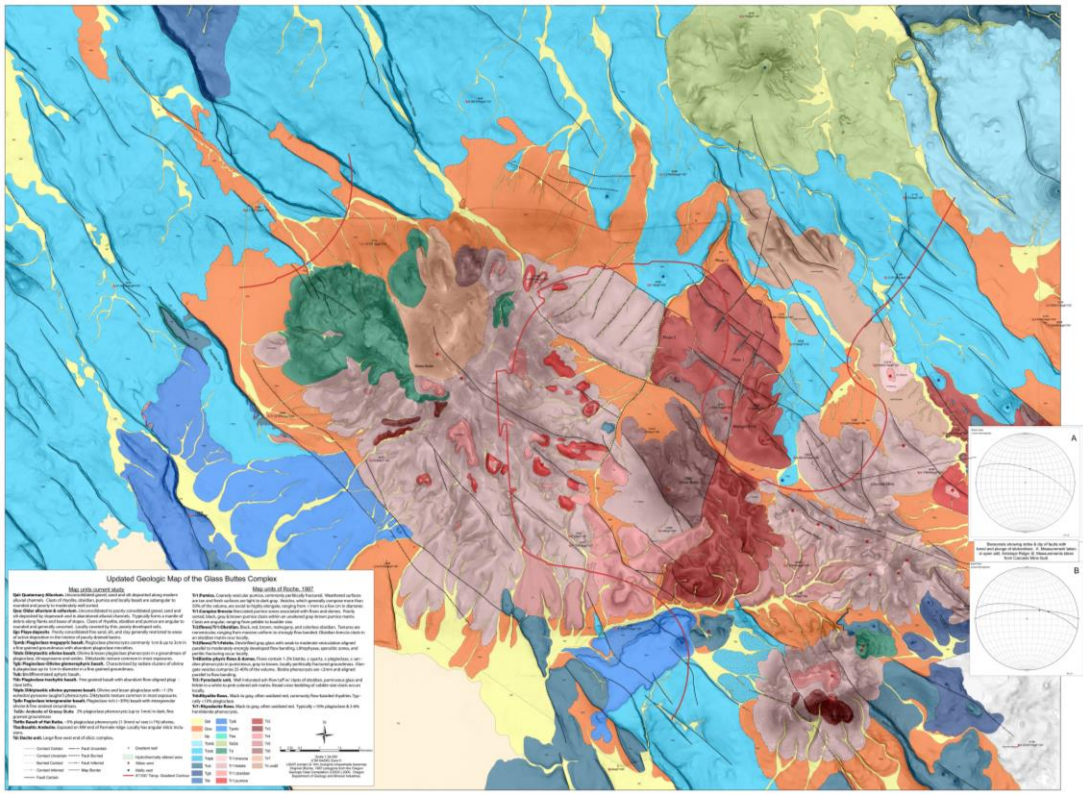
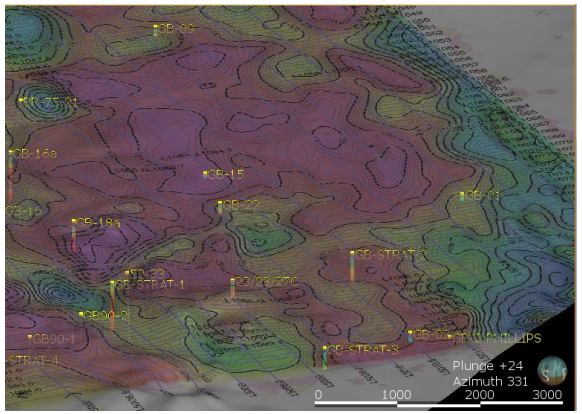




