Glass Buttes Exploration Project

Merging high resolution geophysical and geochemical surveys to reduce exploration risk at Glass Buttes, Oregon

Presented to Oregon Geothermal Working Group

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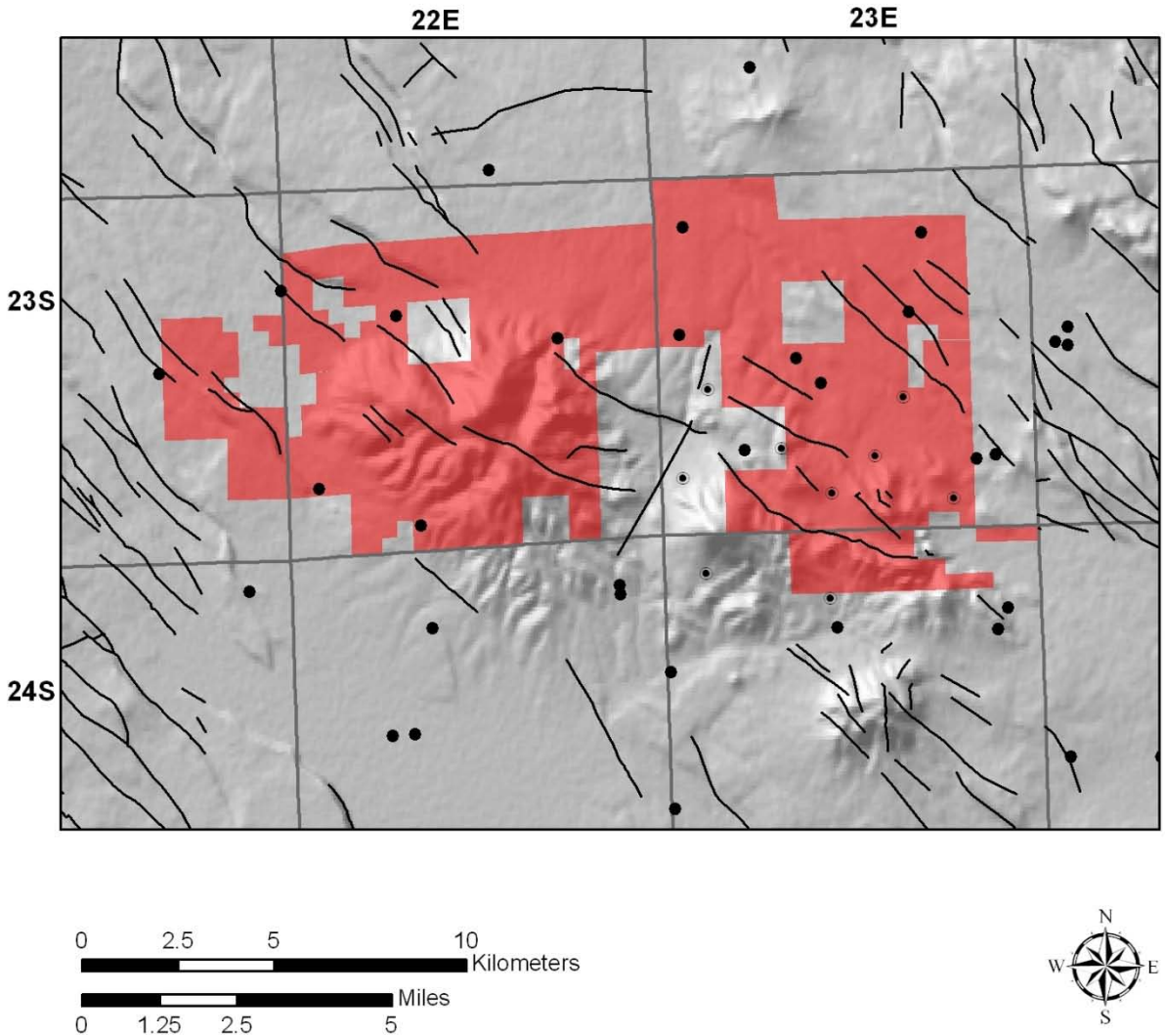
Project's Objectives

The primary objective of this project is to combine a suite of high resolution geophysical and geochemical techniques to reduce exploration risk by characterizing hydrothermal alteration, fault geometries and relationships

The intent of the proposed program is to use an innovative combination of geologic observation, modern remote sensing and geophysical techniques to analyze and structurally model this area prior to siting and drilling.

