Analysis of Borehole Temperature Data from the Mt. Princeton Hot Springs Area, Chaffee County, Colorado*

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Abstract

Mt. Princeton Hot Springs are a group of thermal springs in an accommodation zone in the Sawatch Fault, the western bounding fault of the Upper Arkansas (half) graben in the northern Rio Grande rift. The springs include Hortense Hot Spring, the hottest spring in Colorado with a temperature of about 82°C. A cluster analysis of the chemistry of the waters of the springs indicated that two thermal reservoirs may be feeding the springs. AMAX Exploration drilled 31 thermal gradient holes in the Upper Arkansas Valley in the mid-1970s to investigate the geothermal potential of the area for power production, but abandoned the prospect. Contours of the geothermal gradient based on these data leave the anomaly open to the west, including the highest contours of the anomaly. Five additional temperature gradient holes were drilled in 2009 by Mt. Princeton Geothermal LLC. Drilling problems prevented penetration to the planned depth in the two western holes but the western margin of the anomaly was probably defined. More interesting was the penetration of an isothermal zone in one of the holes at 65°C, slightly hotter than the outflow temperature of the main Mt. Princeton Hot Springs. The topography in the Mt. Princeton area is rugged. On a small-scale, geothermal gradients from individual boreholes form an irregular contour pattern. Much of this irregularity correlates with topographic irregularities. A crude approximation has been used to remove the effects of topography: at each borehole site the elevation of the surface and the geothermal gradient was used to calculate the elevation of the 65°C isotherm (assuming 1-D vertical heat flow). These elevations were then contoured as the top of the warm (65°C) Mt. Princeton Hot Spring aquifer. These contours were much smoother than the geothermal gradient contours and were found to dip gently from the west to Mt. Princeton Hot Springs, where they intersected the surface, and then plunged steeply below the valley to the east. A hotter (82°C) aquifer from Hortense Hot Springs could not be contoured as this aquifer was not penetrated by any of the drill holes. Geothermometry of the Hortense and Mt Princeton Hot Spring waters indicates reservoir temperatures of ~150°C, mixing with a cold meteoric component in the ratio of 1 part hot with 2 to 3 parts cold.

