

Innovative Exploration Techniques for Geothermal Assessment at Jemez Pueblo, New Mexico

Project Officer: Mark Ziegenbein
Total Project Funding: \$4,995,844
April 23, 2013

Greg Kaufman

Pueblo of Jemez

Track 1

Dr. Helmut Tenzer

On the 4th of December 2012 our dear project team member, colleague and friend passed away unexpectedly, at the young age of 57 years.

We thank him for his leading contribution to the drilling and testing planning of this project.

His contributions to the international geothermal industry have been countless.



- **Challenges, barriers and knowledge gaps addressed**

Prior to the project no (drilling) reliable structural information as well as information about the location or extend of a commercially viable geothermal resource was available in this study area that is located in proximity to the Valles caldera. The study area as well as its surrounding show manifestations of multiple geothermal episodes but no well exceeding 240 ft has ever been drilled for better geological classification. In a blind resource like scenario this project has to image and explore through the caldera outflow plume into depths of more than 3000 ft. Drilling west of the Indian Springs fault or east of it that alone, can determine the success of a commercial power generation project and represents a substantial drilling risk.

- **Impact on the geothermal industry/market**

This project is the largest geothermal exploration project in New Mexico since Fenton Hill at nearby Valles caldera. Through its existence, this investigation promotes the geothermal industry in the State of New Mexico, puts the geothermal industry as a whole literally on the map for the state-wide transmission planning of New Mexico's Renewable Energy Transmission Authority (RETA), accumulates geothermal know how present in the state and serves as incubator for subsequent cooperation between the involved parties within the state and beyond.

- **Innovative aspects**

This project validates the integration of high resolution seismic data acquisition and processing tailored to steep and complex structures like faults and fault zones into traditional geothermal exploration methods. Innovative tracer testing and eventually flowing electrical conductivity logging provide insight into the nature of the resource and its conduits well beyond the wellbore. Those tests determine i.e. fracture surface areas and flow velocities in single-well tests.

- **Impact on the Geothermal Technologies Program's goal(s)**

This project validates three new exploration methods. It is estimated that the project will confirm about 10 MWe of geothermal energy capacity.

- **Scientific/technical approach**

Traditional methods like geologic mapping, hydrogeochemistry and mineralogical analysis are combined with enhanced seismic and large surface area covering 3D magnetotelluric. Once those data have been integrated a conceptual model is developed, wells are drilled and the innovative well testing methods are performed in addition to traditional logging tasks and flow testing.

- **Project and project task design**

The project implementation plan follows a logical and reasonable progression from geologic mapping, hydrogeochemistry and mineralogy to geophysical surveys to selecting a well site location to drilling to logging to the final phase of well testing. All new innovative methods are technically feasible because they are not in a basic research phase anymore but have been exposed to either other industries, underwent different stages of modeling or build on innovative research conducted in other DOE funded geothermal projects.

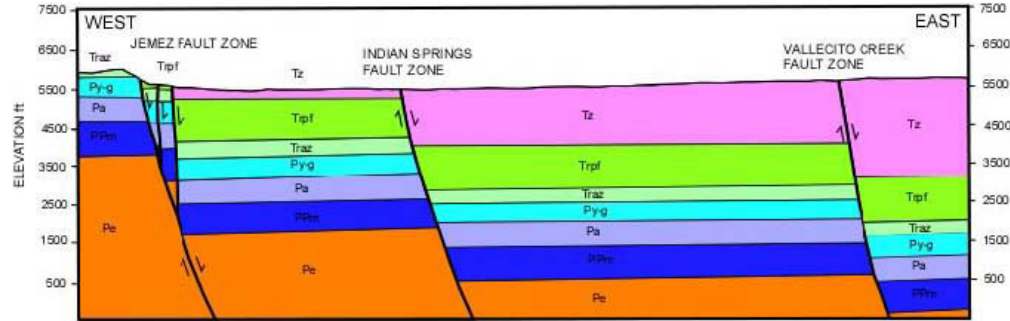
- **Key issues**

The project addresses on how to resolve and image from the surface complex and steep structures like faults and fault zones within a potential resource and how to obtain cost effective information beyond the wellbore without drilling another well, what reduces investment risks. This applies especially to blind resource scenarios.