Glass Buttes

Project Officer: Michael Weathers

Total Project Funding: $8.7M

May 12, 2015

Patrick Walsh

Ormat

Track 2 HRC

Relevance/Impact of Research

Original Objectives

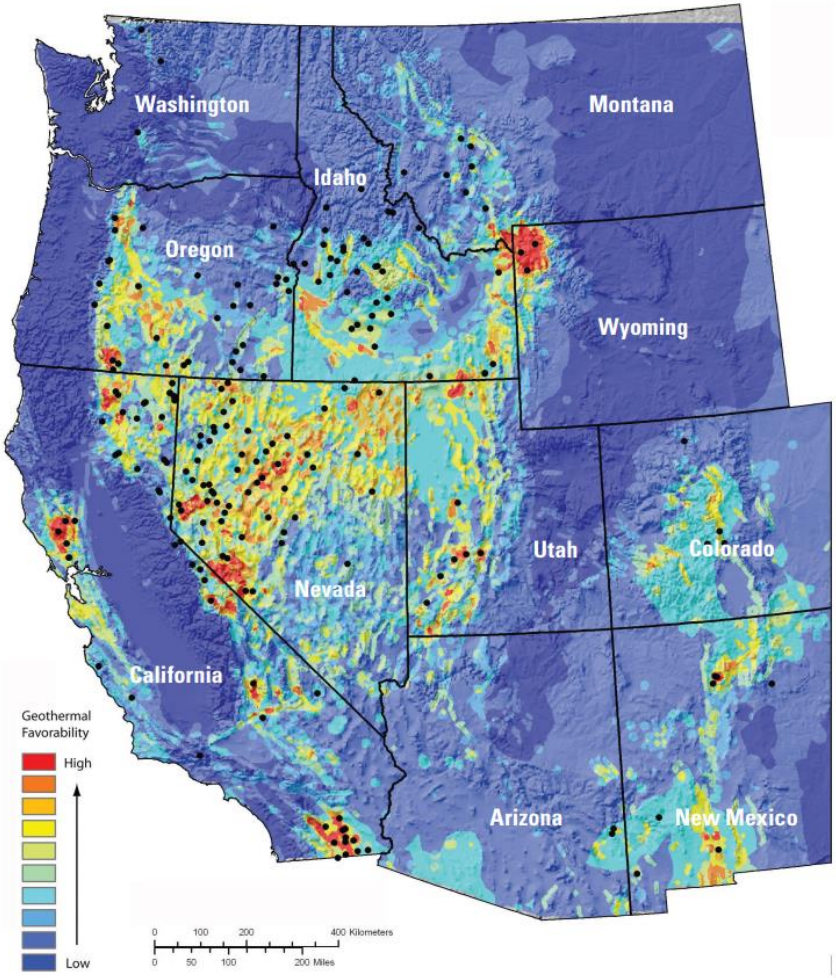
- Combine diverse exploration techniques to reduce exploration risk in blind geothermal systems
- Study two separate prospective areas with a single set of exploration data
  - Midnight Point – faults and fault intersections internal to silicic volcanism
  - Mahogany – faults and relay ramps outside volcanic center

Innovative Aspects

- Merging LiDAR, Hyperspectral, gravity, aeromagnetics, and magnetotellurics datasets into a single model along with historic down-hole lithology and temperature data
- After processing, integration of all geophysical and geological data to a comprehensive 3D model using Leapfrog Geothermal software.
- Modelling of target structures predicted by the comprehensive model

Relevance/Impact of Research

- Prospective structures predicted by the comprehensive model targeted with low-cost core well
- Success with this approach could be used to explore for other blind geothermal systems in the western U.S.



Williams, Colin F., Reed, Marshall J., Mariner, Robert H., DeAngelo, Jacob, Galanis, S. Peter, Jr., 2008, Assessment of moderate- and high-temperature geothermal resources of the United States: U.S. Geological Survey Fact Sheet 2008-3082, 4 p.

Scientific/Technical Approach

Multiple high resolution geological, geophysical and remote sensing methods to define fault with likely permeability

- Surface faults, lithologies and alteration
  - LiDAR – faults and orientations
  - Geologic mapping – lithologies and geologic relationships
  - Hyperspectral - petrology and alteration assemblages
- Subsurface structures
  - Gravity – Deep structures and limited density contrasts of volcanic rocks mask shallow signal
  - Aeromagnetic – High resolution illuminates faults
  - Magnetotelluric – Resistivity gradients and layers clarify fault offset direction and orientation and possibly correlate with alteration observed in previously drilled wells
- Subsurface targets, permeability and temperature
  - 3D geologic model – All data sets included in model
  - Slim well targets – High angle fractures with 3500-4000 target depth
  - Production well target – Dependent on slim well results
  - Reservoir testing – Following drilling

