Joint inversion of electrical and seismic data for Fracture char. and Imaging of Fluid Flow in Geothermal Systems

Project Officer: Eric Hess

Total Project Funding: $1,246, 579

April 22, 2013

Michael Batzle, PI

Colorado School of Mines

Track Name: Fluid Imaging

Relevance/Impact of Research

Project objectives

- Use combined inversion of geophysical data to characterize geothermal reservoirs
- Apply the combined data to quantify hydrothermal fluid flow.
- Develop and train the next generation of geothermal professionals.
- Results extend our ability to understand and utilize geothermal resources
  - Approximately 240 students educated in geothermal assessment
  - New, previously unknown fluid paths identified
  - Drill sites identified for EGS production
  - Resource plan developed for use of hydrothermal fluids
- Involve local groups and individuals in geothermal development

Relevance/Impact of Research

SEG Foundation
Rutt Bridges
Global Geophysical
Chaffee County
Donald S. Reimer, Chaffee Co Engineer
City of Poncha Springs
U.S. Bureau of Land Management
U.S. Forest Service
Becky and Thomas Massey
Dr. Roberta Edwards
Robert Butler
Fred Henderson
Steve Lundgren
Young Life Frontier Ranch
City of Vale and the Community
Vale Elementary School
Sagebrush Saloon
Vale High School
CGGVeritas
Sercel
Local Land Owners
US Geothermal
Spencer Wood & Mark Ferns
Archuleta County: Mike Whiting and Greg Schulte
Stevens Airport: Mark Lavato and Chris Torres
Archuleta School District 50 Joint: Linda Reed
Pagosa Springs Geothermal District: Phil Starks
Zonge
CSU Archuleta Extension: Terry Schaaf
Pagosa Baking Company: Kathy Keyes, Kirsten Skeehan
Pagosa High School: Laura Rand and kitchen staff
San Juan Motel: Kiel Steck
Chimney Rock Archaeological Area: Wendy Smith, US Forest Service
Chimney Rock Interpretive Volunteers – Tannis and Allan
Davis Ranch
Geothermal Greenhouse Partnership
Goodman Ranch
Gerry Huttrer
Ken Levine
Kevin Khung, US Forest Service
KWUF
Pam Leschak, BLM Durango
Matt Mees
Overlook Hot Springs
Pagosa Springs Chamber of Commerce: Mary Jo Coulehan
Pagosa Springs Community Development Corp: Rich Lindblad
Pagosa Springs Golf Club
Pagosa Sun: Jim McQuiggin
Reservoir River Ranch: Levine Family
Jerry & Sally Smith
Southern Ute Indian Nation: Nathan Strong Elk
Spring Creek Ranch: Donald Shahan
The Springs Resort: Carla Shaw
Kristen Swaim Pierce, BLM
First Inn: Lou Woodard

Scientific/Technical Approach

- Collect geophysical data sets of multiple types
  - Resistivity
  - Gravity
  - Self Potential
  - Magnetics
  - Seismic
- Conduct joint inversion on these data (below)
- Additional zones of hydrothermal fluid flow identified
- All tasks complete