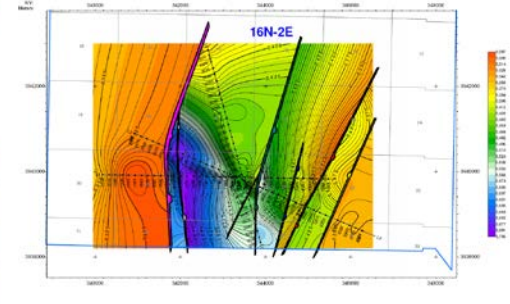
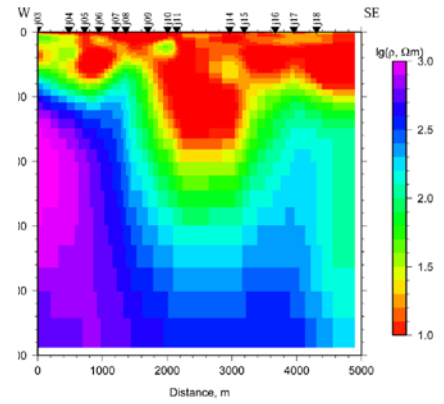
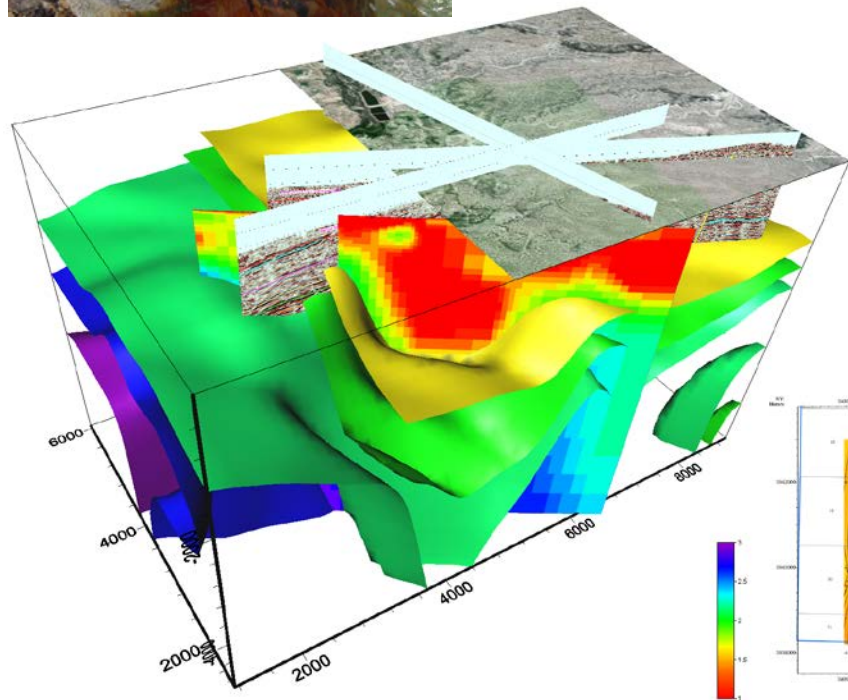
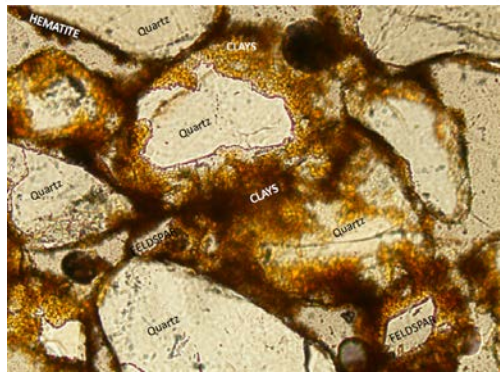
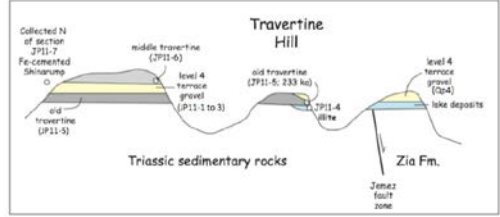
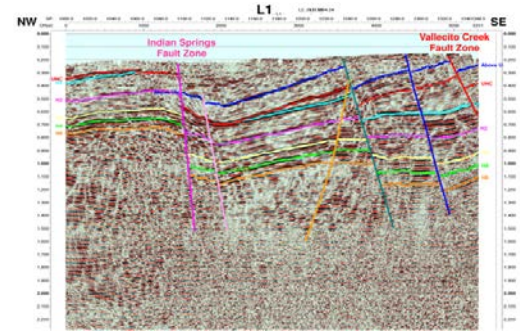
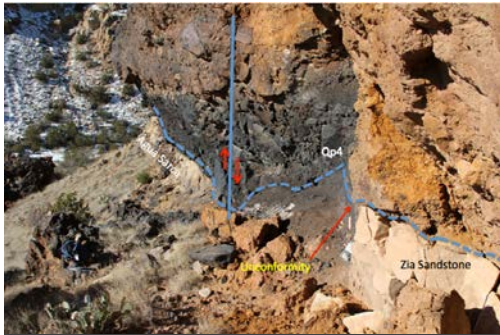
- **Execution of project tasks**