Technical Accomplishments

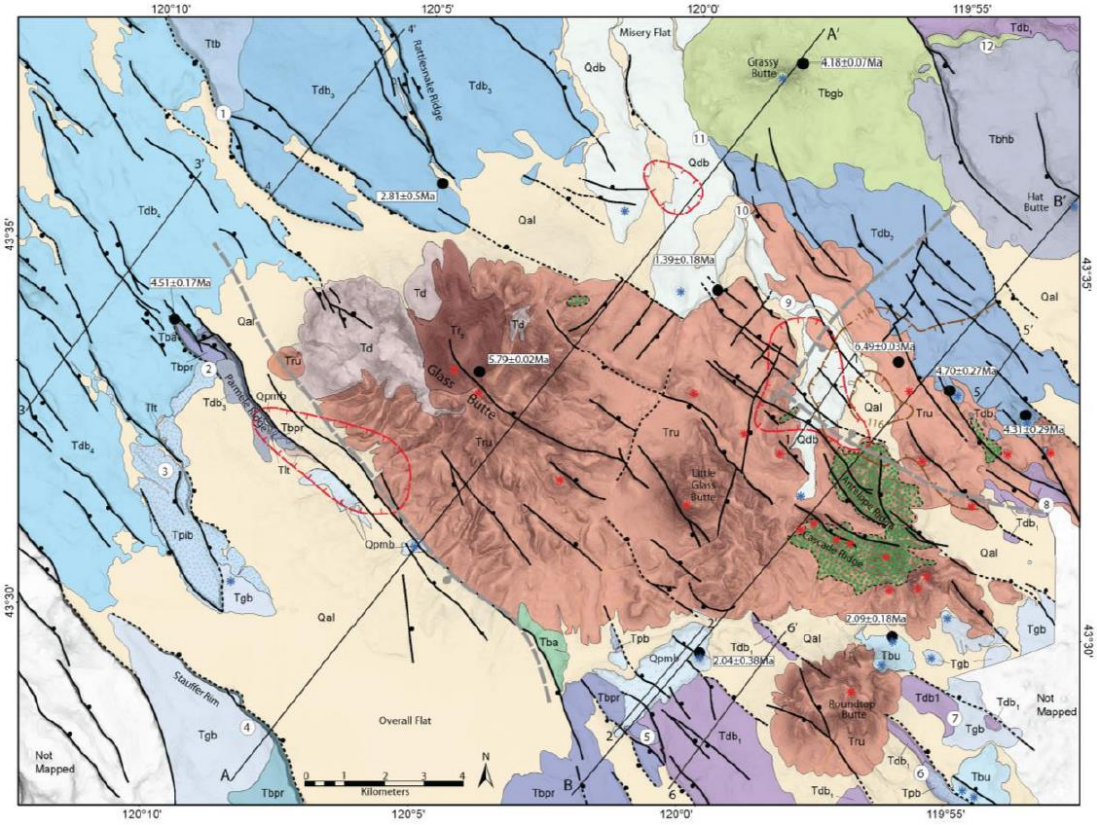
- Completion of suite of high resolution geophysics
- Integration of all datasets into state of the art 3D model
- Interpretation of data and selection of drilling target
- Successful completion of test well 52-33 to 3000 ft. TD

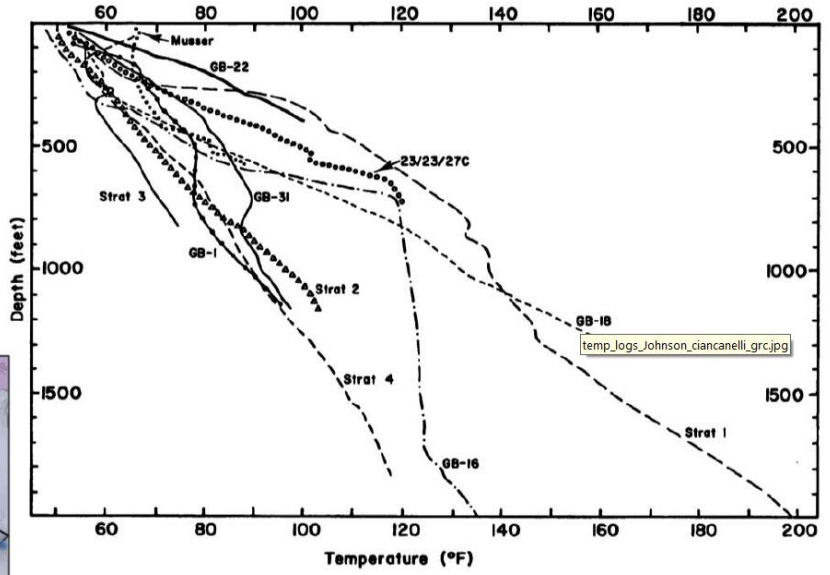
Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Complete surveys and select well target	Presented results to TMT and moved to phase II	
Drill test well	Completion of core well 52-33 to 3000' TD	November 2014

