# Preliminary results for a near surface 3D seismic survey of a geothermal system in Colorado

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#### **Overview**

- Geophysics Field Camp
- •Geothermal Energy in the US
- •Hypotheses
- •Study Area and Geological Setting
- •Self Potential Survey
- •3-D High Resolution Seismic Survey
- •Conclusions
- •Future Work

## Field Camp 2007 - 2010

#### •Four years of Joint Geophysics Field Camp

- Colorado School of Mines
- Boise State University
- Imperial College London

#### •Geophysical Methods Used

- Deep and shallow reflection seismic
- Electrical resistivity
- Electro-magnetics
- Self potential
- Magnetics
- Gravity
- Passive seismology
- Well logging and VSP

#### **Geothermal Energy**

- •The United States leads the world in geothermal electricity production with 3,086 MW of installed capacity from 77 power plants.
- •Current development will increase this to almost 4,000 MW.
- •This represents over 30% of world online capacity and meets the energy needs of approximately 4 million homes.
- •Geothermal is estimated to cost 3.6 cents per kilowatt-hour, versus 5.5 cents per kilowatt-hour for coal (Mims, 2009).
- •Colorado has a target of 30% renewable energy by 2020 (Minard, 2010).

#### **US Heat Flow Map**



Source: SMU Geothermal Lab (http://smu.edu/geothermal/heatflow/heatflow.htm)

#### **Colorado Heat Flow Map**



Modified from Colorado Geological Survey, 2010

#### Hypotheses

•Explore new joint inversion techniques to image subsurface structure, fractures, faults and fluid temperatures in the Mt. Princeton shallow geothermal system.

•Explore the possibilities of geothermal power generation in the Upper Arkansas Valley.

•Reduce exploration risk (1 in 10 success)

### **Study Area and Geological Setting**







#### Modified from Richards et al., 2010











#### **Chalk Creek Valley**





From: Richards et al. 2010

#### **Chalk Creek Valley**





From: Richards et al. 2010





#### The Self Potential Method



#### Self Potential Acquisition

•Self potential and electrical resistivity studies in the 2008 field camp showed evidence for upwelling of hot water



#### Interpretation

- •East-West fracture with upwelling hot water anomalies
- •Wells to north and south of fracture have cold & hot water respectively.



## **3-D High Resolution Seismic Survey**

•A 3-D high-resolution seismic survey was conducted during the 2009 field camp with the following acquisition parameters:

- Footprint of survey was approximately 240 m x 240 m
- Source was an Industrial Vehicles Minivib Model T-15000
- Total of  $\sim$ 400 shots into a 576 channel Geode recording system

### **3-D Survey Design**

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#### **3-D Seismic Survey Results**

- •Review shot records and first arrival events
- •Two layer refraction model
- Refraction tomography
- •Preliminary reflection stack

#### Shot Records (North to South)



#### Shot Records (South to North)



#### **First Arrivals**



398,600

398,800







#### **Two Layer Refraction Model**



398,600

<sup>398,800</sup> 

#### **Two Layer Refraction Model**



#### **Tomography: Bedrock Elevation**

Assume Bedrock Velocity ~ 3300 m/s



#### Self Potential with Bedrock Contours



#### Self Potential with Bedrock Contours



#### Conclusions

•Bedrock low trends from west-southwest to east-northeast.

•The bedrock low may have been formed by glacial scouring or is an old river channel.

•SP upwelling events are located along the bedrock low.

•The low refraction velocities suggest the granite is heavily fractured and most likely hydrothermally altered.