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with contributions from

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for the

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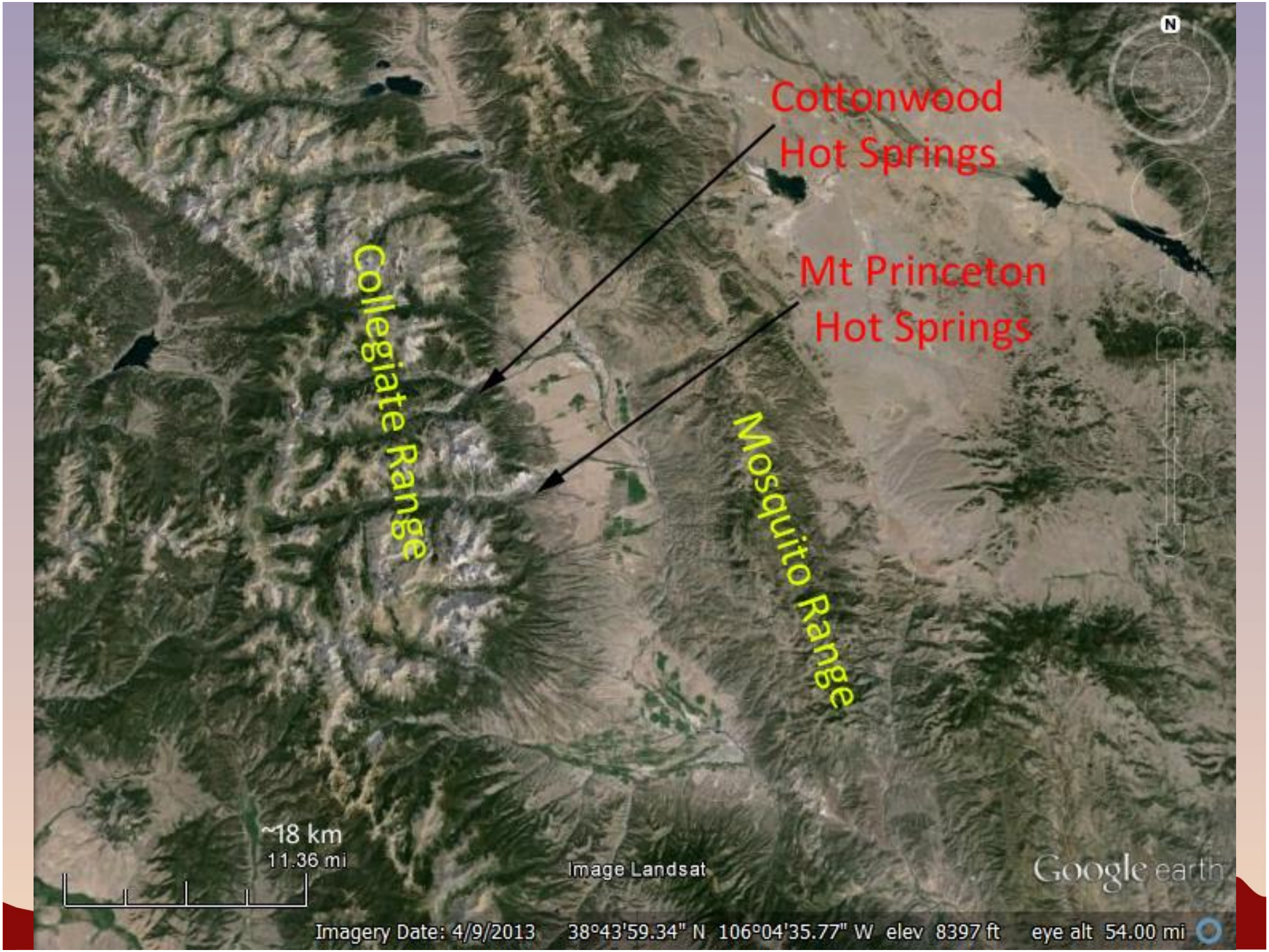
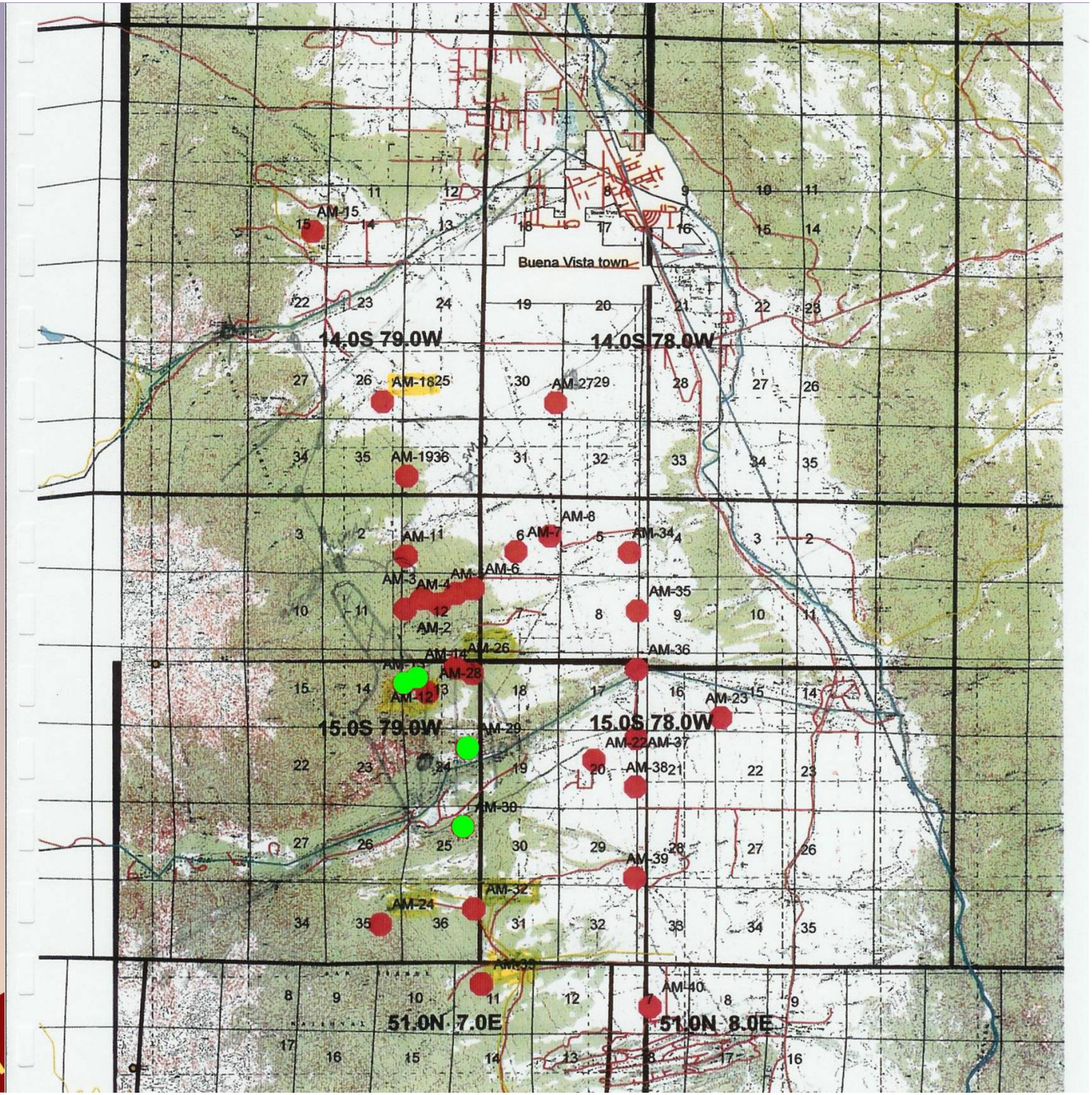
COLORADO GEOLOGICAL SURVEY