Glass Buttes Lease Map



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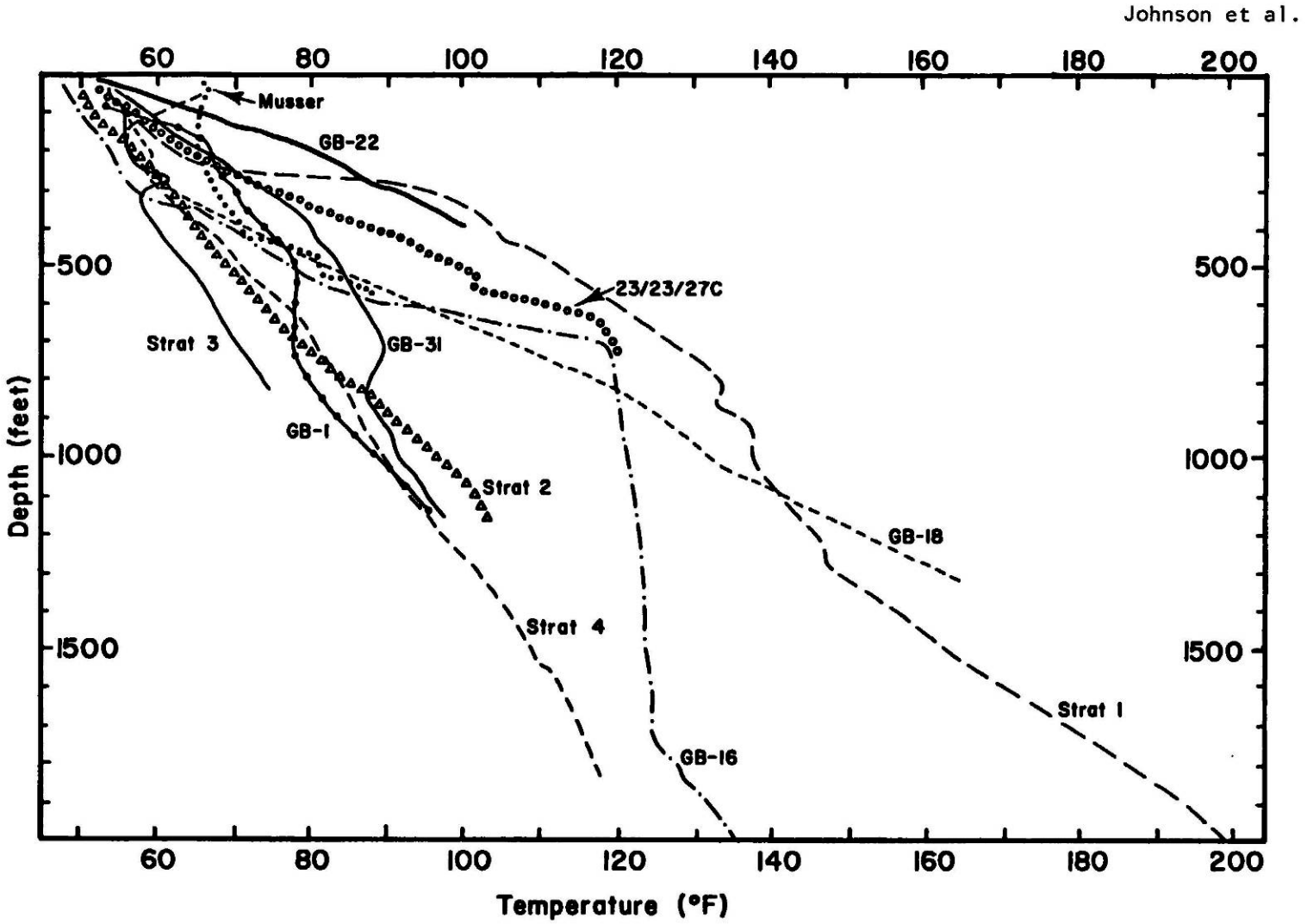
Temperature logs



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Ormat-DOE joint project

- Principal invesigator

  Patrick Walsh (Ormat)
- Co-investigators
  - John Dilles (OSU)
  - Ian Madin (DOGAMI)
  - Brigette Martini (Ormat)
  - Paul Spielman (Ormat)
  - Ezra Zemach (Ormat)
- DOE
  - GTP - DOE Golden Office

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Exploration program

- **Phase I – Exploration**
  - Characterize fault geometries and relationships
  - Characterize mineral assemblages (indicating hydrothermal alteration)
  - Geologic field work
  - Geophysics
    - Gravity
    - High resolution aeromagnetic
  - Remote sensing
    - LiDAR (Light Detection and Ranging)
    - Hyperspectral
  - 3D geologic model to site slim wells

