Detachment Faulting & Geothermal Resources - Pearl Hot Spring, NV

April 25, 2013

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(formerly University of Kansas)

Detachment faulting and Geothermal Resources – An Innovative Integrated Geological and Geophysical Investigation of Pearl Hot Spring, Nevada

- Timeline
  - Project start 01/29/2010 - 01/28/2013 (Phase I: 98% complete, project extension in the work as part of latest partner change)
- Budget
  - Total project funding $ 4,242,519,
  - DOE $2,299,237, awardee share $1,943,282 (now at UT Austin)
- Completion of Phase I provides all the information needed for selection of the best location for the slimhole wells. Currently working on decision (scientific/financial) whether to drill slim holes; if not, the Phase Report will act as the final report.
- Partners: Rockwood Lithium (?) (former partner Ram Power Inc. and previously Sierra Geothermal Power Inc.), University of Oklahoma, University of Kansas)

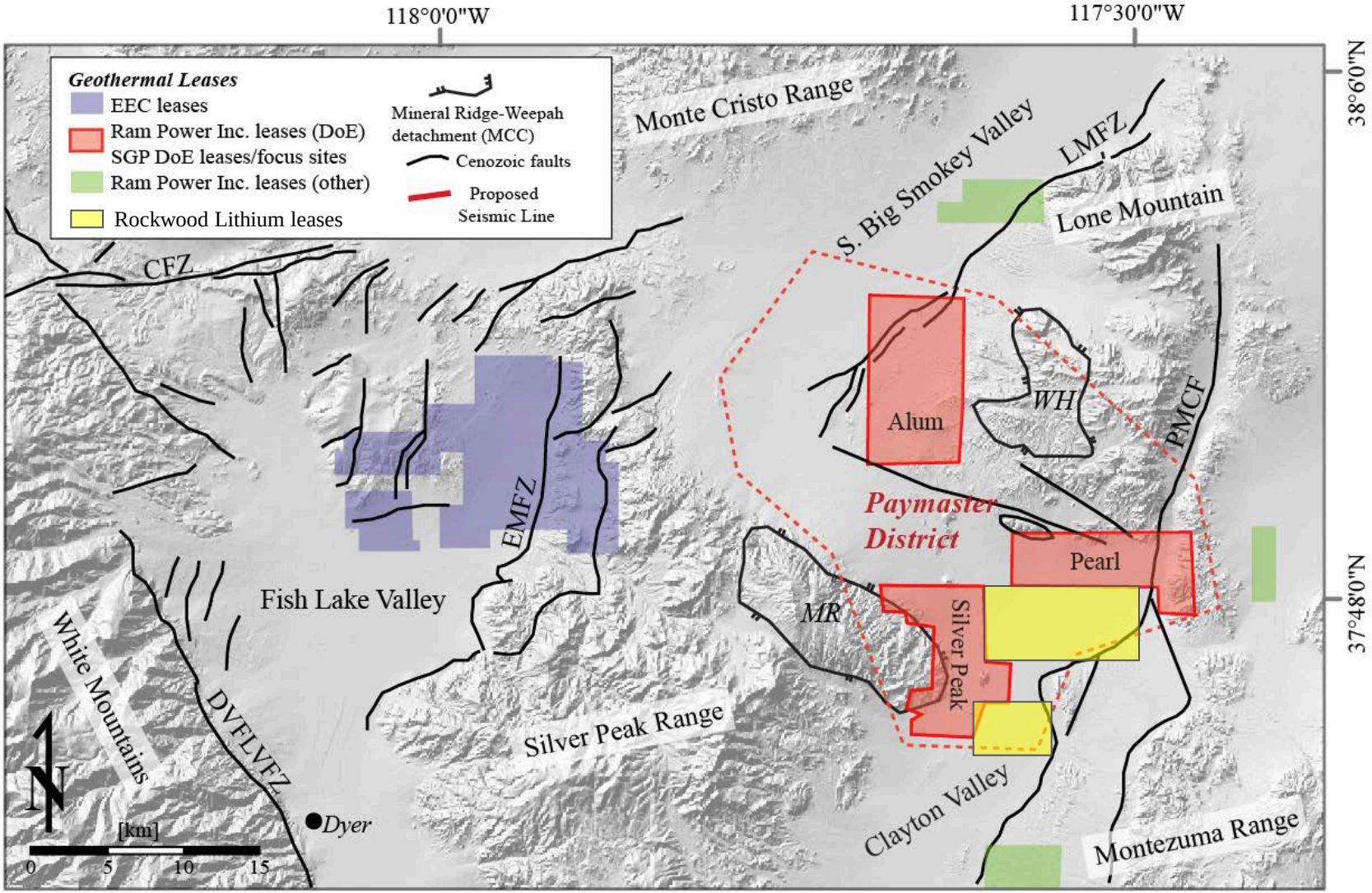
Summary of project management plan

Stockli is the project leader (not at UT Austin) and he and his KU/UT team carried out all structural, geological, and thermo-chronometric analyses during Phases I as well as the data integration and construction of a 4D model. Active source seismic data acquisition, processing, interpretation, and potential fields work as carried out by Drs. Keranen and Keller and their team from the University of Oklahoma.

We have worked closely with Sierra Geothermal Power and Ram Power Inc. staff during phase I. Rockwood Lithium will likely take the lead during phases II and III with Stockli and his team in charge of the scientific monitoring, evaluation, and continued data integration. We were also working with Ram Power on Silver Peak and Alum projects to help with geology, geochronology, and geophysics (other DoE projects) prior to the abandonment of their Paymaster/Clayton opeartions/intersts.