Rationale for Study

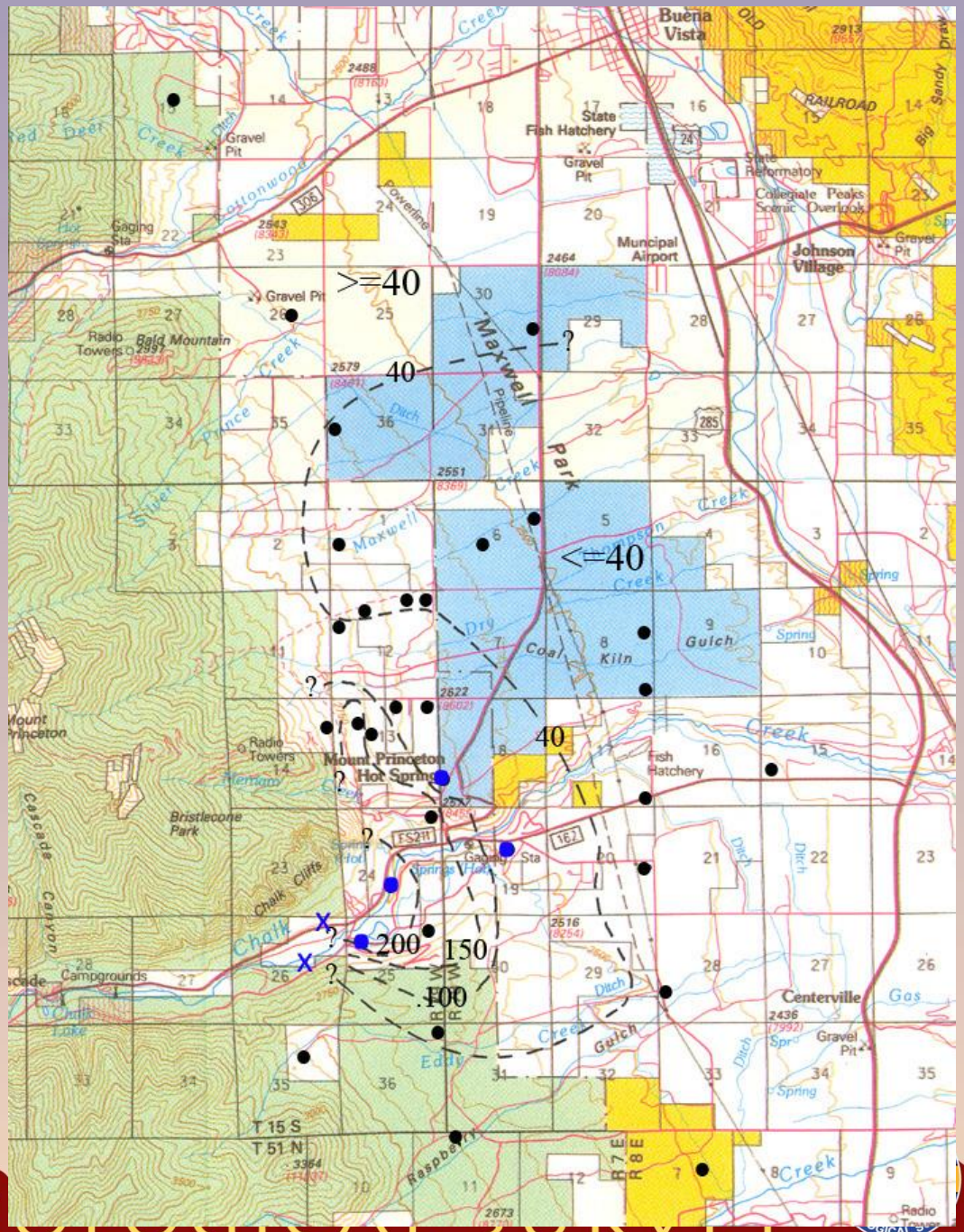
- Colorado has many thermal spring scattered around the state, primarily in its western two thirds (Rocky Mountains and Western Slope)
- Mt. Princeton includes the hottest spring in Colorado, Hortense Hot Spring, surface temperature 82°C (boiling T at this elevation = 90.5°C)
- Geothermometry studies (primarily chalcedony) indicate mixing with meteoric water and a reservoir temperature of ~150°C.
- No deep drilling at this site (or any other site in Colorado) to test geothermometry predictions.
- Would like to know as much as possible about system from available data – this study focuses on temperature information from shallow temperature gradient drilling.


Cottonwood
Hot Springs
Mt Princeton
Hot Springs
Collegiate Range
Mosquito Range
~18 km
11.36 mi
Image Landsat
Google earth
Imagery Date: 4/9/2013 38°43'59.34" N 106°04'35.77" W elev 8397 ft eye alt 54.00 mi

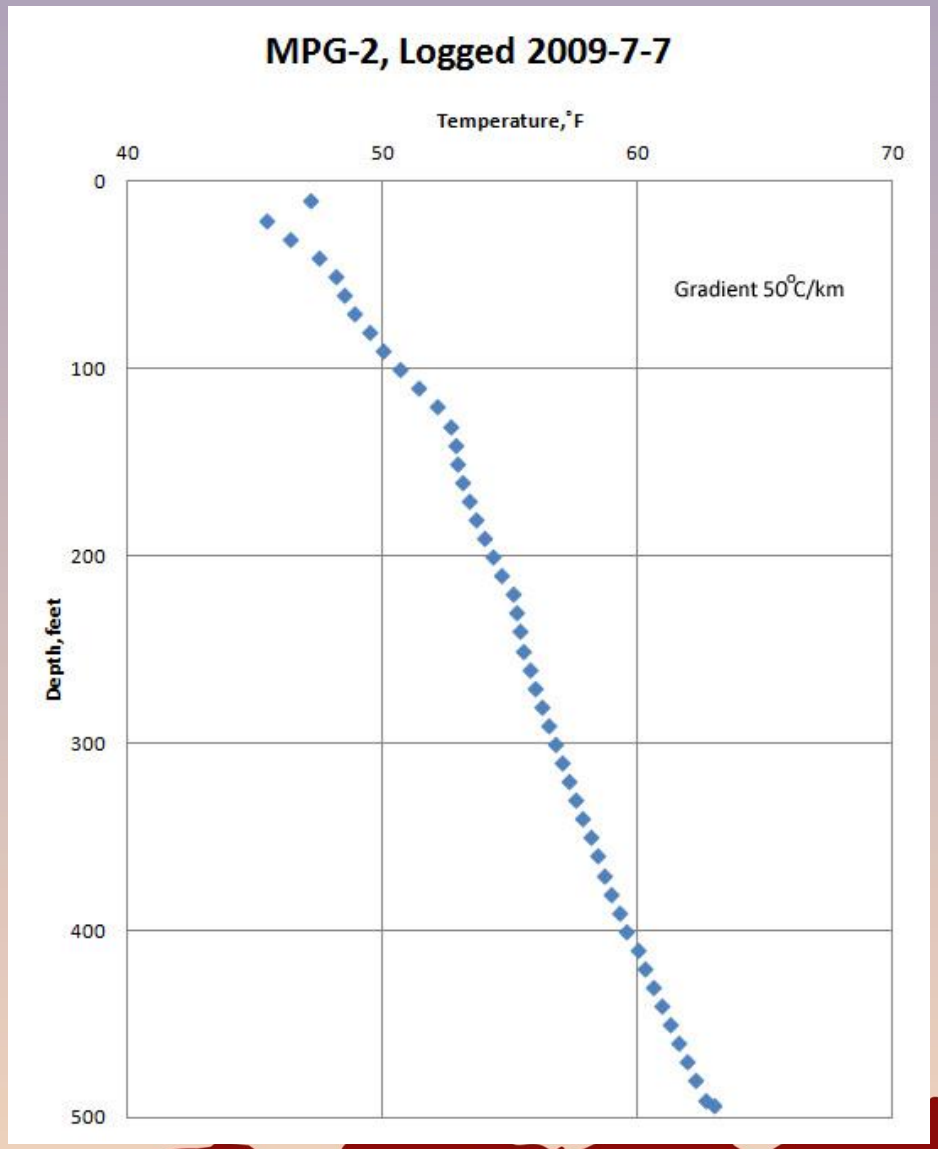
Distribution of AMAX Legacy Thermal Gradient Well Data