Accomplishments, Results and Progress

Geologic and temperature gradient mapping

- Detailed mapping completed in collaboration with OSU





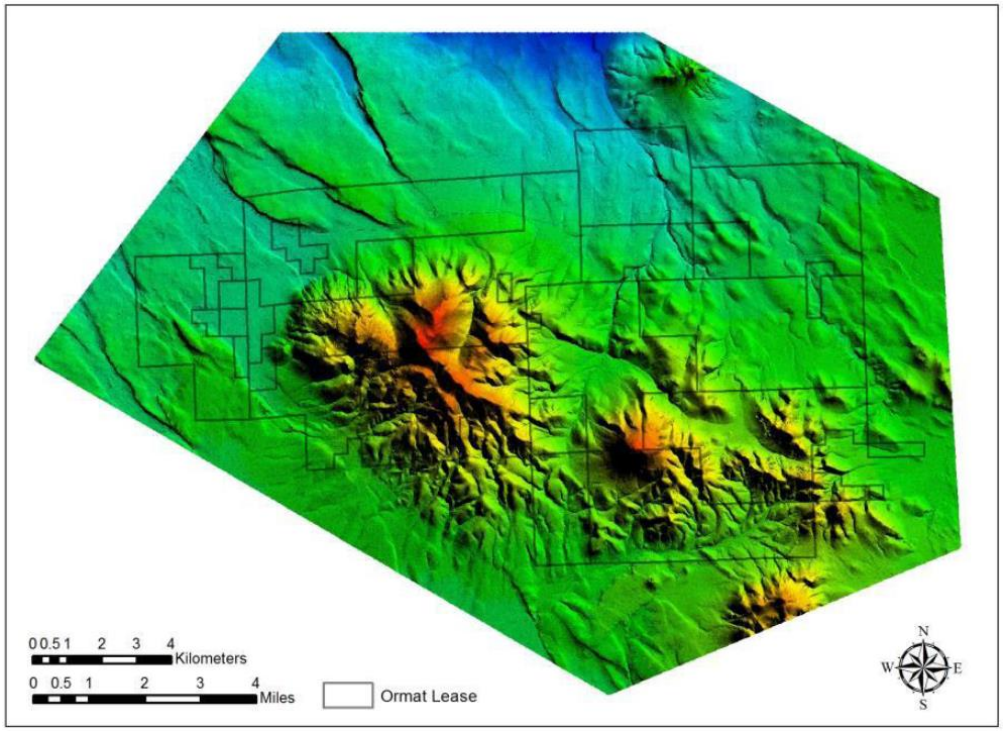
Johnson & Ciancanelli, 1989

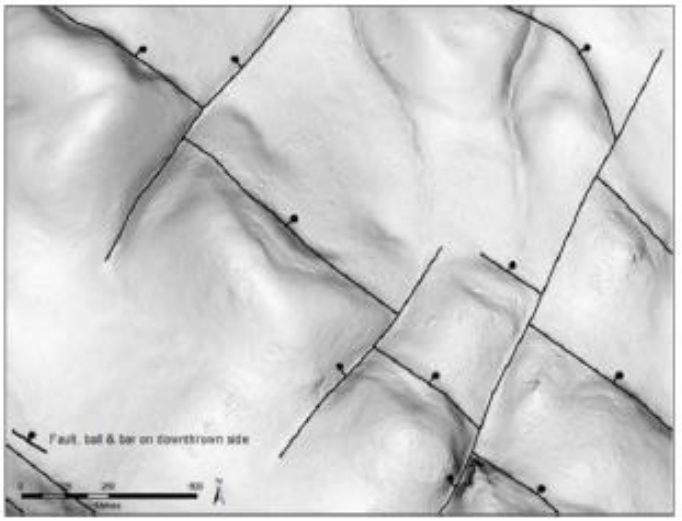
- Temperature logs from intermediate-depth drilling used to delineate gradient anomalies
- Red hatched lines indicate 165˚ C/km (10˚ F/100ft) temperature gradient anomalies in the eastern (Midnight Point) and western (Mahogany) areas.