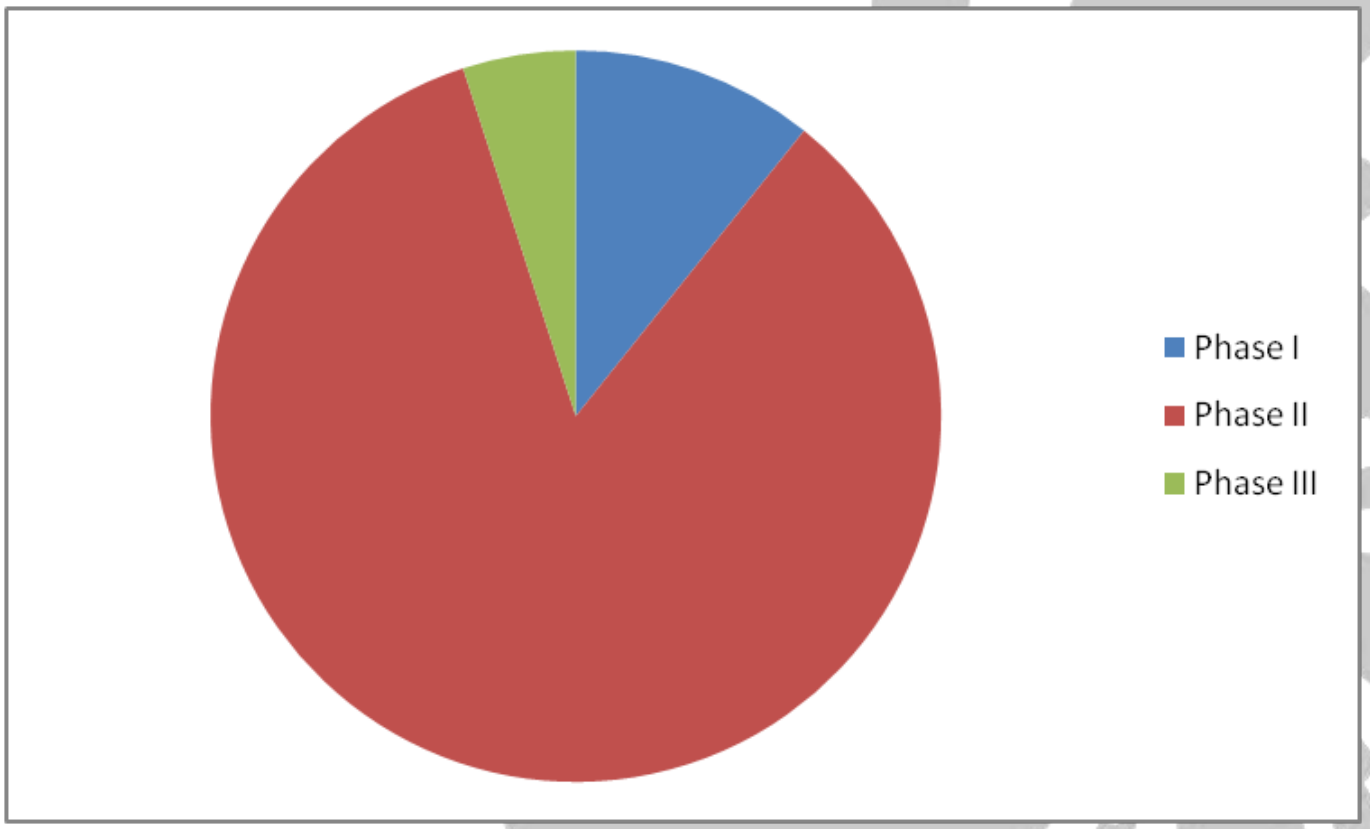
Exploration program

- **Phase II & III– Drilling & Flow Testing**
  - 2 slim holes ~3500 feet
  - 1 production well ~5000 feet
  - Wells Flow test
  - Reservoir properties (permeability, temperature)
  - Project economics
  - Power plant estimation
- Evaluation of methodology