Variance from original project plans/schedule and the corrective action(s):

Stockli and his team relocated to UT Austin in 8/12. Award is currently being moved from KU to UT. No spending or fund availability since 8/12 (incl. subcontract to OU, causing delays). Ram Power undergoing internal restructuring. Back on track at end of novation. Phase I is 90+% complete.


118°0'0"W
117°30'0"W
38°6'0"N
37°48'0"N
Geothermal Leases
EEC leases
Ram Power Inc. leases (DoE)
SGP DoE leases/focus sites
Ram Power Inc. leases (other)
Rockwood Lithium leases
Mineral Ridge-Weepah detachment (MCC)
Cenozoic faults
Proposed Seismic Line
Monte Cristo Range
S. Big Smokey Valley
LMFZ
Lone Mountain
CFZ
Alum
WH
PMCF
Paymaster District
Pearl
EMFZ
Fish Lake Valley
MR
Silver Peak
White Mountains
DVFLVFZ
Silver Peak Range
Clayton Valley
Montezuma Range
Dyer
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Objective of Pearl Hot Spring/Clayton Valley Project

Systematic Integration of new thermochronometric, structural and geological analyses, reflection and refraction seismic surveys and existing geophysical data into a 3-D Earth Model to elucidate the tectonic and 4-D thermal evolution of southern Clayton Valley and the Weepah Hills (Pearl Hot Spring and adjacent geothermal plays).

The ***combination of surface and subsurface thermochronometric constraints with a detailed 3-D Earth Model*** is a unique new approach to exploration. Detailed 3-D structural imaging coupled with a better understanding of the long-term thermal evolution should enable significantly improved siting of geothermal exploration wells, and ultimately the location of geothermal production wells.

Summary of scientific/technical approach (Phase I)

(1) Structural and geological analysis of Pearl Hot Spring Resource

(2) (U-Th)/He thermochronometry and geo-thermometry

(3) Detailed gravity data collection and integrated modeling (supplemented by some magnetic and resistivity data)

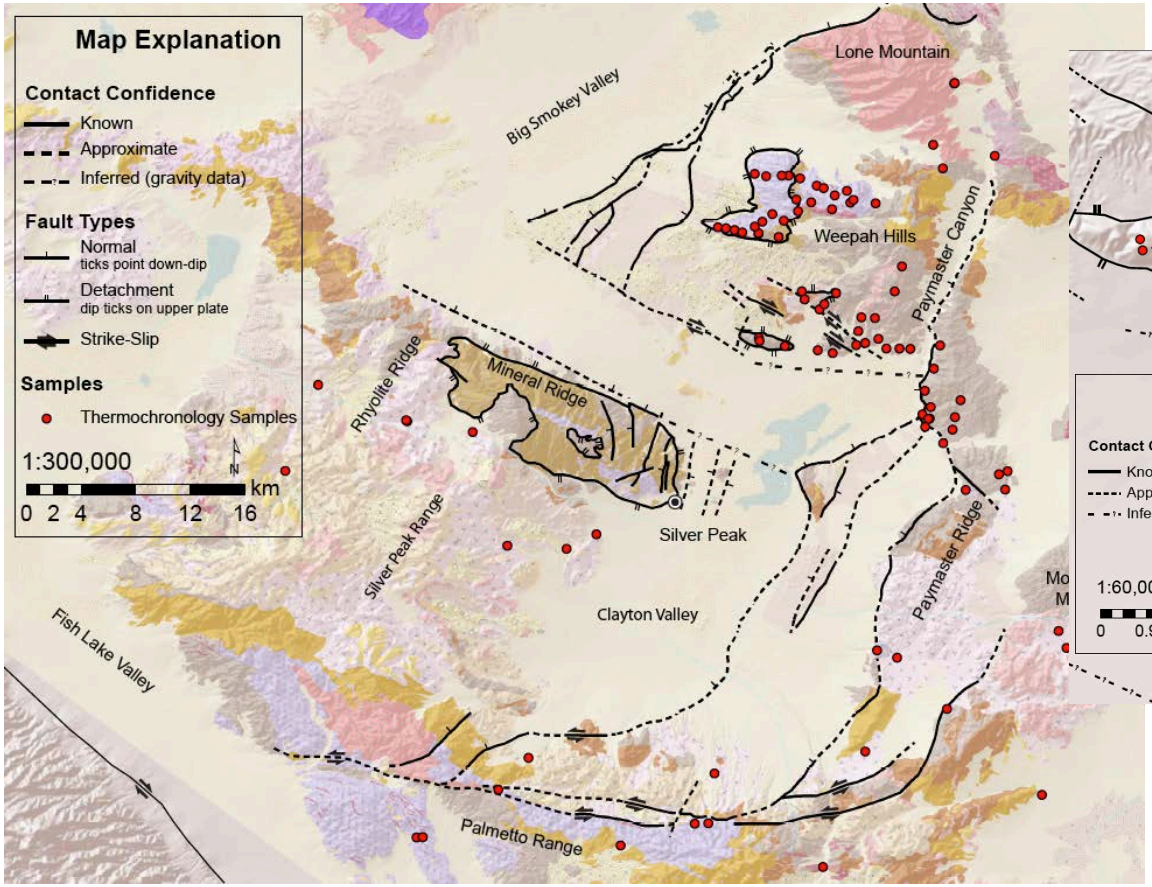
(4) Reflection and Refraction Seismic (Active Source)