The tasks have been executed in time and budget according to technical expectations. The project was even able to add and manage additional tasks that have not been part of the original project plan, like the implementation of a seismic monitoring network. Up to now project delays have not been related to scientific/technical issues.

Geological interpretation before the project started in April 2010

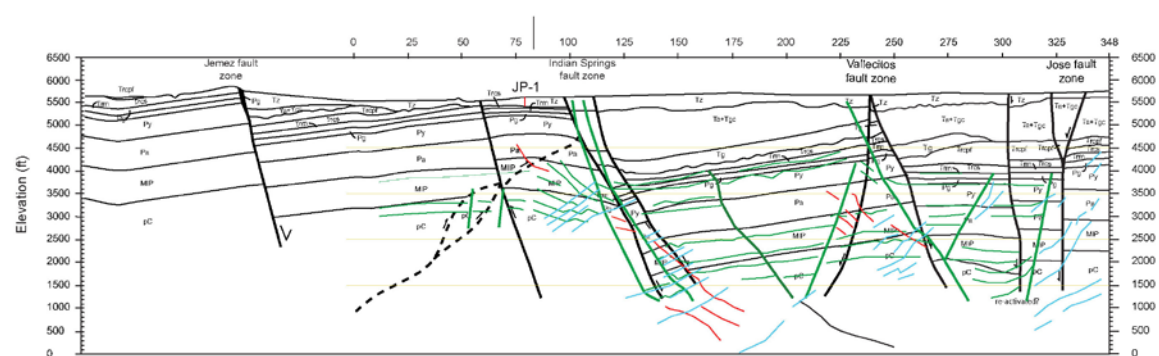
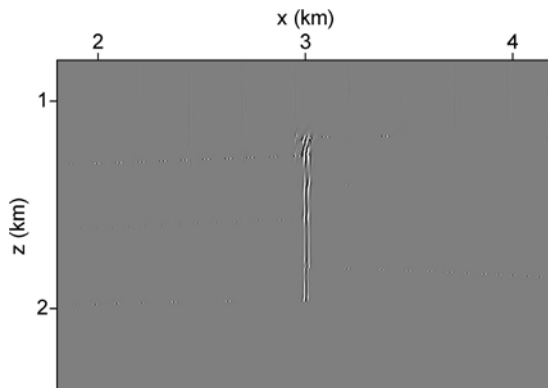
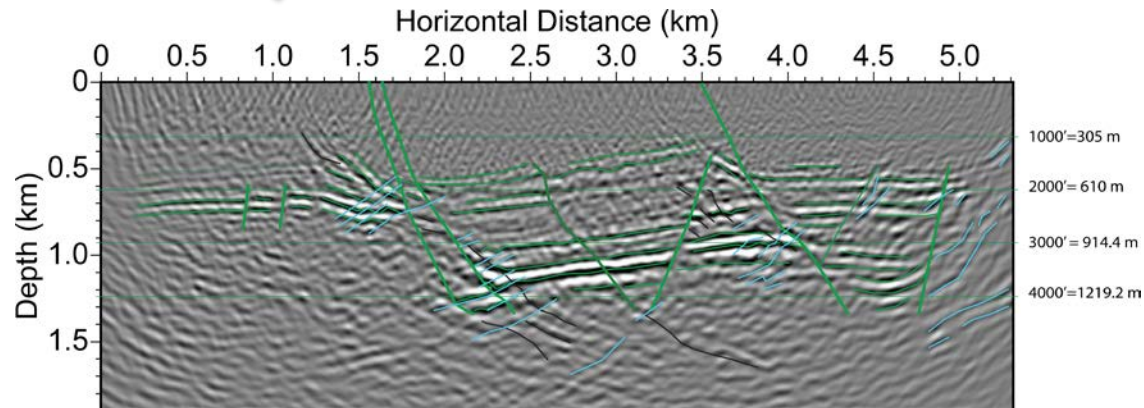
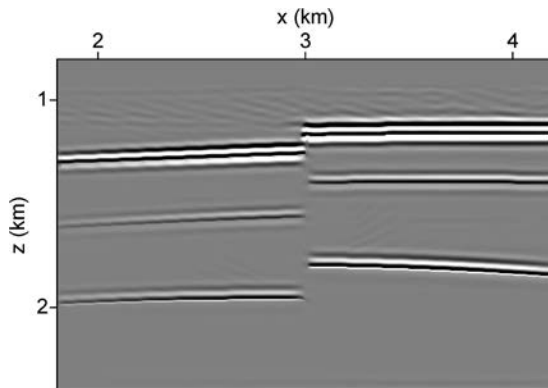
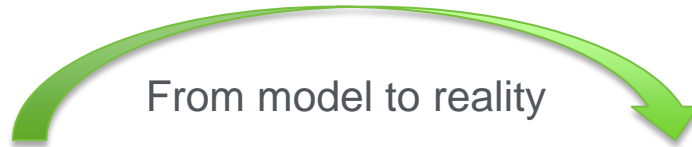