Glass Buttes - DOE funding breakdown

Project Total Budget: ~ $9M

~$4.5 in DOE funding with 50% Ormat cost share



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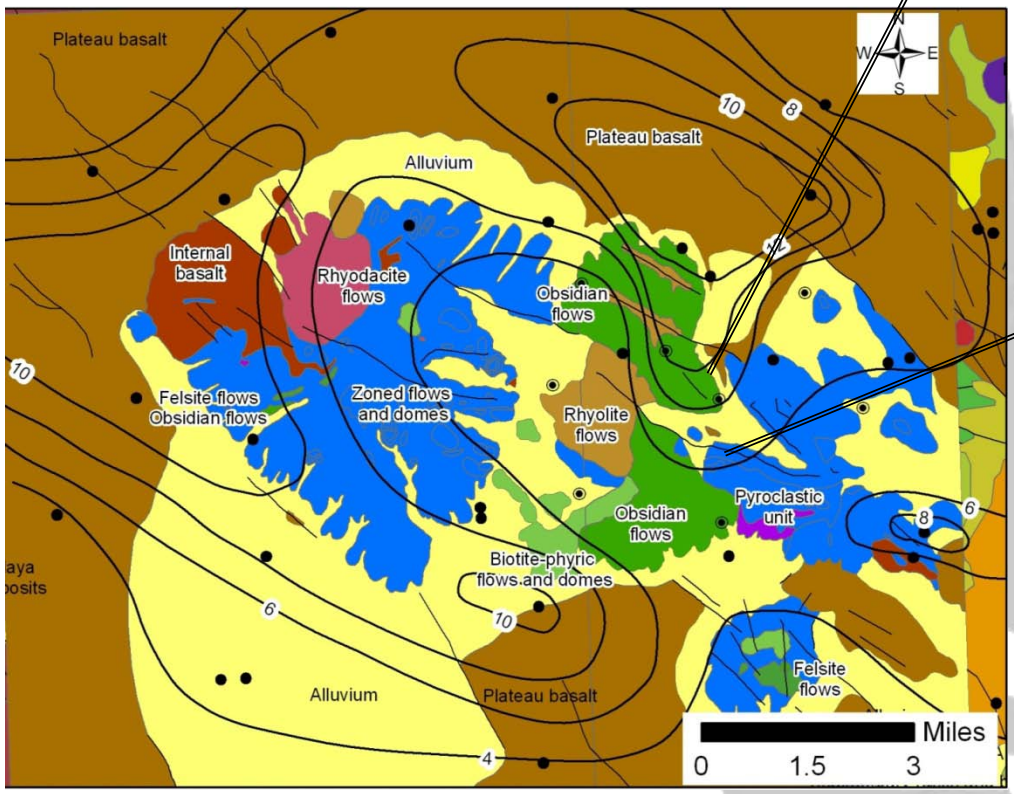
Geologic field work



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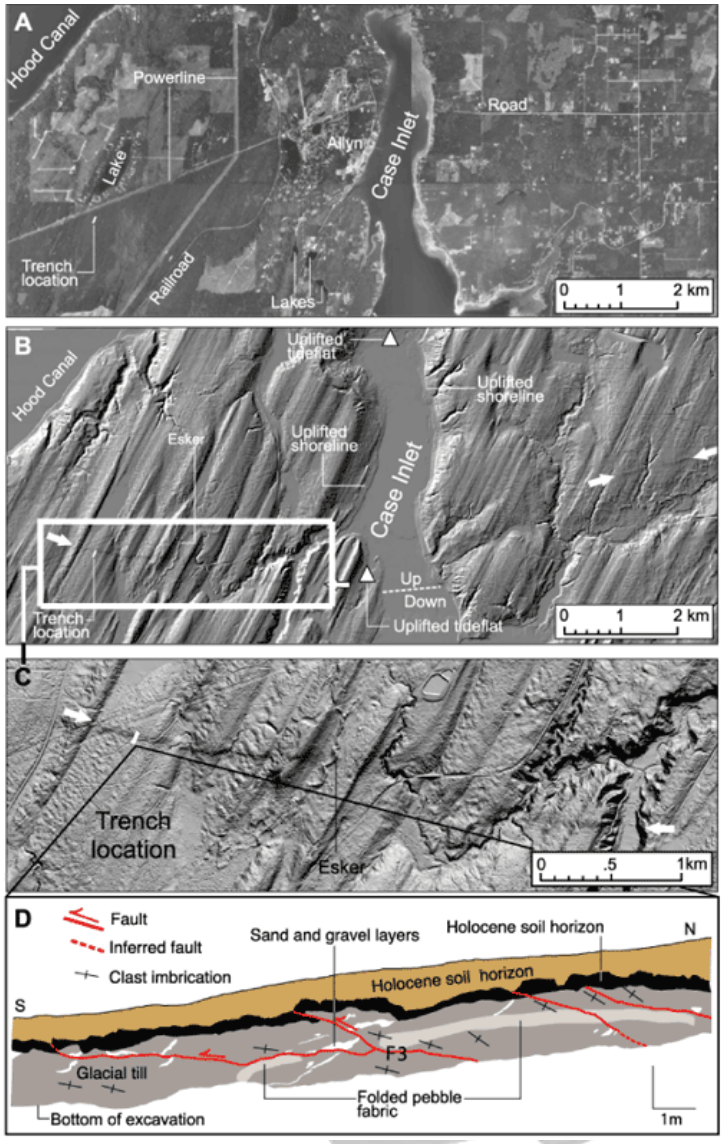
LiDAR



