Geothermal Association
23-25 October, Zakopane, Poland
www.energia-geotermalna.org.pl/vi-ogolnopolski-kongres-geotermalny/

Seventh African Rift Geothermal Conference (ARGeo-C7)
29 October–4 November, Kigali, Rwanda
www.theargeo.org ■

OCT
14-17
2018

SAVE THE DATE

Geothermal Resources Council
GRC

GRC ANNUAL MEETING *& EXPO*

PEPPERMILL
RESORT SPA CASINO
RENO, NEVADA, USA