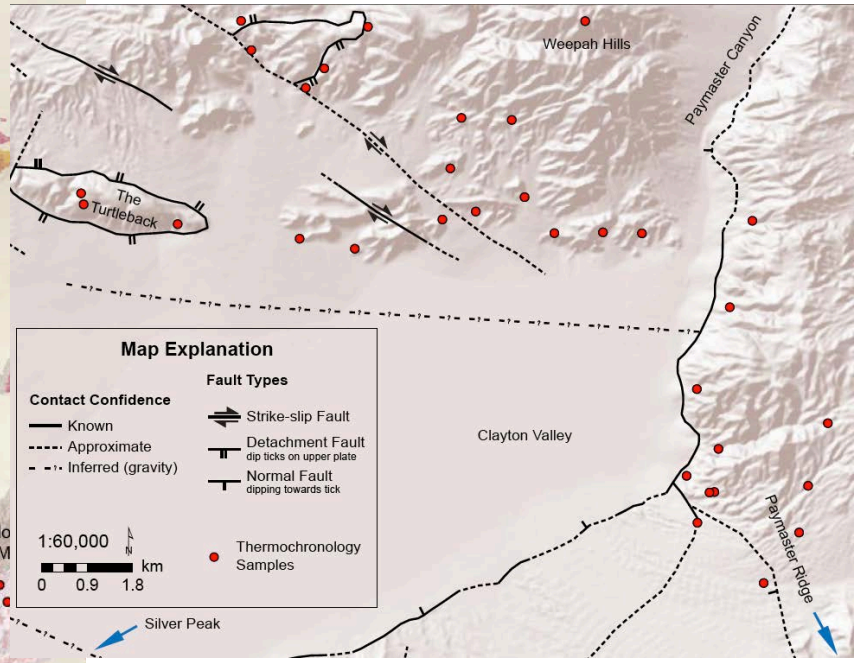
(5) Integration with existing and new geological/geophysical data

(6) 3-D Earth Model, fully integrating all data

Innovative approach combining classic work with new geochemical and geophysical methodology to detect blind geothermal resources in a cost-effective fashion

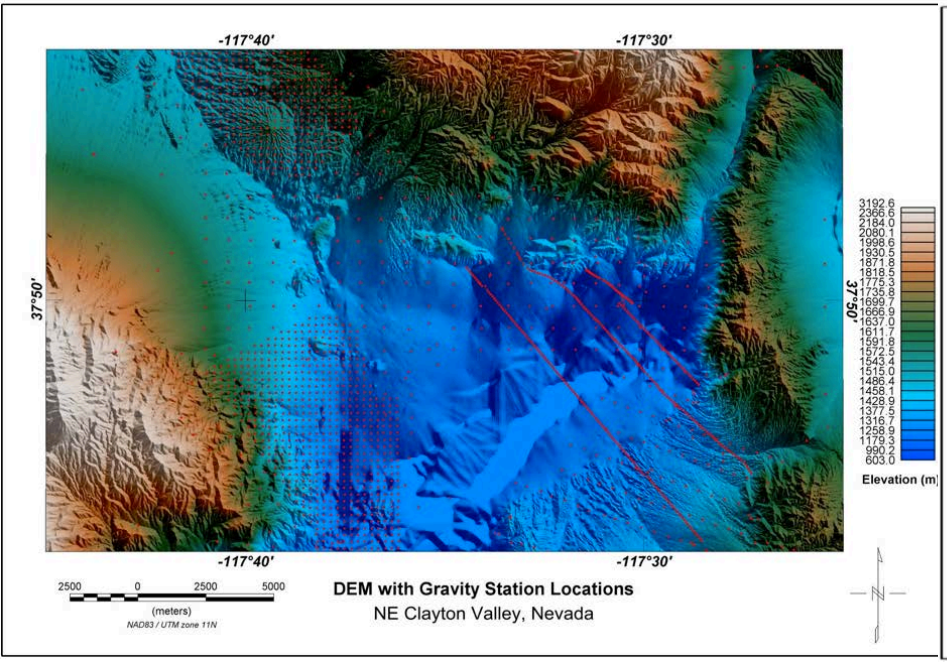
Geological and Structural Mapping in around Clayton Valley and low-T thermochronometry (2010-13)

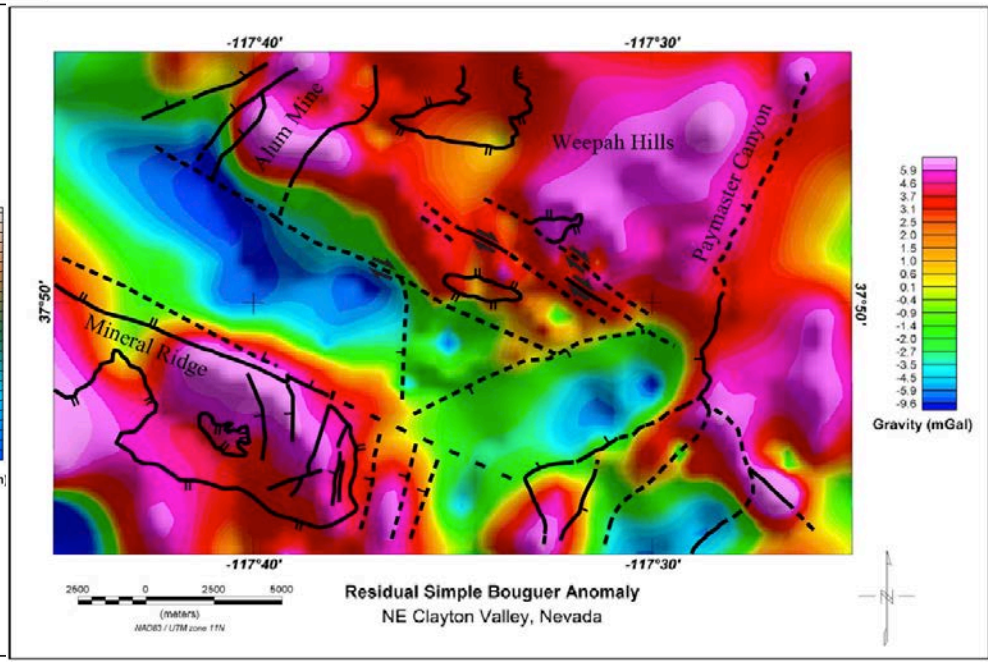




Structural Mapping Completed
Thermochronometry sampling Completed
(U-Th)/He analytical work Completed
(lateral data integration in progress)