USGS – Tacoma Fault identification

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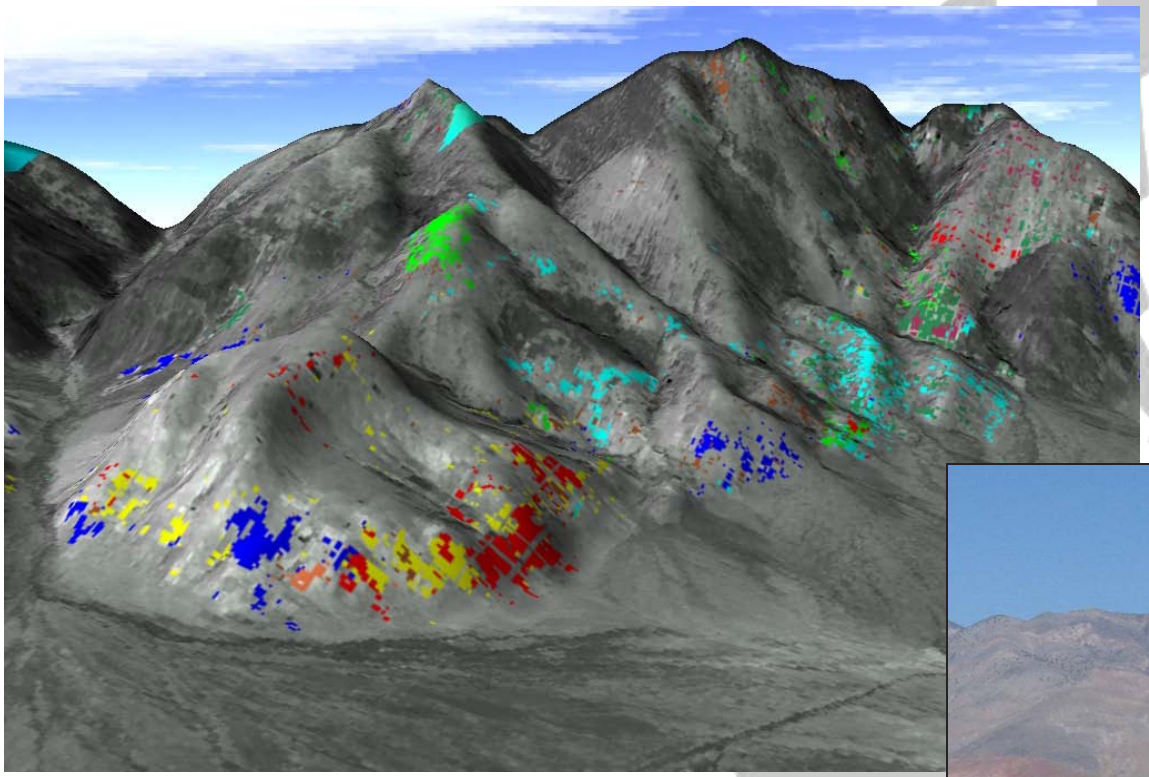
http://earthquake.usgs.gov/regional/pacnw/ships/results/tacoma.php

Remote Sensing – Non-Invasive Regional Mapping

- Airborne-based platform
  - Hyperspectral (specific material identification on a localized-scale including minerals, plants, man-made, etc.)



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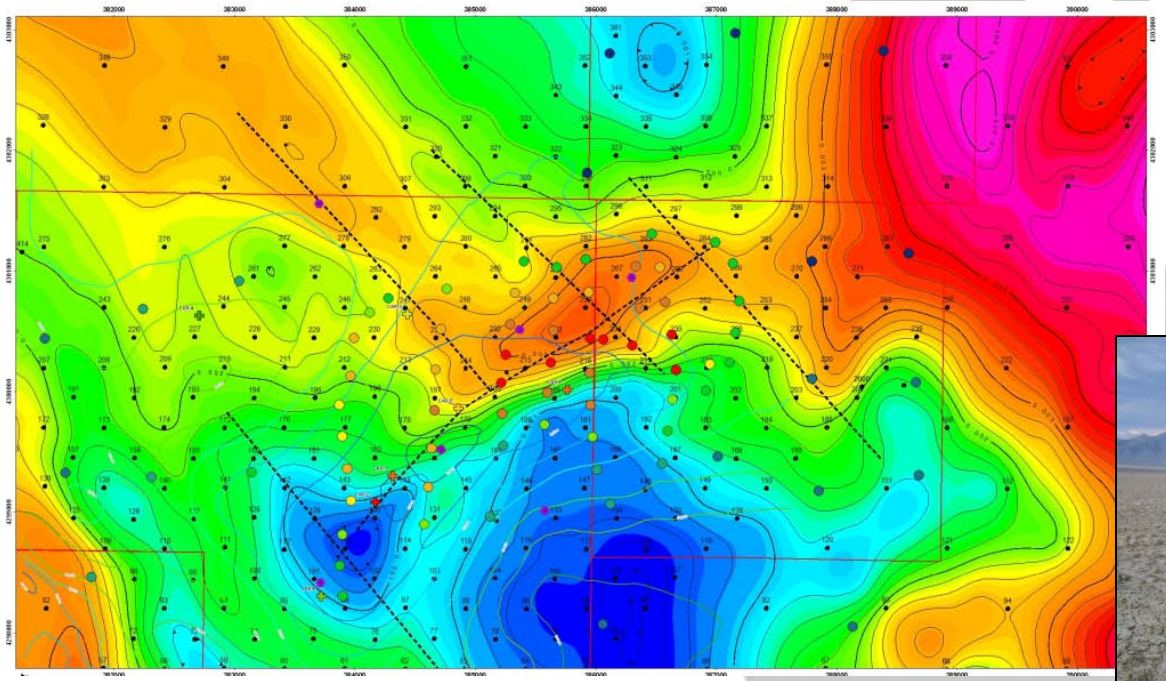
Geophysics – Lets us 'see' into the sub-surface