Accomplishments, Results and Progress

LiDAR collected over entire project area

- Structural analysis
- Combined with detailed geologic mapping

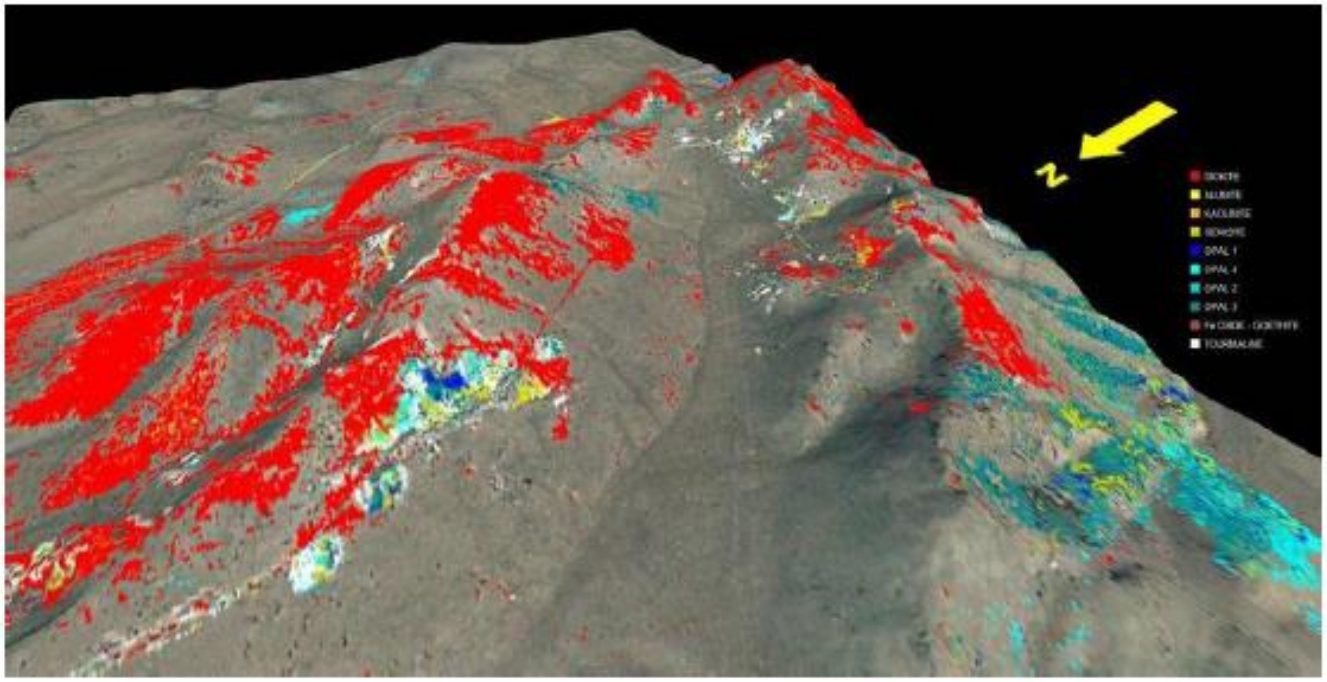




Hyperspectral

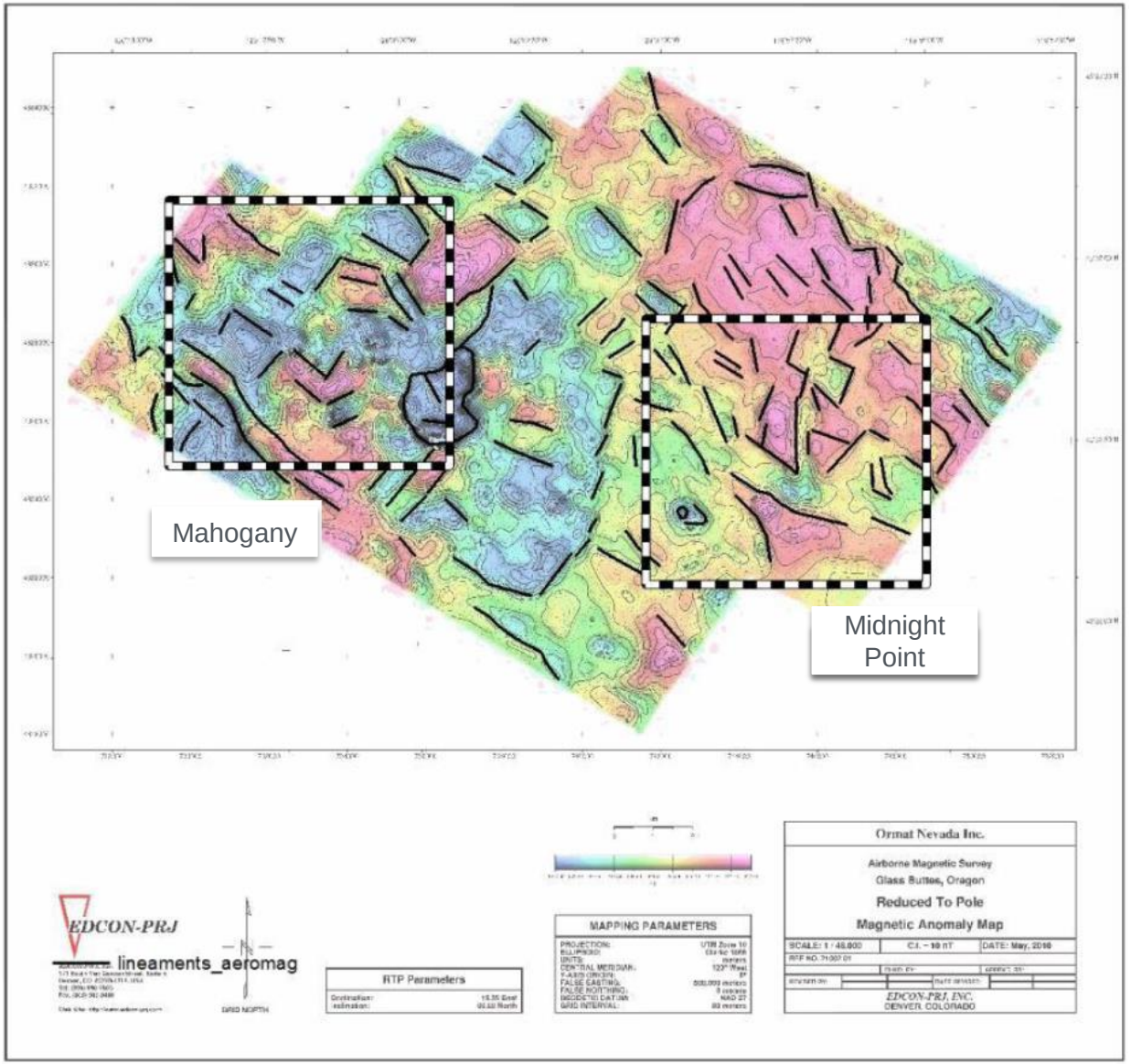
- Mineral alteration distribution measured from airborne hyperspectral data is mapped on 1 m color imagery which is in turn draped on 1m LiDAR imagery for elevation.

- Field mapping found an unaltered basalt unit overlies hydrothermally altered silicic rocks, suggesting the alteration is related to the emplacement and eruption of the silicic volcanic centers at the eastern end of the complex, dated at 6.49±0.03Ma