Gravity Data for Clayton Valley & Subsurface Structural Model

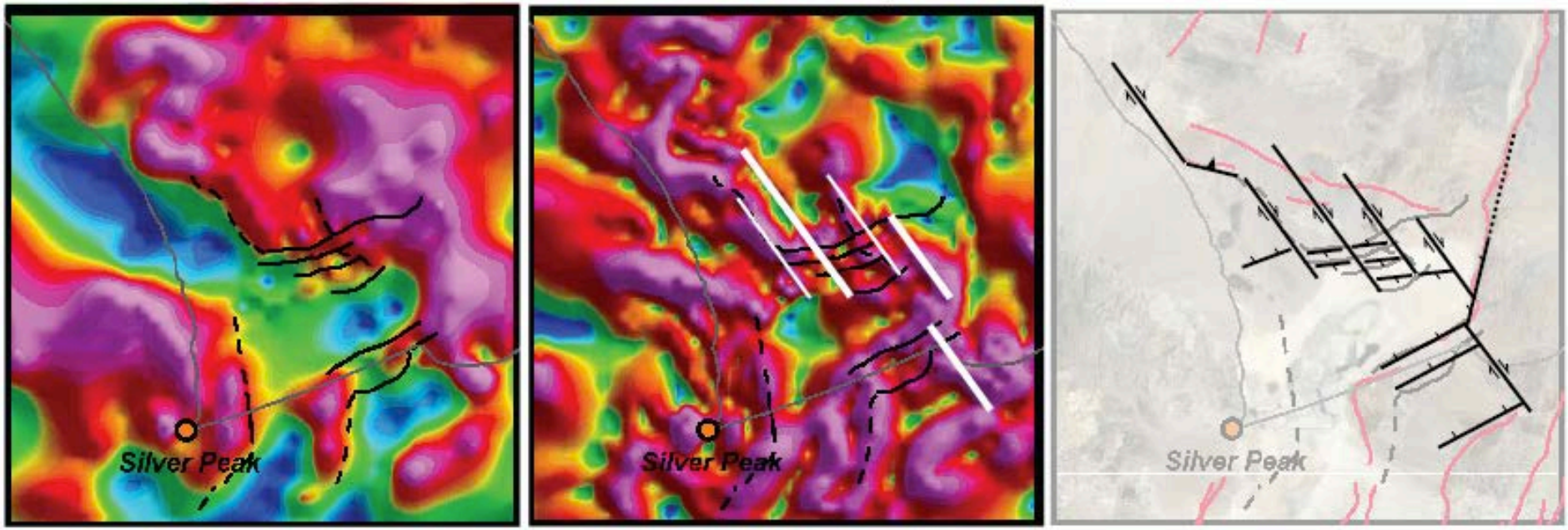




Gravity: Data spacing 50 m along three lines parallel to seismic survey (red lines). Additional arrays (red dots) with spacing ranges from 100-500 m along-line with lines are from 500-m to 2-km apart. Processing data using Oasis Montaj (gravity gridding and derivatives), TopCon (for elevation data), and Matlab/Excel (data reduction).
Instruments: Two Scintrex CG-5 gravimeters with TopCon GB-1000 geodetic receivers for elevation/positioning.

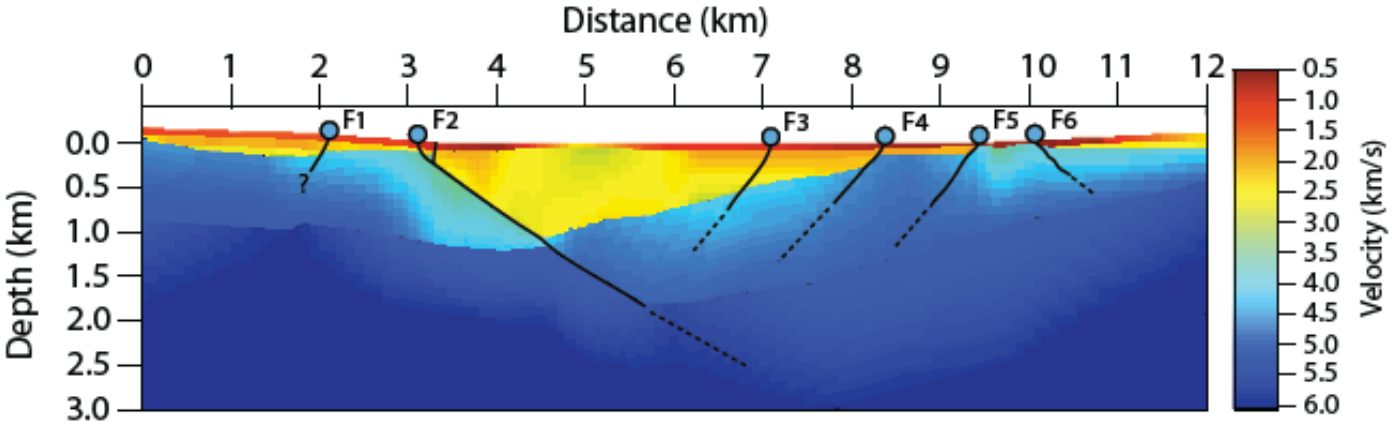
Outcome: Self-consistent surface and subsurface structural model