- For example, gravity data maps differences in measured gravity vs. expected 'earth-induced' gravity
  - Mapping of structure (faults/fractures) provides one set of controls on system permeability



NV - Gravity

- Gravity can also reveal gross lithology (rock-type) at depth

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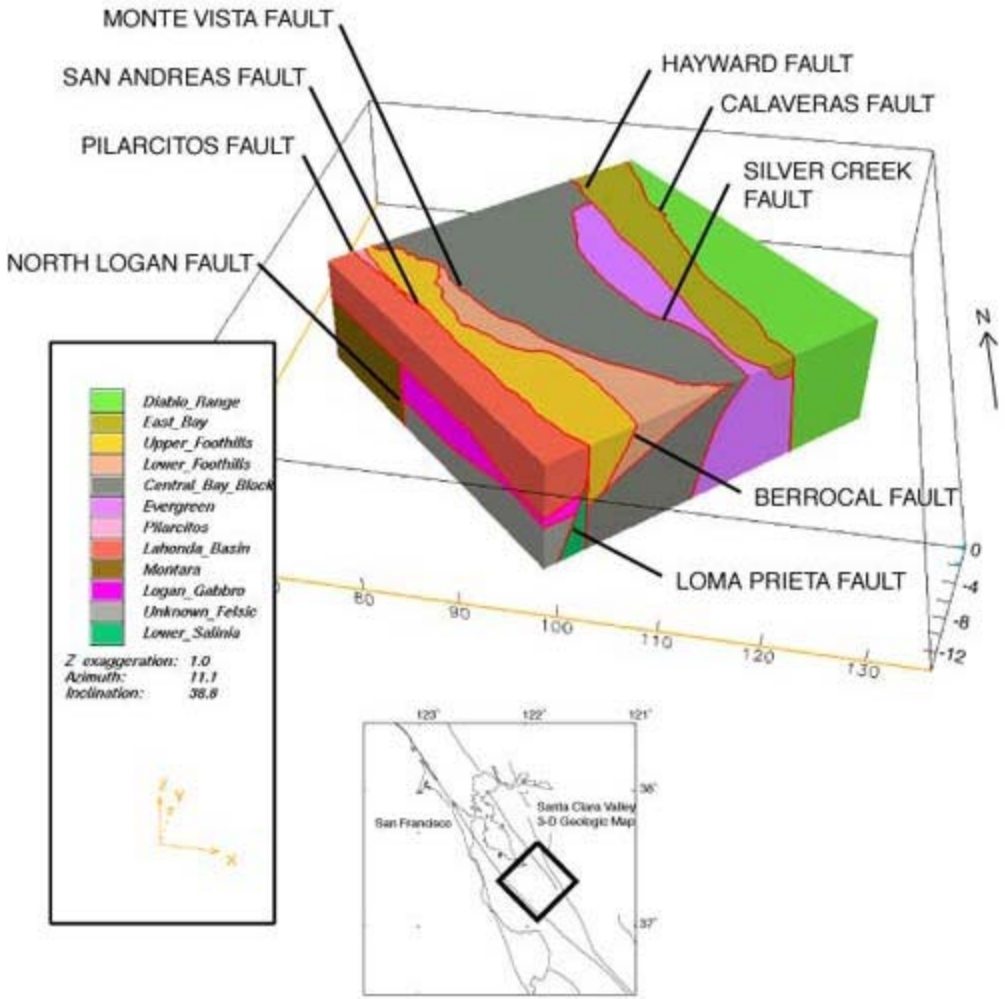
Create 3D geologic model based on exploration data to site wells