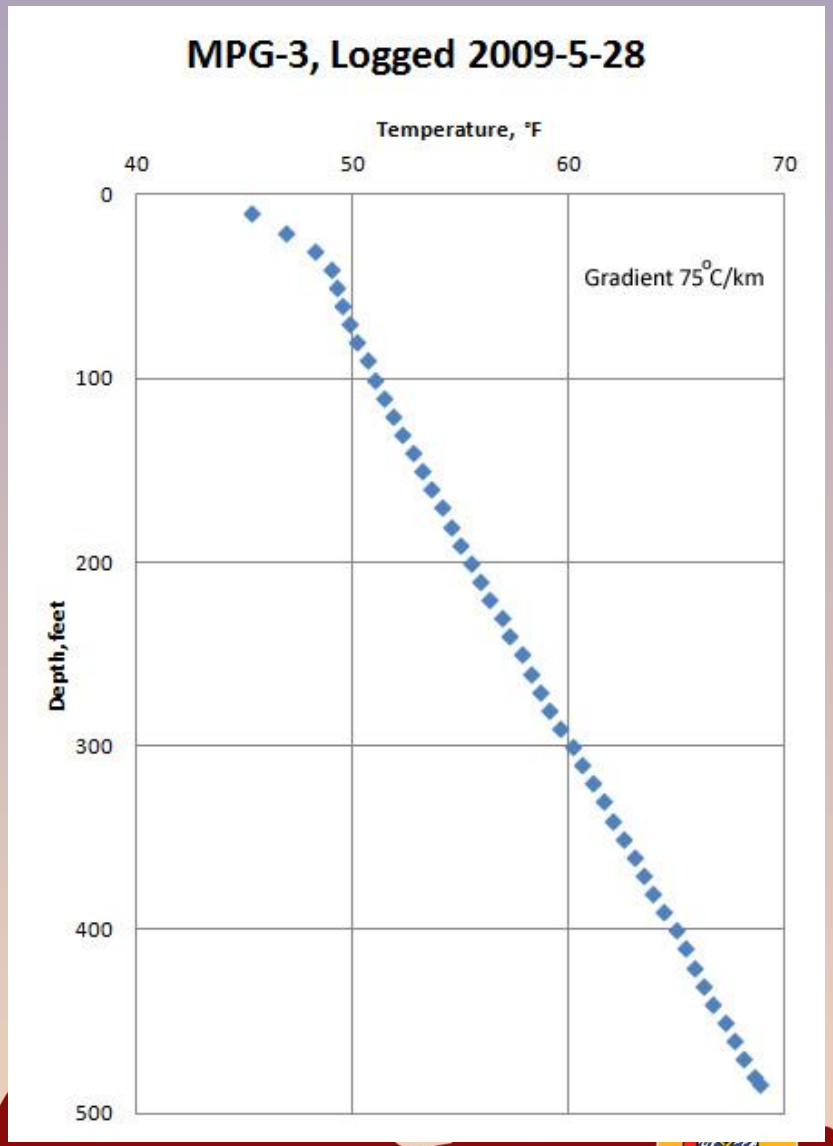


Sites of New Thermal Gradient Wells

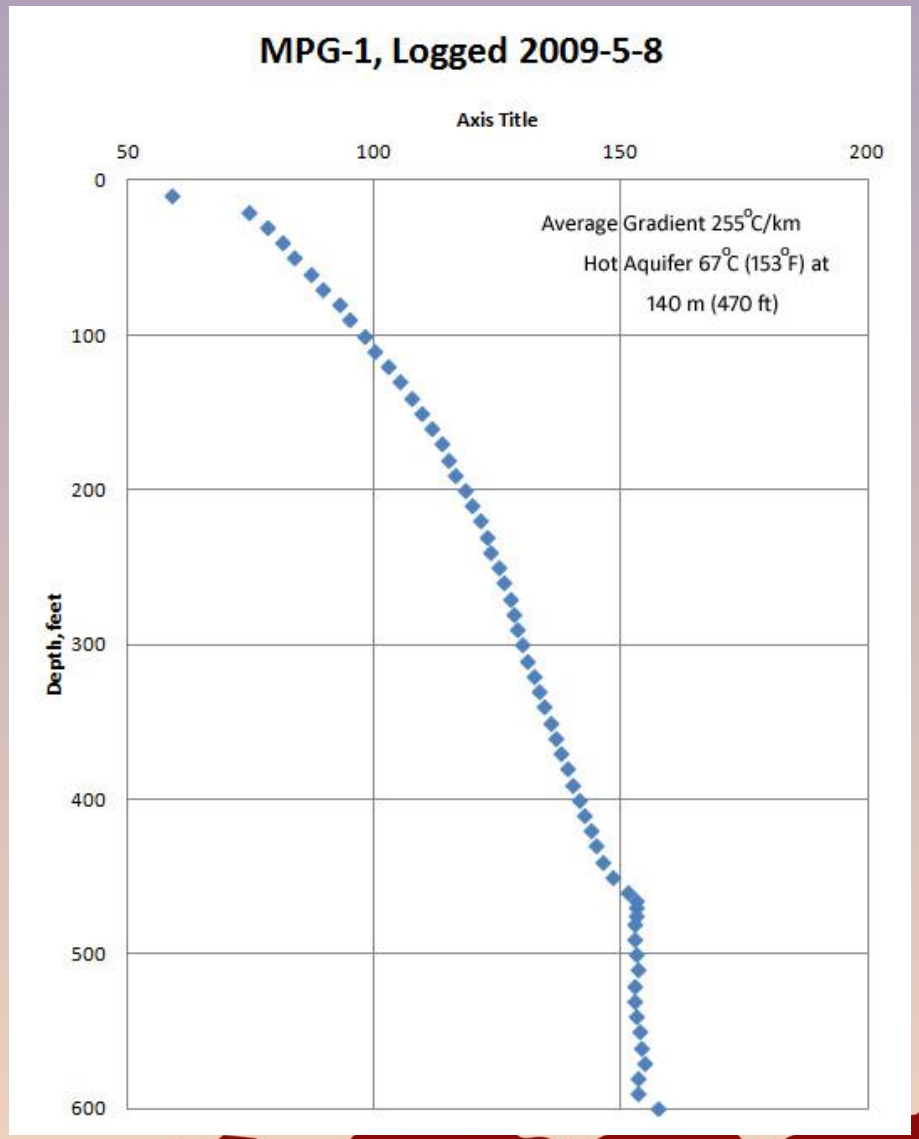


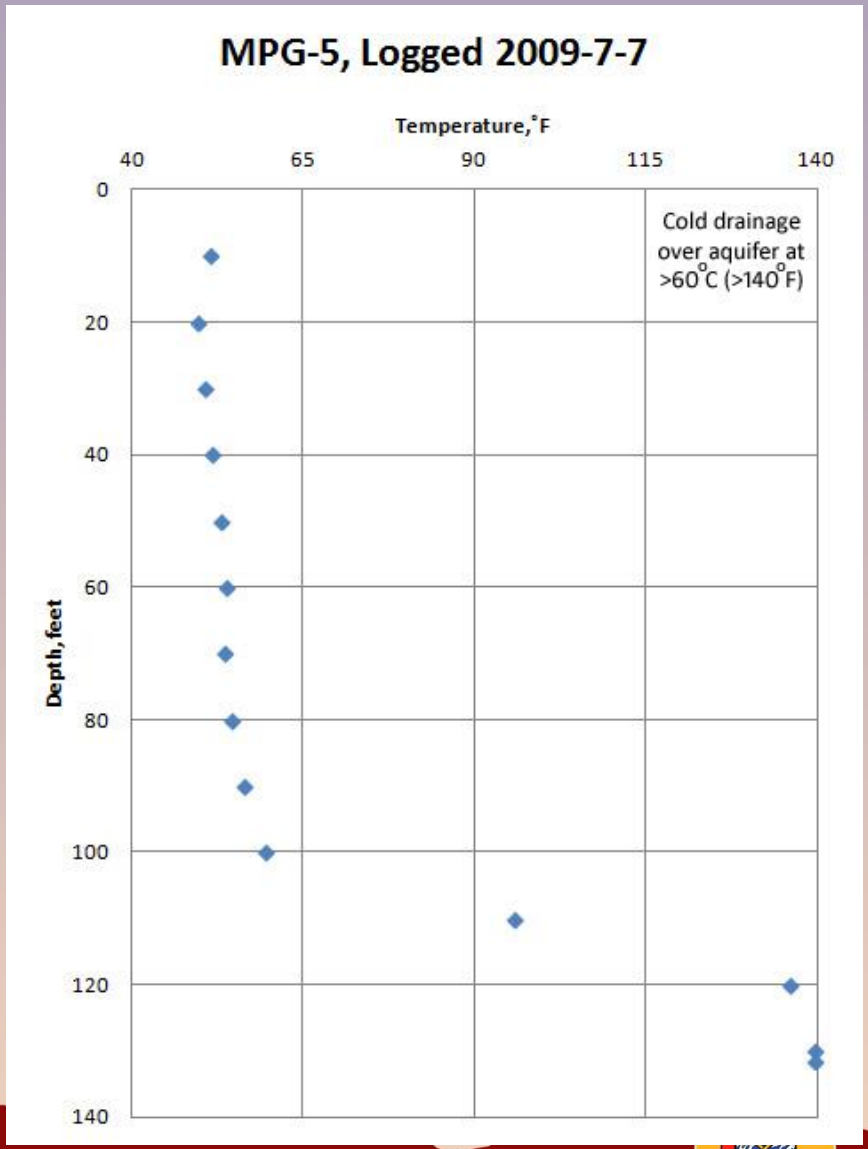
New Temperature Gradient Data I



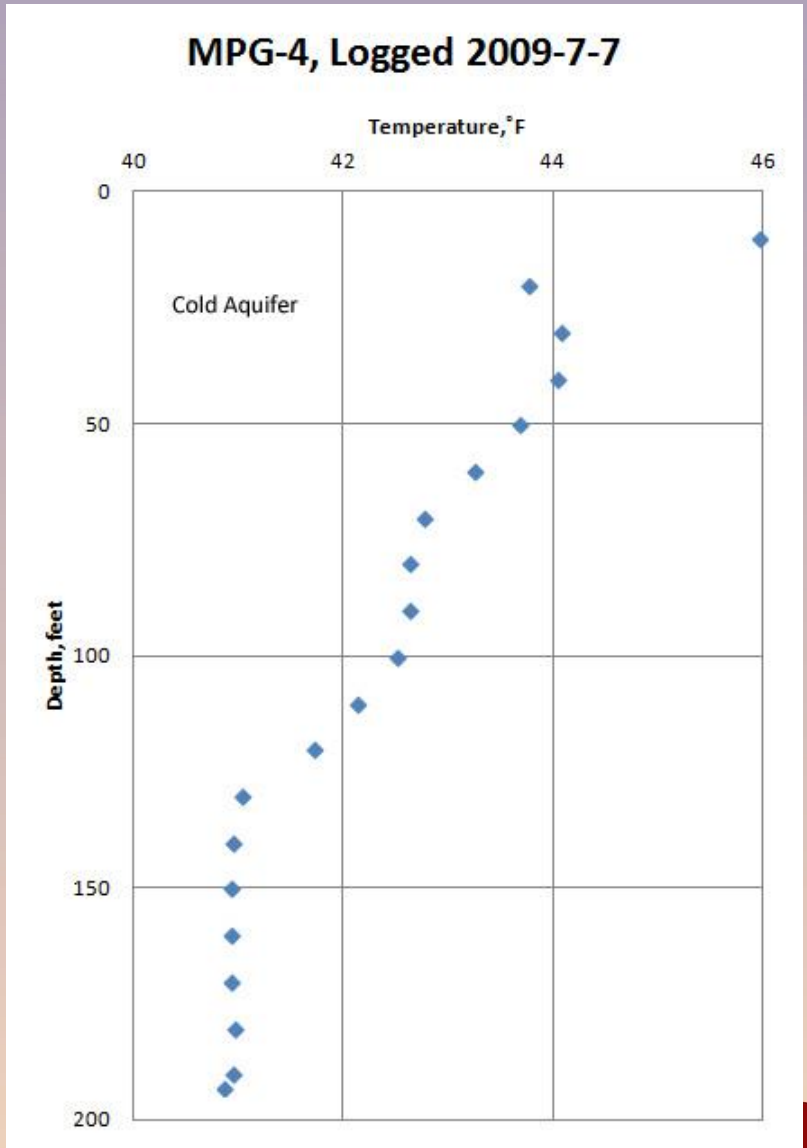


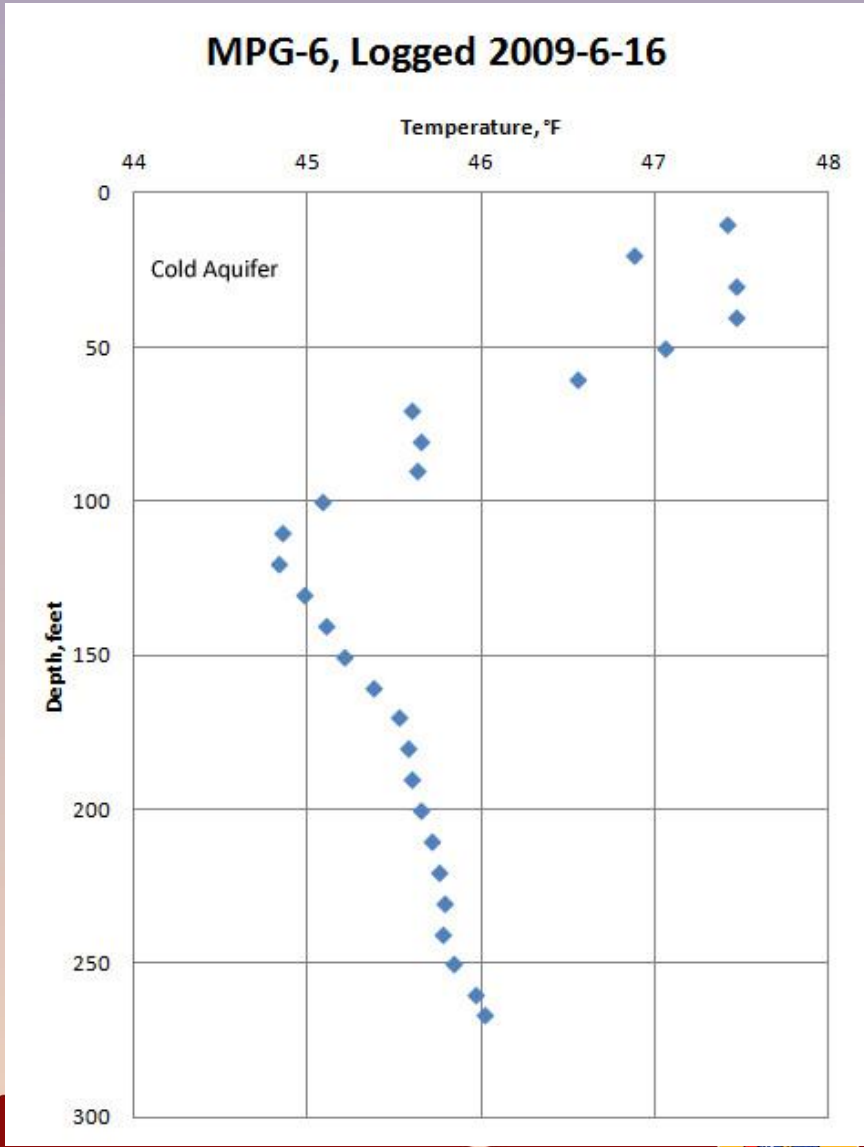