Gravity/Magnetic Data for Pearl and Detailed Structural Model

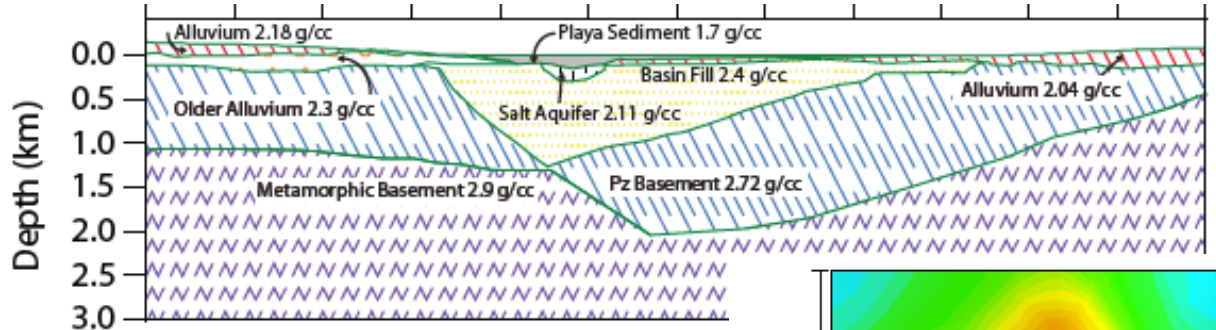


Gravity: Data spacing 50 m along three lines parallel to seismic survey (red lines). Additional arrays (red dots) with spacing ranges from 100-500 m along-line with lines are from 500-m to 2-km apart. Processing data using Oasis Montaj (gravity gridding and derivatives), TopCon (for elevation data), and Matlab/Excel (data reduction).
Instruments: Two Scintrex CG-5 gravimeters with TopCon GB-1000 geodetic receivers for elevation/positioning.
Structural Mapping: Integration of existing, Ram, and new geological and structural mapping and fault kinematic analysis and integration with potential field data

Outcome: Self-consistent surface and subsurface structural model

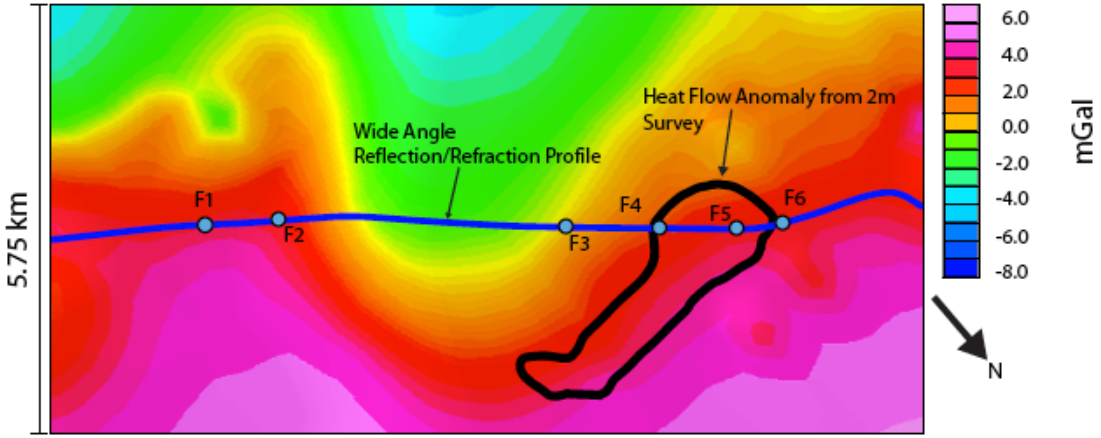


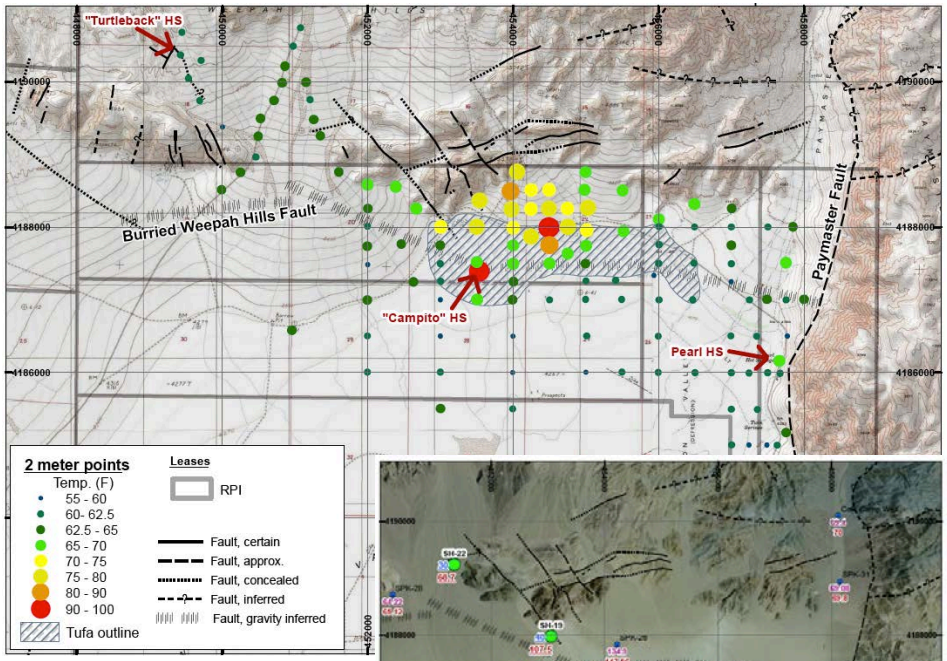
Line A: 15 km 2D line (13 ~20-70kg shots) 10-20 geophone spacing