http://pubs.usgs.gov/of/2001/of01-223/jachens.html

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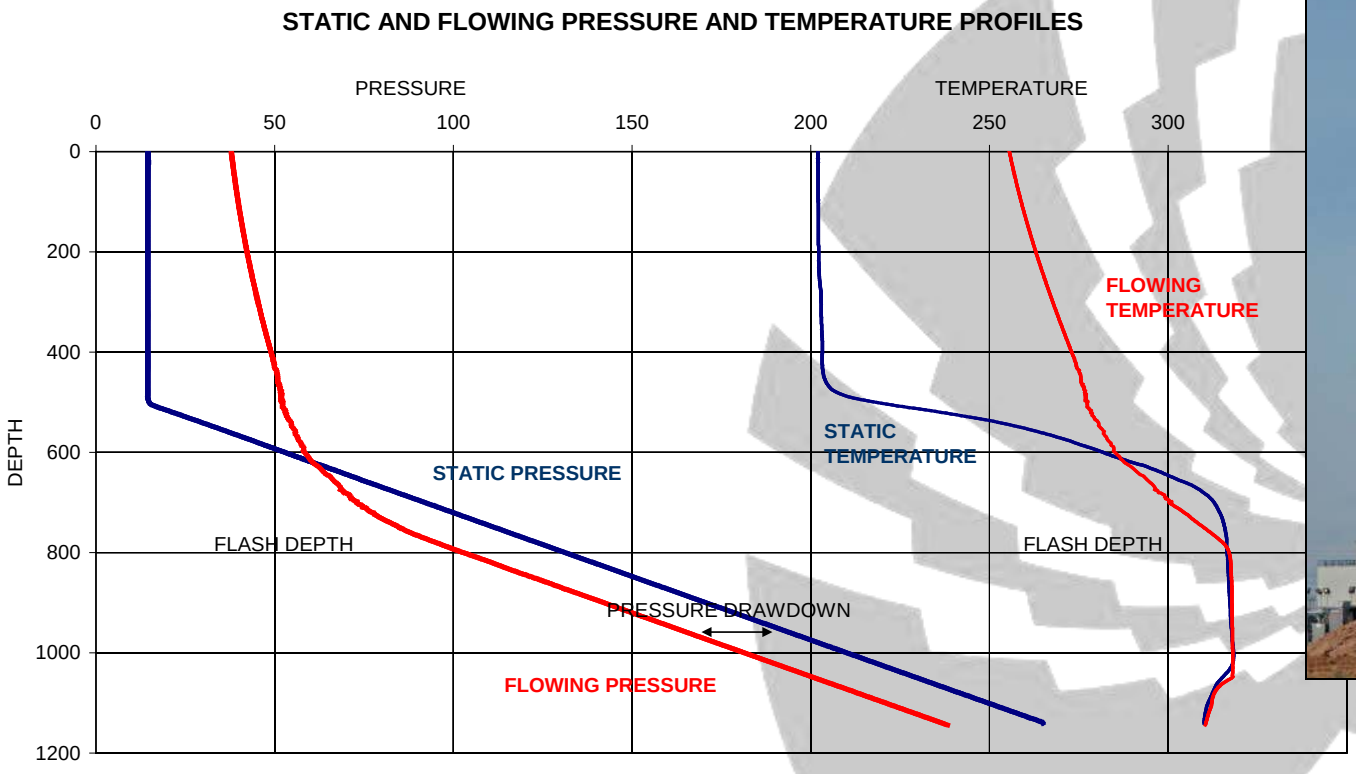
Drilling – the first ‘physical’ measurement of the resource

- Moderate depth slim holes – a deeper measurement of subsurface temperature and potential permeability (~3000ft)



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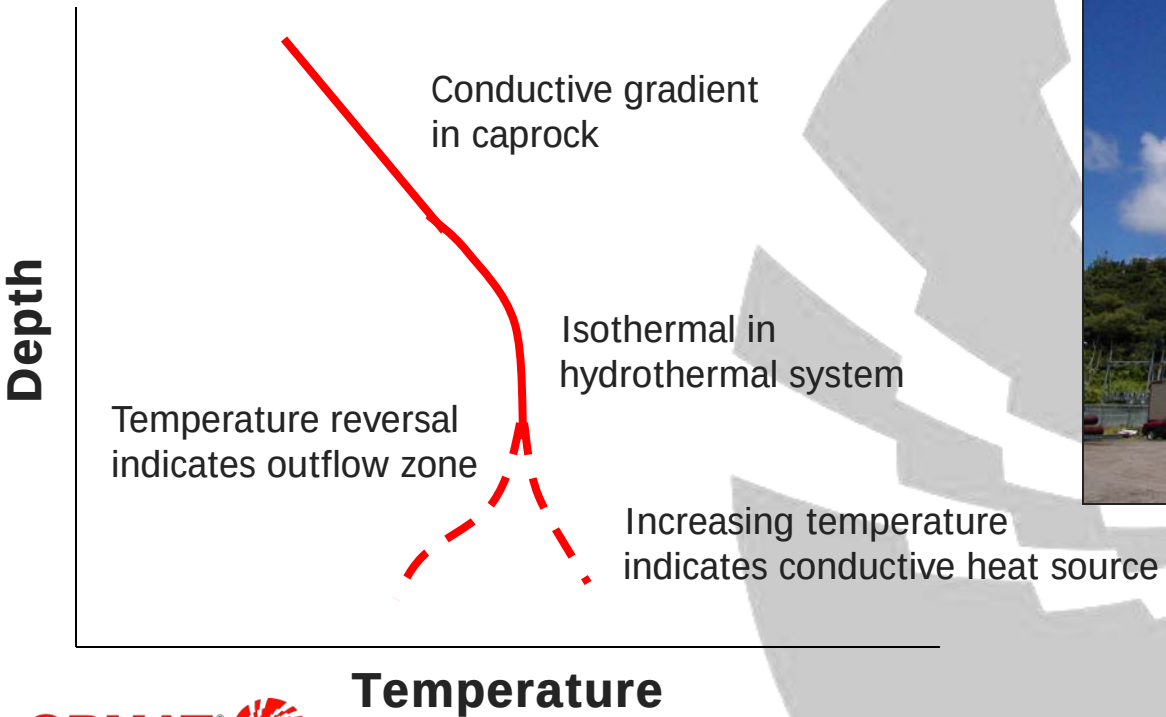
Drilling – the first 'physical' measurement of the resource