Data Integration & Innovative Enhanced Seismic Data Acquisition and Analysis

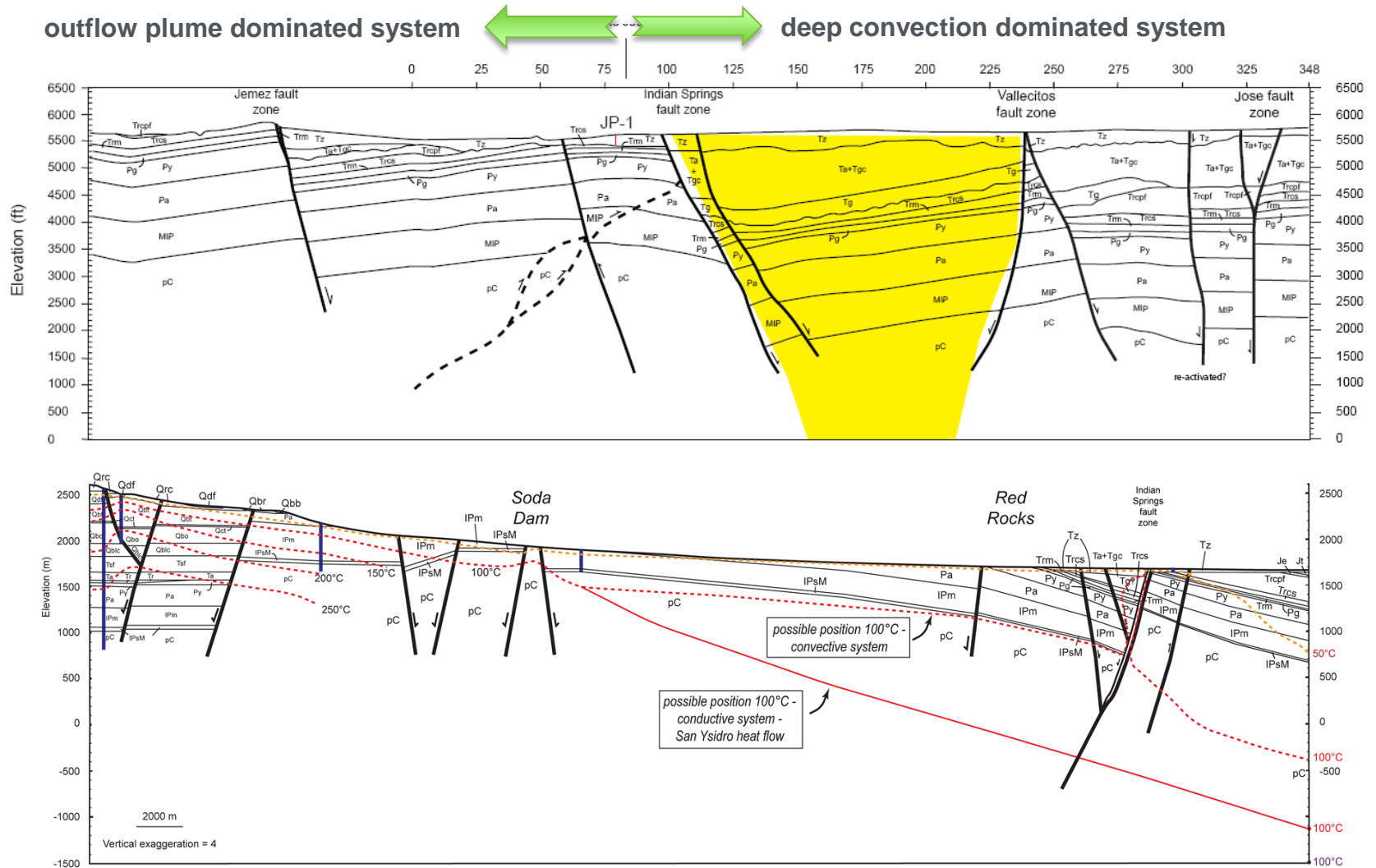


Current Seismic Analysis and Progress