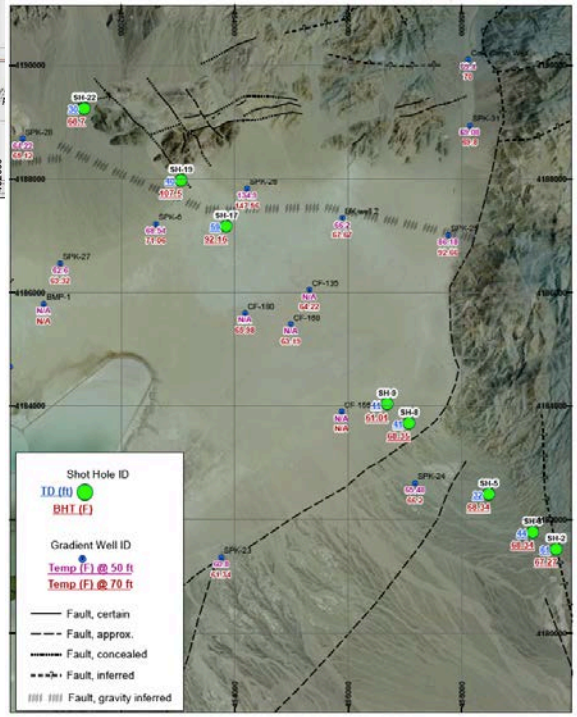


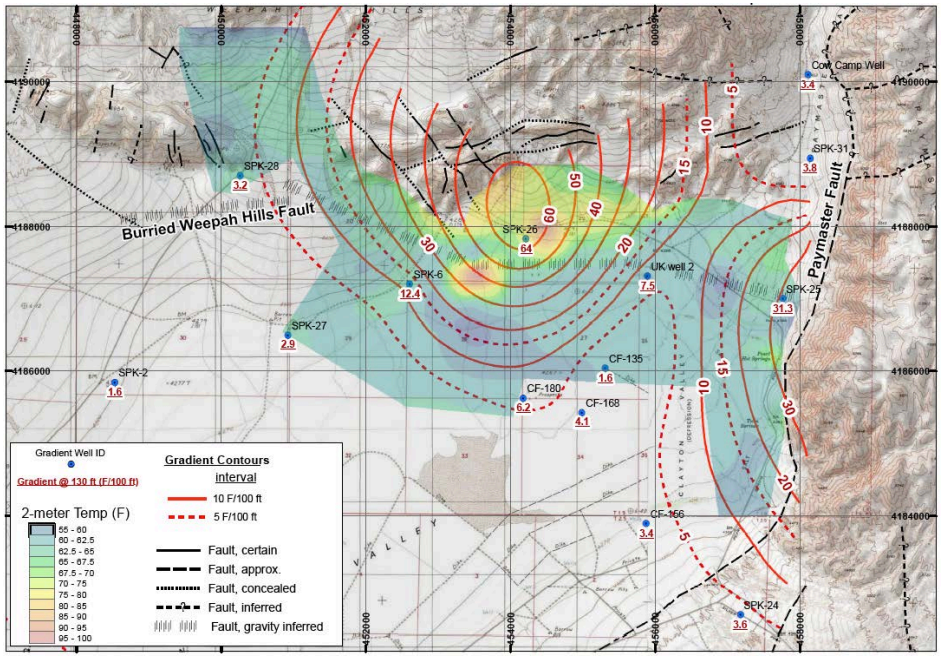
Line B: 2 km high-res 2D line 5 m shot & geophone spacing (see below)

Reflection and Refraction Seismic Survey (acquired in Jan. 2011 Š processed in 201/12) McGuire Thesis 2013