- Deep production/injection hole drilling – Final definition of the geothermal reservoir (temperature, pressure, permeability) - spatially and with depth



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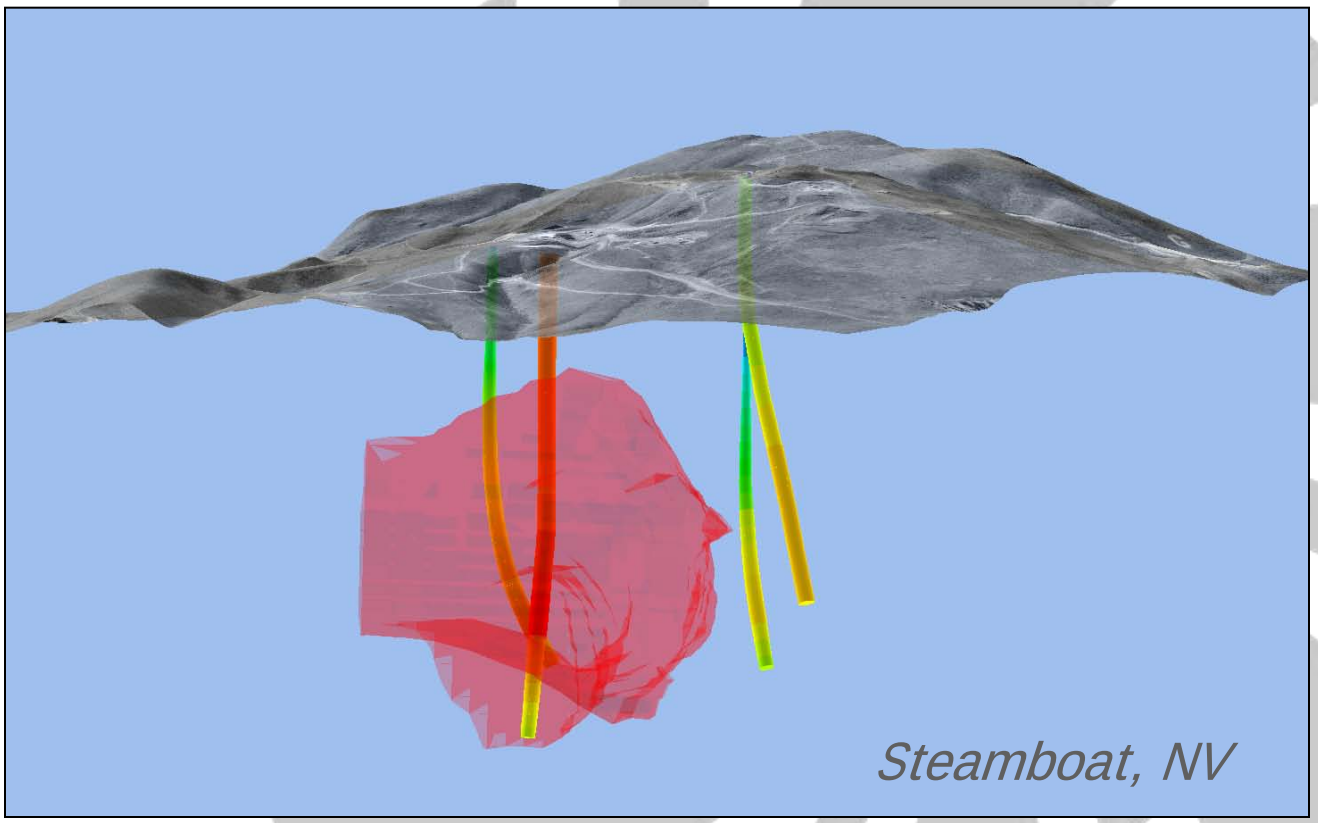
Resource Modeling/Testing

- Multiple types of geological, geophysical and geochemical data coupled with temperature gradient information builds a geothermal resource model



Progress

- Initial geologic field work
- Widely spaced gravity (~1 km)
- Hyperspectral collected, currently being processed
- Aeromagnetic data being collected