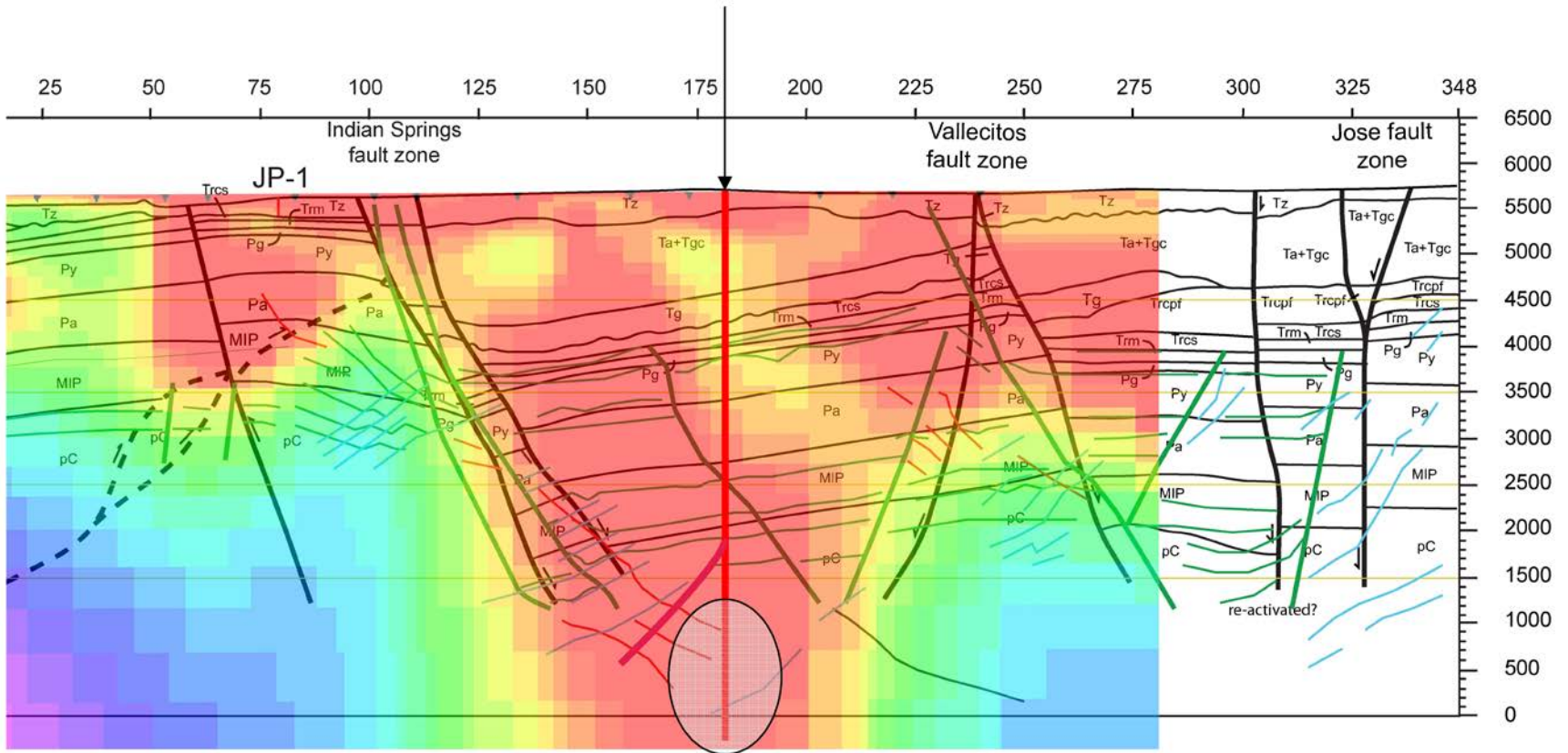
Elastic-wave reverse-time migration with a wavefield-separation imaging condition



