POTENTIAL APPLICATION OF TEMPERATURE GRADIENT DRILLING OR OTHER TEMPERATURE SURVEYS IN THE WESTERN BRANCH OF THE EARS: SUCCESSFUL EXAMPLES FROM THE BASIN AND RANGE, USA

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TEMPERATURE GRADIENT DRILLING

- First used to target “blind” ore bodies in basins
- Inadvertent discovery of a “blind” geothermal system in Montana, USA in 1960s
- Used extensively across Basin and Range in 1970s and 1980s to both find new undiscovered systems, define upflow-outflow thermal patterns, and target deep wells
- 1990s to present for targeting deep wells
- Methodology
  - Drill 500 to 1000’ TD (150 m to 300 m)
  - Install plastic or steel pipe, plugged at bottom
  - Fill pipe with water, let equilibrate, measure temperature profile
- Plot temperature gradient (°C/km) in map view
- Evaluate shape of thermal profile
Exploration: Where to look in the first place?

Especially for Blind Systems

375 favorable settings identified in 250x400 km area in middle of B-R region

Inferring concealed structures in the middle of a basin with gravity data
Carson Sink, Nevada

Blind Systems

Stars = Power Plants

~10 Kilometers
Historically, more discoveries of hidden geothermal resources are due to TGH drilling than to any other exploration technique in Nevada.

Where magmatic heat is not present, temperature gradient anomalies point towards shallow to mid-level convection anomalies.

Broad anomalies due to outflow and radial conductive heat-flow around the convective up-flow area.
Variability in Shallow Thermal Anomalies

Shallow Outflow Plumes, both a helpful and not helpful

From David Blackwell
Dixie Meadows, Churchill County, NV

Steam vents

Advanced argillic alteration

Hot springs
Thermal Profiles in Wells

Desert Peak
Benoit et al., 1982
Example TGH results, Hawthorne area 1

1) Conductive background gradient
2) Elevated Conduction
3) Convection and Outflow

Conductive background geothermal gradient
Reversal
Isothermal
Figure A: Crosses fault from QTa into Meta-volcanics

Figures from Lazaro et al. (2010) and Meade et al. (2011)
Resource Scale Exploration and Development: Case Studies

Temperature Gradient Map

Temperature Profiles

Drill Targeting

Thermal Model

Power Production
Active Geothermal Features:

- Fumaroles
- Hot Springs
- Sinter
- Craters
- Mud pits
- Alteration
Bradys Hot Springs, 26 MWe

Thermal Manifestations

Regional 100K scale Quaternary fault data set
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≤ 200 m temperature gradient holes
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Regional 100K scale Quaternary fault data set

≤ 200 m temperature gradient holes

~25 moderate to deep production, injection wells (up to 3 km deep)
Thermal Manifestations

Regional 100K scale Quaternary fault data set

≤ 200 m temperature gradient holes

Final 5 Production wells

Final 4 Injection wells
Thermal Manifestations

Detailed geologic mapping

≤ 200 m temperature gradient holes

Final 5 Production wells

Final 4 Injection wells
Bradys Hot Springs, 26 MWe

Thermal Manifestations

Detailed geologic mapping

Final 5 Production wells

Final 4 Injection wells
Surface temperatures can be mapped with thermal infrared sensors, especially at night.

Brady’s Hot Springs steam/hot ground anomalies mapped with ASTER satellite TIR images.
No Thermal Manifestations

≤200 m temperature gradient holes
Thermal Manifestations ≤200 m temperature gradient holes ~30° moderate to deep slim holes, production, injection wells (up to 3 km deep)

Final production wells

Desert Peak, 23 MWe
No Thermal Manifestations ≤200 m temperature gradient holes ~30 moderate to deep slim holes, production, injection wells (up to 3 km deep)

Final production well field

Detailed mapping

Desert Peak, 23 MWe
Bradys and Desert Peak area

Temperature Gradient vs Max BHT in TGHs
Salt Wells, 14 MWe

Spring Temperatures

Sinter, Alteration, Fault Termination, Well Field
Variety of Shallow Temperature Equipment

Geoprobe: up to 60m+ depth
NV Exploration, Inc.

Impact hammer & 2-meter rods
University of Nevada, Reno

2-meter portable drill
Geoglobal (Wilmarth & Melosh)
Portable rock drills can be used to insert 2-meter probes into bedrock.
When 2-m temperatures are measured near the earlier temperature gradient wells, the shallow temperature anomaly defined by the wells (30 m depth) is reproduced.
Black lines = 1°C contours on 2-meter temperatures
Heat Loss from shallow thermal aquifer ~ 18 MW
Desert Queen area, Nevada
Astor Pass, Nevada

Upwelling zones beneath carbonate tufa towers

Shallow temperature surveys can map shallow thermal outflow plumes
1. Temperature gradient drilling and 2m temperature probes (or similar) can be very effective
   - Finding new resources, especially blind (e.g., Desert Peak)
   - Delineating the extent of known resource areas
   - Targeting deep wells
2. Most effective when combined with structural data and geophysics as available for deep well targeting
3. Many amagmatic, structurally controlled reservoirs are small in XY extent relative to the XY extent of the thermal anomaly
4. 40% of Great Basin systems are blind, estimated that 75% of total resources in Great Basin are blind (with many yet to be discovered and developed)
5. How many blind resources are in the EARS?
6. How many remain to be discovered?

McGinness Hills, Nevada
72 MWe, blind resource