New Temperature Gradient Data II

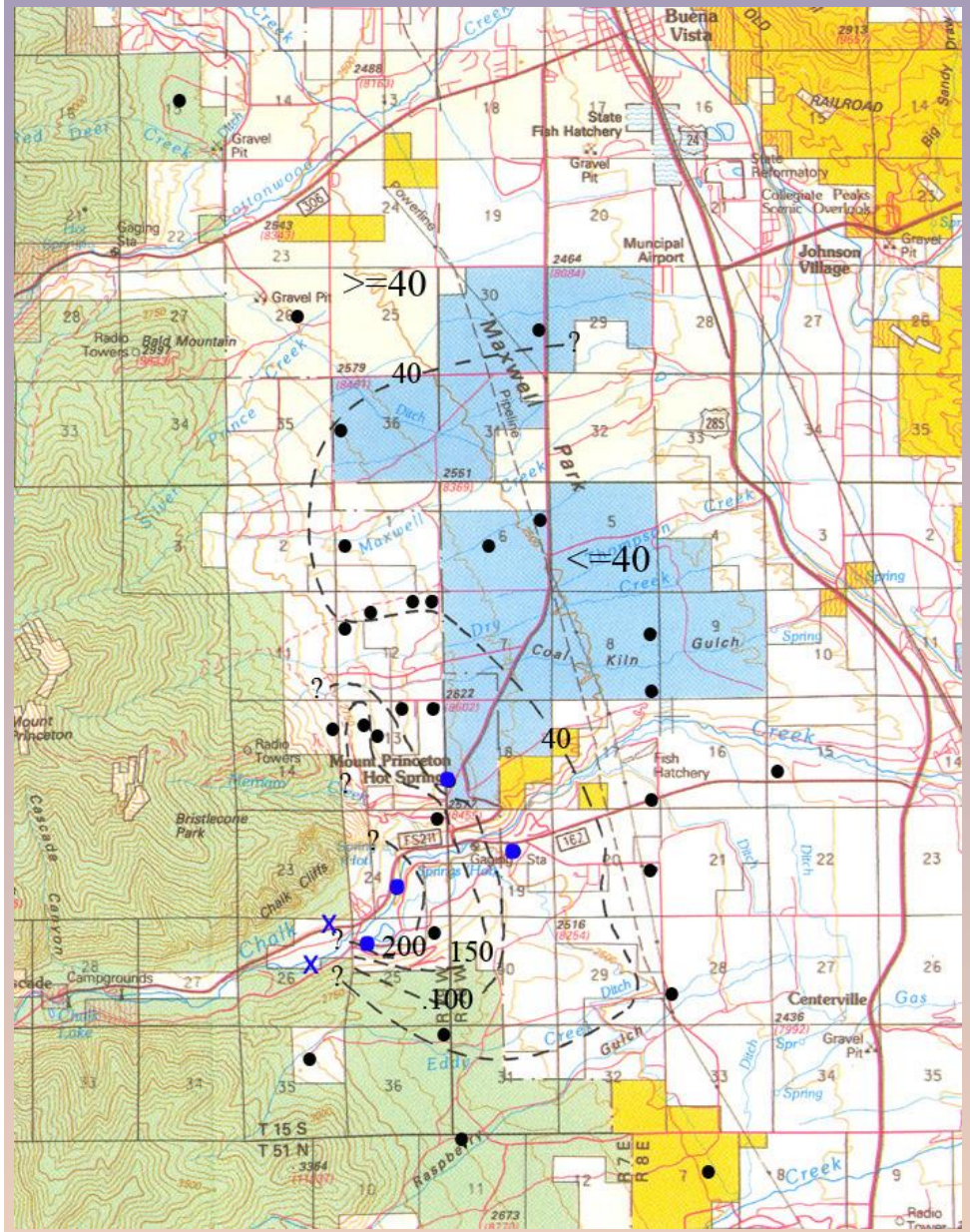




New Temperature Gradient Data III

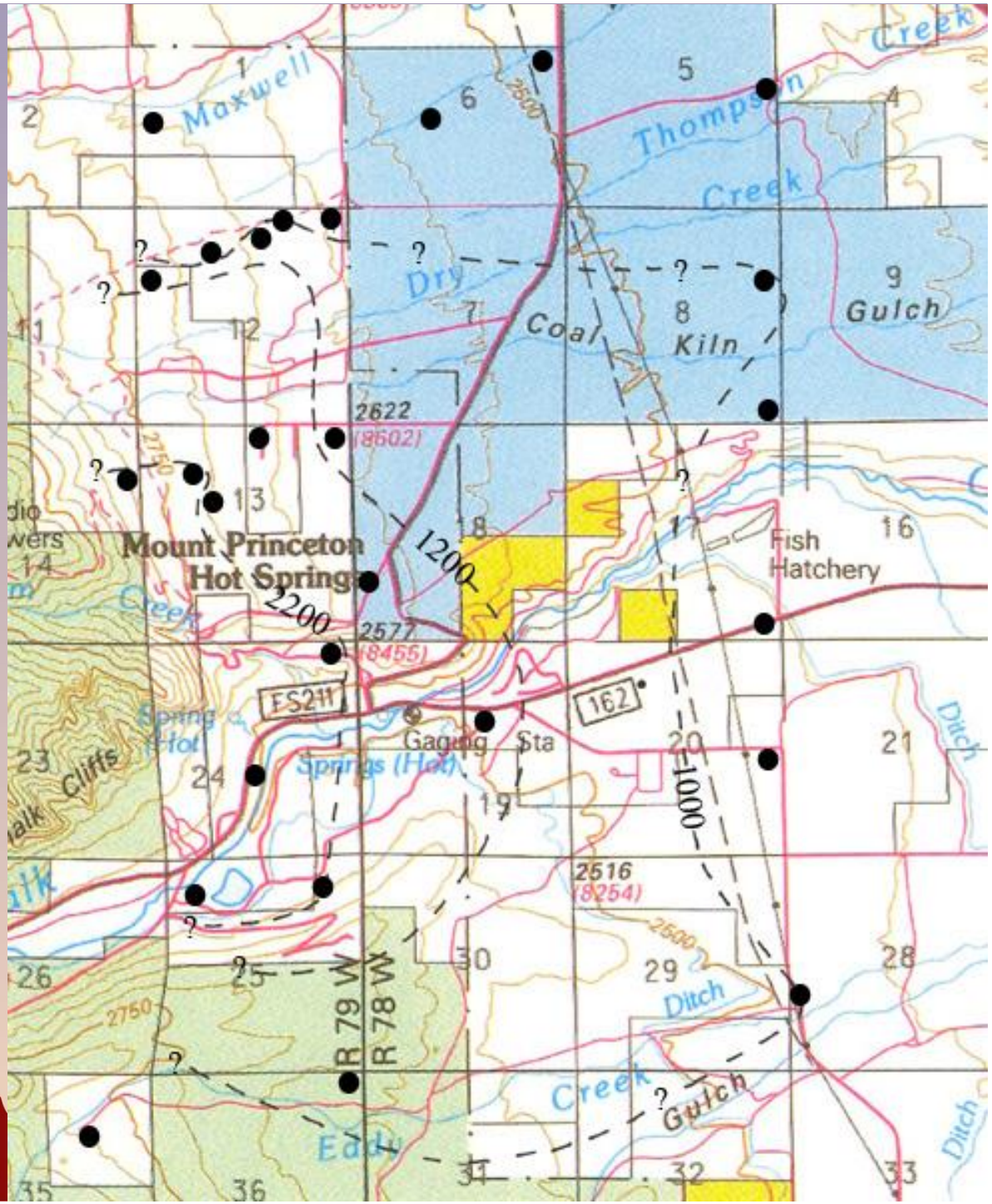






- Topography has strong influence on geothermal gradients in vicinity of Mt. Princeton: in