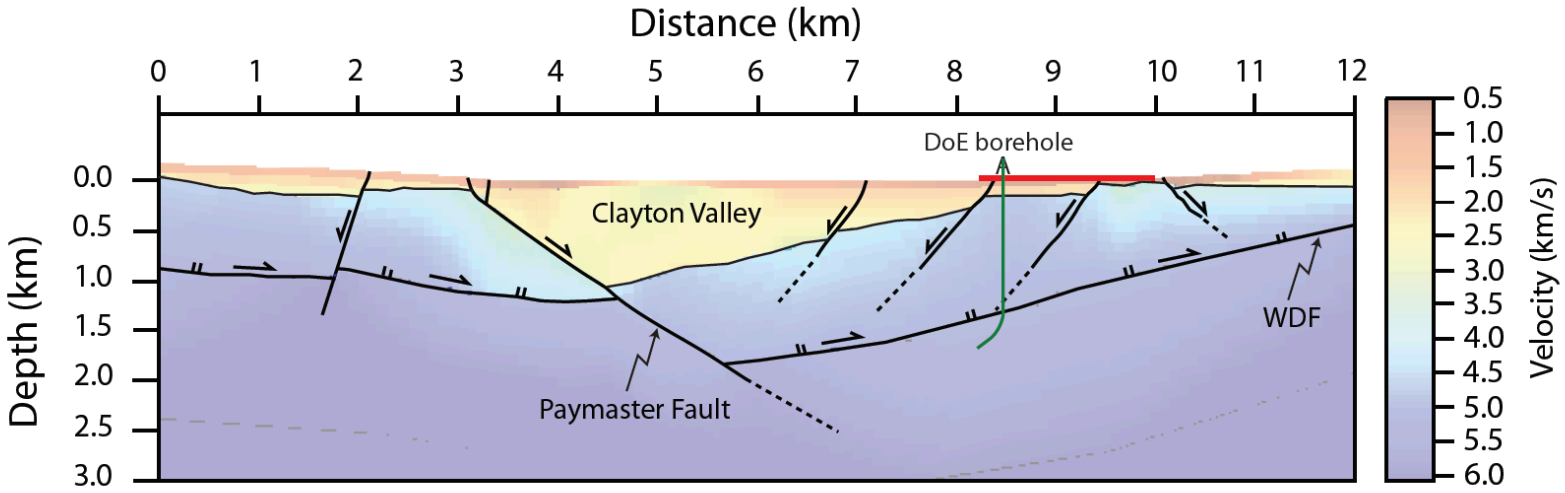




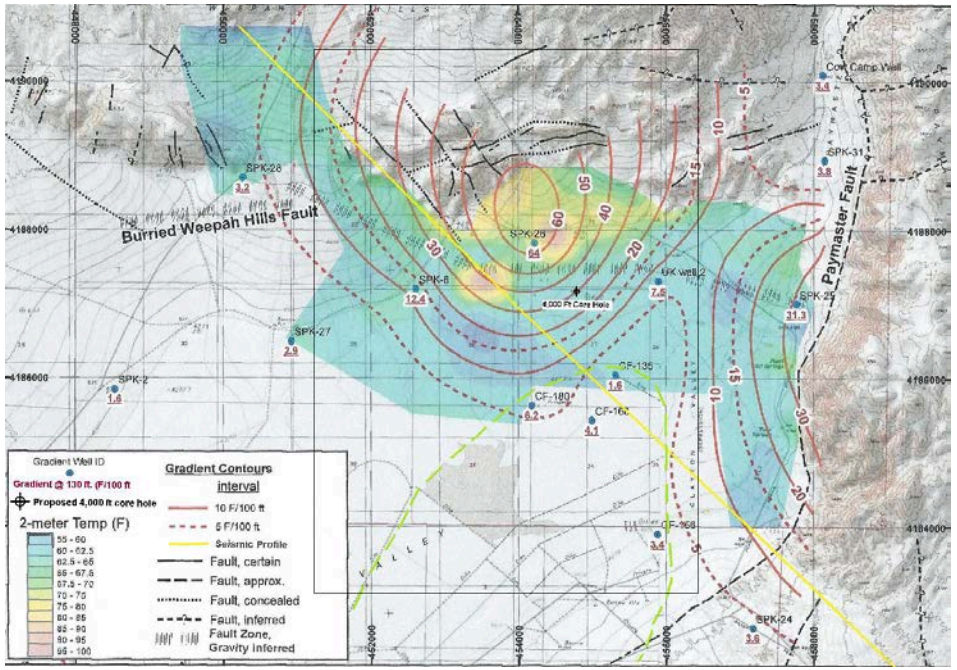
Near-Surface Thermal Gradient Surveys (Old & New)

Compilation of existing thermal gradient Holes and new data. New data consist of (1) 2m survey conducted by Ram Power Inc. (2) Instrumented Seismic Shot holes (8)

Clearly outlining thermal anomalies in basin!



Core Borehole Location Selection based on Integrated Geologic, Geophysical, and Shallow Temp Gradient Survey (acquired in 2010 Š 2012)



PHASE I CONCLUSIONS AND DRILL SITE SELECTION

(1) Structural geometry of the basin, suggests the presence of high-angle dilational faults, transferring slip from NW-trending strike-slip faults across these dilational steps eastward, before intersecting the Paymaster Canyon Fault (PCF). These step-overs are along the northern edge of the Valley control the thermal anomaly (see 2m survey). The dilation step-overs likely create fracture permeability in the upper plate of the Weepah Hills Detachment (WHD).

(2) The seismic data show that both the PCF (south side of Valley and Pearl Bath House area) and WHD are very reflective. The high-amplitude reflectivity suggests that the fault is heavily mineralized - a clear indication for geothermal fluid flow along the fault. There is also good geophysical evidence for geothermal fluid flow along faults. Velocities are slow along the faults, indicating (most likely) geothermal fluids moving along them.

PHASE I CONCLUSIONS AND DRILL SITE SELECTION (part 2)

(3) These antithetic high-angle faults appear to either sole or cross-cut the WHD (expressed as a major velocity boundary in the subsurface) at about 1.3-1.5 km. The shallowly S-dipping detachment is likely a good candidate for hydrothermal circulation. The WHD is cut by the PCF along the S basin margin at about 6000-6500 ft. It is conceivable that if the detachment acts as a conduit that hydrothermal fluids "surfacing" along the PCF at Pearl Hot Spring Bathhouse and along the dilational antithetic faults ("main anomaly") are linked at depth.

(4) The geochemical data is spotty due to the lithologies encountered, but the youngest ages from around the basin are centered along the north side of the valley next to 2m survey anomaly. Thermochronometric ages from the lower Pz strata in the hanging wall of the WD are largely clustering around 35-50 Ma in age. Samples from the footwall of the WHD cluster uniformly from 14-9 Ma. In contrast, samples from the vicinity of the thermal anomaly are dramatically reduced and are generally <<10 Ma (compared to other Pz upper-plate samples ranging from 35-50 Ma!). The thermochronometric anomaly spatially coincides with the 2m shallow thermal anomaly. No age reduction was observed in the Pz rocks adjacent to the Pearl Hot Spring Bathhouse location (anomaly is of lesser magnitude and below the detection limit conventional (U-Th)/He).