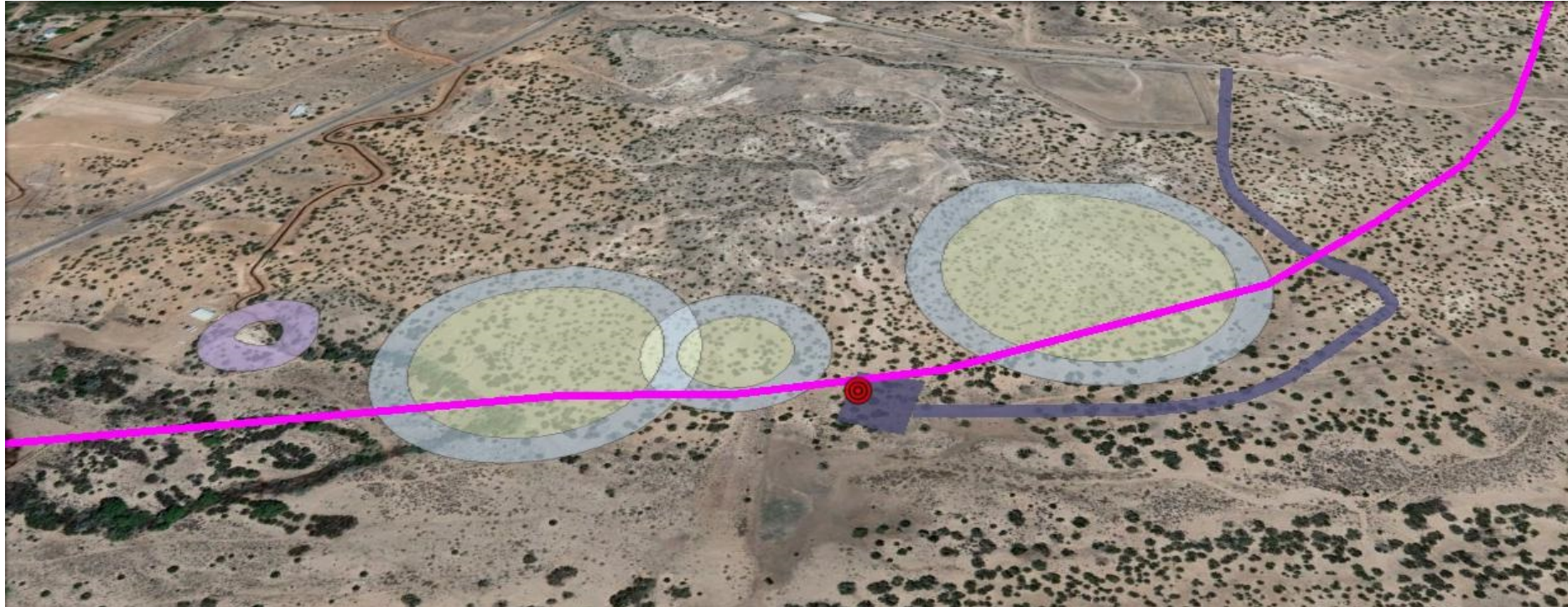
Conceptual Geothermal Model in 2011



Approved Drilling Plan for 2012



NEPA Based Spud-In Adjustment Process



After initial drilling plan approval the project had to adjust the spud-in location in a risk and cost mitigation process in order to address archeological findings as well as a potential future road construction project in addition to cultural use of the area. Those adjustments resulted in project delays.