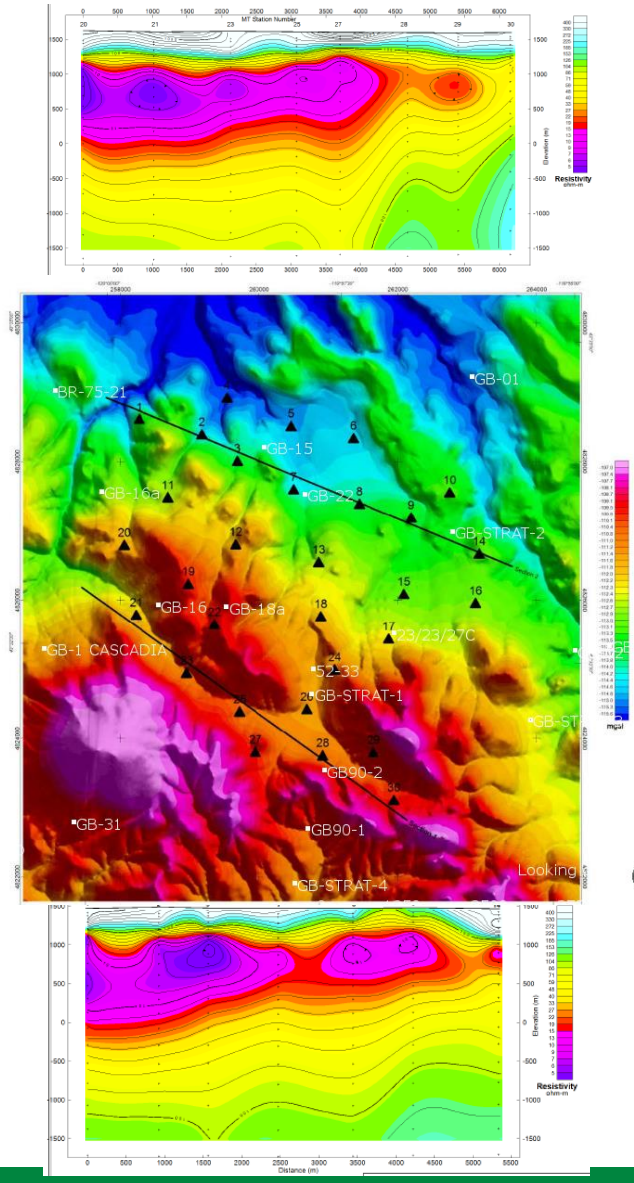
Aeromagnetics

- Reduced to pole (RTP) map with black lines showing interpretations.
- Most features are faults with the exception of the circular features which are likely indicative of volcanic sources.



Magnetotelluric (MT) Survey

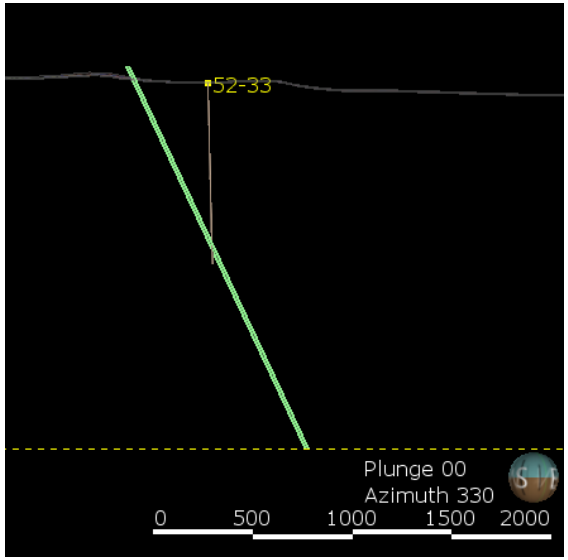
- MT maps vertical and lateral variations in resistivity that define “layers” and can be interpreted to provide the locations of high-angle structures.
- Vertical layering may relate to thermal alteration products, primary lithology, groundwater content and salinity or all of the above.
- A pronounced low-resistivity zone in the vicinity of the Strat-1 well was detected and thought to represent a zone of structural intersection.
- MT indicated increased fracture permeability here, also indicated by the intersection of multiple inferred faults from the DEM, gravity and magnetic surveys. Core well 52-33 was permitted to test this location.



Accomplishments, Results and Progress

Results

- Core well 52-33 successfully completed to 3000 ft. TD
- Fault structures seen in 52-33 at expected depths
- Conductor seen in MT interpreted as hydrothermal reservoir may have been caused by fluid-filled permeable tuff unit
- Temperature gradient was not encouraging



Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
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Future Directions

- DOE project complete following drilling of first well

Milestone or Go/No-Go	Status & Expected Completion Date

Summary

- Completed study objectives through first well
- Methodologies tested in this study have been adopted for Ormat exploration procedures
- Permitting delays slowed project and prevented additional drilling