Milestones and go/no-go decisions for FY10-12 (Phase 1)

(accomplished and planned completion):

- Geological Mapping and Structural Analyses (March 11)
- Thermochronometry and Geothermometry - sample collection & processing (Jan 11), isotopic analyses (Dec 11)
- Gravity (Plus Magnetics/Resistivity) Data (March 11)
- Thermal gradients - shot holes and 2m survey (RPI) (Jan 11)
- Reflection/Refraction Seismic Survey (BLM and EA permit) - data acquisition (Jan 11) and processing (Feb 12)
- 3-D Earth Model Integration and Evaluation (Feb 12)

Go/No-go decision: slimhole drilling (currently in evaluation by Ram)

Recommendation: Drilling of a 4,000-5,000’ core slimhole south of thermal anomaly intersecting both high-angle normal fault and WHD at depth.

Accomplishments, Expected Outcomes and Progress

Progress to date and/or planned accomplishments/outcomes:

Project funds conditionally released in May 2010, BLM permission granted in Oct 2010, and DoE-KU contract signed in Nov 2010.

2010-11: Structural mapping and thermochronlogy sample/data collection

2011: Acquisition and interpration of seismic and gravity data

Fall 2011: Move to University of Texas Austin (pending novation since 8/11)

Winter 2011/12: Data compilation & integration into 3-D Earth Model

Summary of immediate plan:

Completion of Project Novation (no spending since 8/11!) and likely new partner (Rockwood Lithium) and lateral move to SW in Clayton Valley coupled with integration with new data (integration of our data with Rockwood and Ram data)

Final evaluation of integrated phase I results and new data and drill site evaluation

Start permitting of drill site #1 (in collaboration with Rockwood Lithium)

Go/No-go decision: slimhole drilling (ASAP) and drilling by end of year 2013

Future Directions

We hope to demonstrate that our innovative and integrated approach presents geothermal operators with a very ***cost-effective approach*** to help plan the location of exploration and ultimately production of utility-grade geothermal wells. Test our structural and geothermal models for permeability and ***fluid flow along detachments*** and intersecting high-angle normal faults (fault or fracture control) and evaluate importance of ***fault interaction*** of NW-trending strike-slip faults with high-angle and detachment faults (creation of rejuvenated fracture permeability).

Besides the exploration and scientific benefits, the project will result in the education of several graduate (3) and undergraduate (3) students, helping ***train a new generation*** in renewable energy exploration, as well as temporary employment for students (3 graduate and 3 undergraduate students), collaborators, and any contractors (e.g., drillers).

If the exploration work identifies a viable resource (as indicated by Phase I), then the economic impact will include long-term employment and significant development potential for the local region.

Mandatory Summary Slide

- Low- and intermediate-temperature thermochronometry is becoming a powerful and very cost-effective geothermal exploration tool (locating long-live and blind geothermal anomalies) (e.g., Gorynski et al., 2010)
- Complex fault interactions (detachment, high-angle faults (syn- and post-detachment), and NW-trending strike slip) require a holistic and integrated structural, geological, geophysical, and geochemical approach to pinpoint resource and drilling location
- The Pearl Hot Spring Project conducted by KU/OU and SGP researchers focuses on a unique 3-D Earth Model to minimize structural/thermal uncertainties and elucidate the 4-D thermal evolution of the geothermal resource to optimize the drill location sitting and exploration success (Phase I - McGuire, MS thesis 2013 (OU), Burrus, MS thesis 2013 (UT))
- The result of this innovative approach point to a viable geothermal resource and should lead to drilling and testing of two geothermal exploration wells (cored) after careful end of phase I go/no-go evaluation (Phases II & III)

Data Sharing

DOE's GTP requires that all projects provide data to the DOE Geothermal Data Repository for linking to the National Geothermal Data System.

- Types of data generated (Phase I) and dissemination/archival:
- - Geochronology data (isotopic) - http://matisse.kgs.ku.edu/geochron/ (NSF supported site)
- - Geological Mapping - Publication and on-line availability (KU digital thesis rep and NBMG on-line maps)
- - Gravity and Magnetic Data - UT El Paso Nation Gravity and Mag Database
- - Seismic raw data - IRIS/PASCAL repository and UTIG (although mostly marine)
- - Data, metadata, and interpretations will also be published in peer-reviewed journals and publications
- Phase II and III publications will be directly served to the DOE GDR as they will be more common geothermal data (temp, fluid composition, flow rates, etc.)

- All data above will also be made available as data or served through the above portals to the nascent "DOE Geothermal Data Repository" - currently under development by Boise State University. The DOE Geothermal Data Repository will be made public through the National Geothermal Data System, or retained in the DOE Geothermal Data Repository as business confidential, where applicable.

Mandatory Summary Slide

- **Phase I** key exploration results and the integrated 4-D geological and geothermal model clearly point to (1) a significant (N Clayton) and (2) a potential (Pearl Bath House) geothermal resource. Integration of data with Rockwood Lithium and Pearl data are requiring a revaluation of geothermal resource plays and drilling recommendation (underway 3/2013).

Summary Table:

	FY2011	FY2012-3
Target/Milestone	Phase I (subtasks 1-3) completion and site selection for slimhole(s)	Award novation, evaluation of slimhole site selection, go/no-go decision, and drilling of slimhole(s) (if decision is go)
Results	Completed 3/2012	Decision by 4/13, drilling (if go) by end of 2013 (Phase II)