Permitting

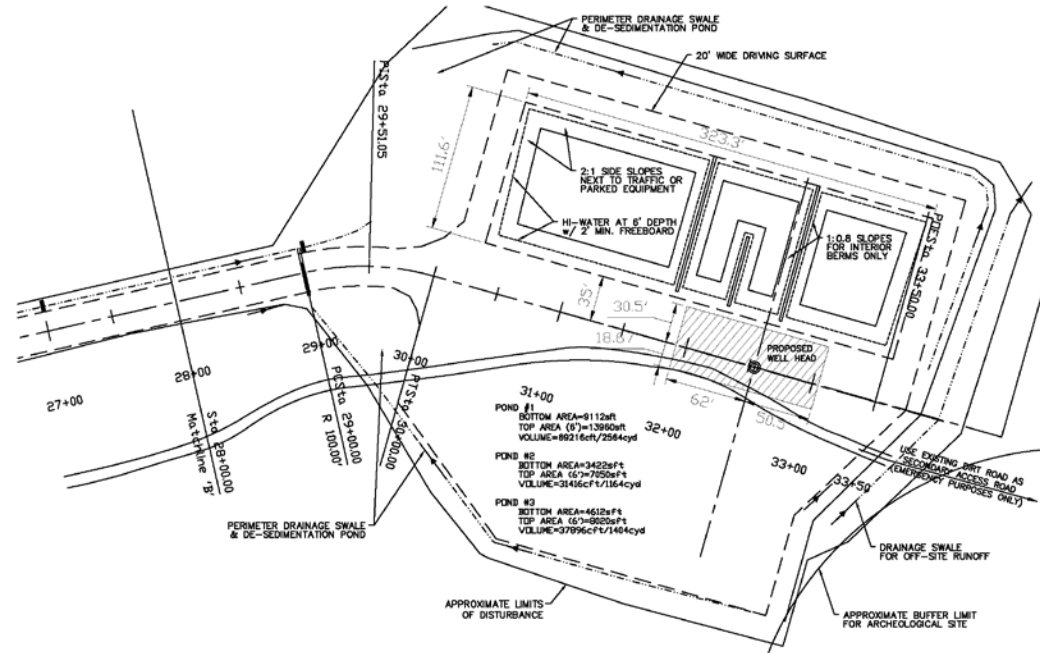
This well is drilled on land of the Pueblo of Jemez, a sovereign tribal nation. Because the Pueblo is developing this well itself (as opposed to leasing the development to an outside entity) the project falls outside of any regulatory scheme. In consultation with DOE, it was decided to voluntarily comply with drilling and environmental regulations of the State of New Mexico.

The responsible departments of the State of New Mexico did not provide resources for peer-review of the regulatory process. The solution identified with the DOE was that the Pueblo of Jemez would hire a vendor that functions as a regulator, reporting to the DOE, and would monitor the project to ensure conformity with the state regulations. The vendor selected also completed a drilling permit application that is identical to those required by the state including all drilling parameters and pad and pit designs.

In using the “Vendor Regulator” approach, the administrative processes have a quick turn around. The New Mexico drilling permits have been issued and reviewed by the DOE.

However, developing a permitting, compliance and inspection solution, as well as procuring it, resulted in project delays.

Access Road & Drill Pad Engineering and Construction



The access road & drill pad engineering has been finished. Following the findings of the construction cost schedule, the project is producing its own crushed aggregate base course (CABC) out of the Jemez Borrow Pit, owned by the Pueblo of Jemez. Following Pueblo procurement processes, construction is expected to start at the end of March 2013, and is scheduled to take about 5 to 6 weeks.