general, negative correlation between elevation and gradient.
- Gradients influenced by depth to warm (60-65°C aquifer)
- Therefore contoured elevation of 65°C isotherm.

Map of the elevation of the 65°C isotherm in the Mt. Princeton Area



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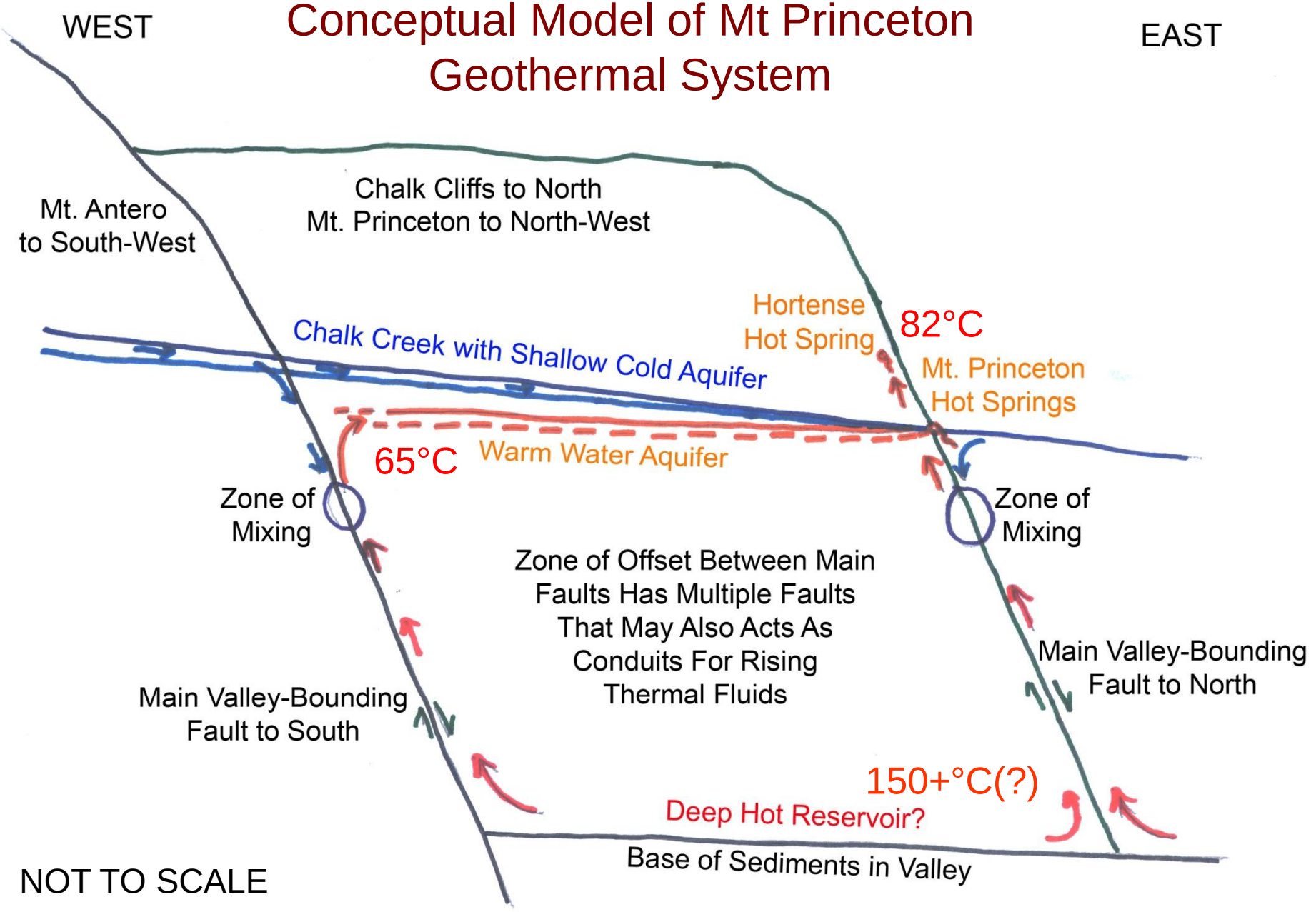
Conceptual Model of Mt Princeton Geothermal System



THANK YOU

- Acknowledgements:
  - Partial support for this work has been from contracts from the Department of Energy through the Colorado Governorôs Energy Office, and the National Geothermal Database System Project through the Arizona Geological Survey.

- For Further Information
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      - Geothermal
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