Procurement and Management of the Drilling Operation

- The Pueblo of Jemez is the operator of the drilling operation. A turn-key solution strategy has been rejected due to its inherent profit margins that increase costs substantially.
- The project still follows the original drilling cost schedule as budgeted in 2011/2012.
- Competitive procurement of drill rig and construction services is done directly by the Pueblo of Jemez.
- Competitive procurement of all other related products and services is done through TBA Power.
- The project intended and still desires to use drill bits from Novatek, developed out of funds of the GTO.
- Unfortunately those bits are not made available to the project.
- Under the leadership of the Technical Project Manager, the well is drilled by the following team:

Human Resources:

Axel Sperber	-	Remote Lead Drilling Engineer
Virgil Welch	-	Drilling Consultant, Manager and Field Supervisor
Tim Jones	-	Tool Pusher
John Tuttle	-	Drilling Fluids

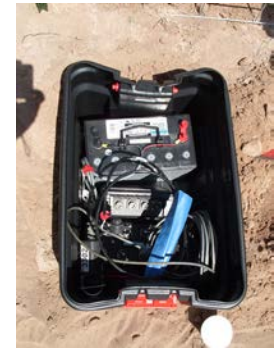
Vendors:

Hydro Resources	-	Drill Rig and Crew Provider
Sinclair	-	Drilling Fluids
TBA Power	-	Mud Logging by Tribal Employee & Project Geologists
INTERA	-	Compliance Management & Inspection

And many more.

Job Creation

- On average 6+ permanent full-time jobs have been created.
- 4 to 9 members of the Pueblo of Jemez found not only permanent full-time employment but are now also IGSHPA accredited Geothermal Drillers and Installers that attend college. They are listed as Geo-Technicians within TBA Power's tribal service unit called "Team Wolverine". The initial expectation according to original project plan was to create for tribal members 6 to 8 full-time positions for 3 to 4 months only.



- Seismic has been proven to be a very effective and high resolution structural method needed for drilling planning and resource interpretation resulting in a conceptual model.
- Magneto Telluric interpretation together with seismic results in a very solid structural understanding of the resource. Further information can only be obtained by entering the resource through drilling.
- Deploying a seismic monitoring network allowed us to address public concerns properly and document the natural local seismicity in the region.
- More detailed hydrogeochemistry combined with all other surface exploration methods, resulted in a better conceptual understanding of the geothermal resource, leading to a general project program change from a two well approach to a one deep well approach.

Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Pass TMT Stategate from surface exploration and drilling planning into the drilling phase.	Data evaluation and exploration interpretation have been approved by the TMT. Passed through Stagegate.	2/2012
Developing drilling permit and monitoring plan.	Both have been approved by the DOE.	12/2012

Milestone or Go/No-Go	Status & Expected Completion Date
Finish Drilling Operation	Site construction started, drilling expected to be finished in June.
Phase 3 Review	Following the drilling phase, the Phase 3 design will be reviewed with the Technical Monitoring Team

Once the well is drilled and tested as part of this project, all information will have been explored that is needed to conduct a reservoir assessment for potential investors. If the findings support the commercial development of the resource, it is expected that further testing and exploration steps will be taken as part of a commercial development program.

In order to continue testing and evaluation beyond the scope of the project, the goal is to leave the well in Precambrian open hole which allows most flexible subsequent access for investor driven testing and operations.

- Permitting a geothermal development project on tribal land has great advantages compared to permitting on private or public land.
- Procuring non-turn key drilling solutions is much more cost effective than turn-key solutions.
- The current oil and gas boom in the U.S. results in higher rig costs, especially rig mobilization charges.
- Adding seismic to the exploration program created a substantial risk reduction in regards to drilling planning as well as drilling cost management.

Timeline:

Planned Start Date	Planned End Date	Actual Start Date	Current End Date
10/1/2009	10/1/2011	1/29/2010	12/31/2013

Budget:

Federal Share	Cost Share	Planned Expenses to Date	Actual Expenses to Date	Value of Work Completed to Date	Funding needed to Complete Work
\$4,995,844	\$100,000	\$4,995,844	\$1,797,555.71	excellent	\$3,298,288.29

- We met all DOE requirements to pass through the stagegate into the drilling phase.
- We met additional requirements to voluntarily comply with the State of New Mexico drilling regulations.
- We adjusted the spud-in location to avoid newly discovered archaeological sites which required additional NEPA clearance.
- We are on schedule as adjusted by DOE to meet these additional requirements.