Accomplishments, Results and Progress

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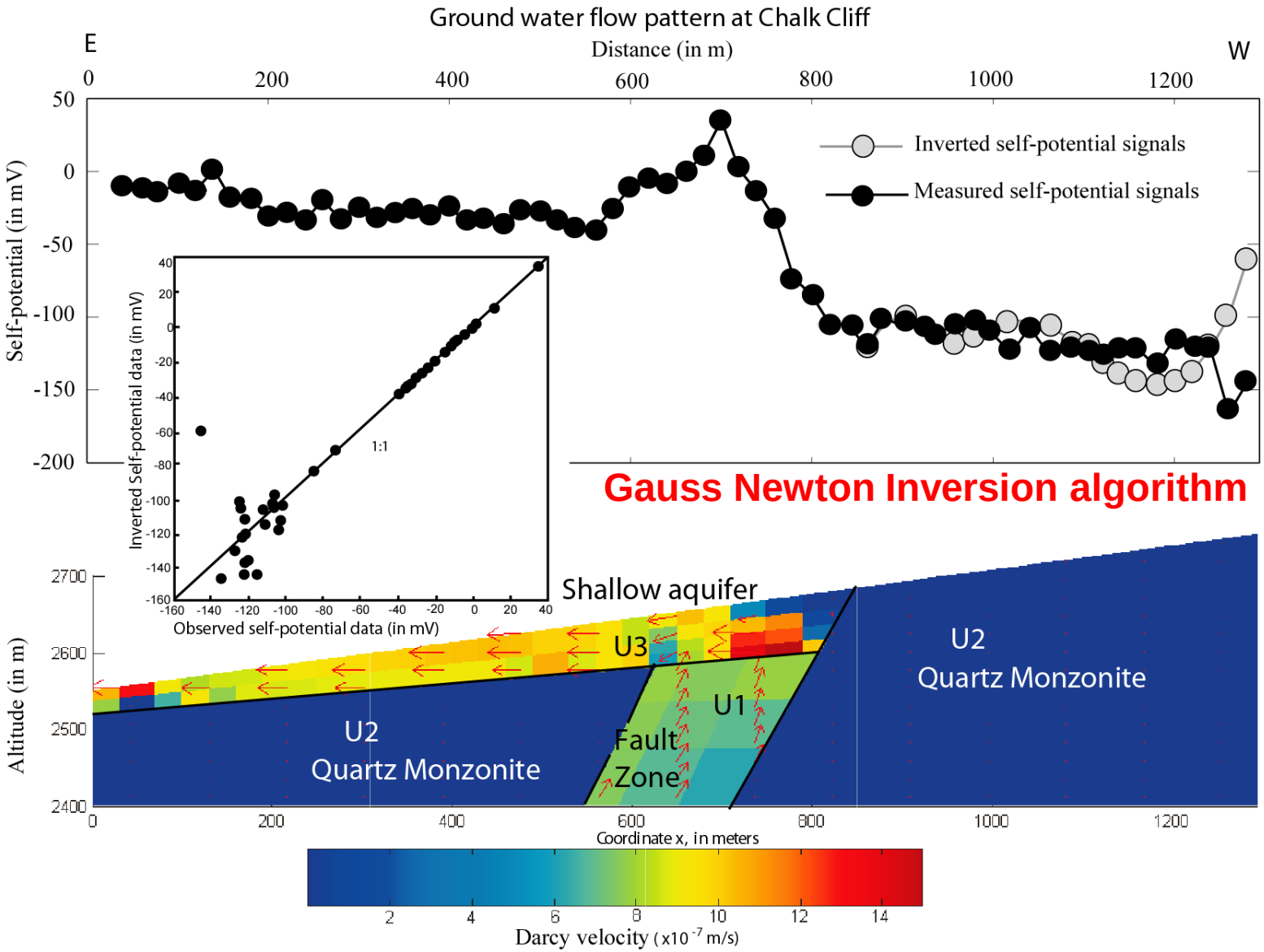
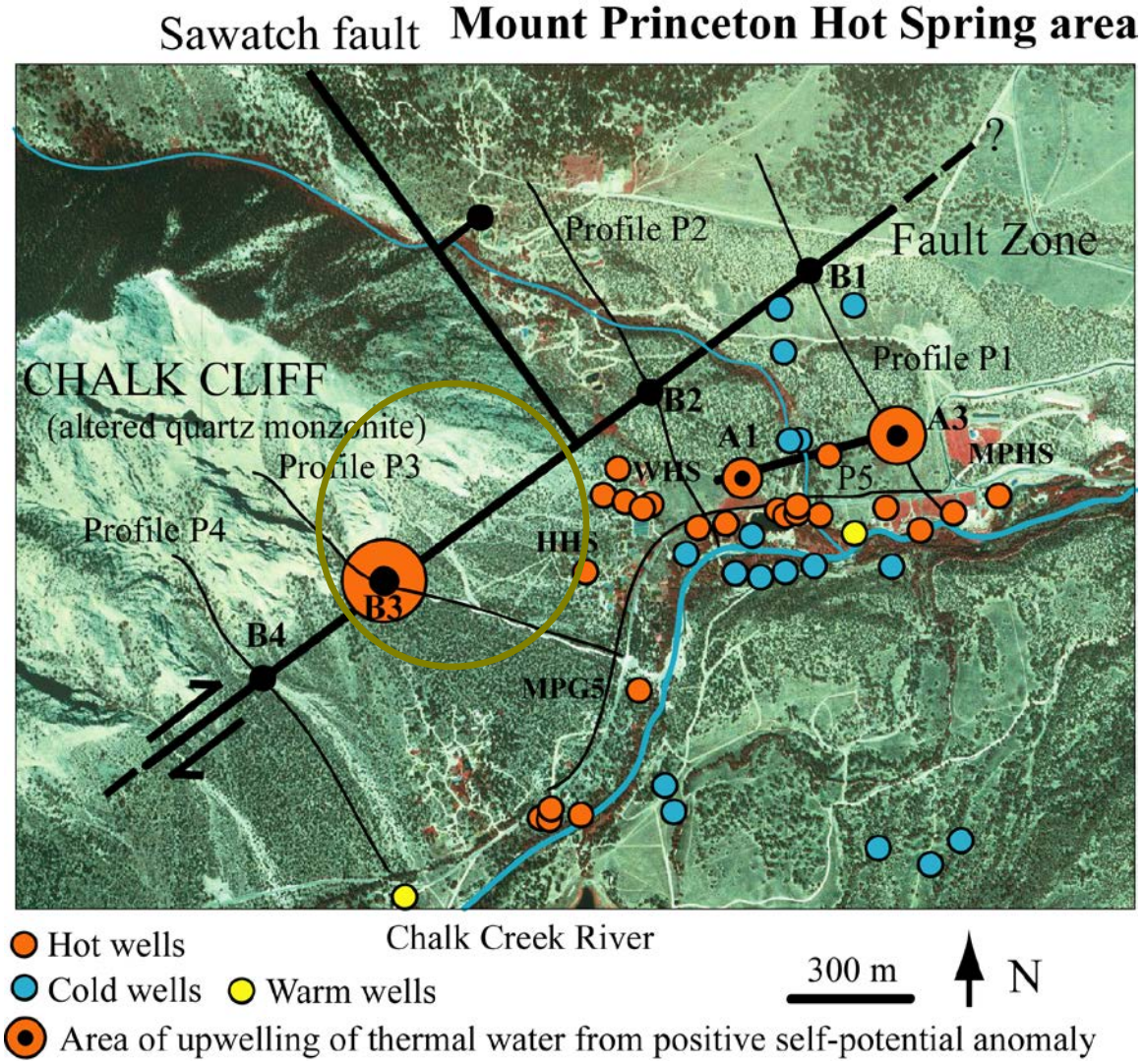
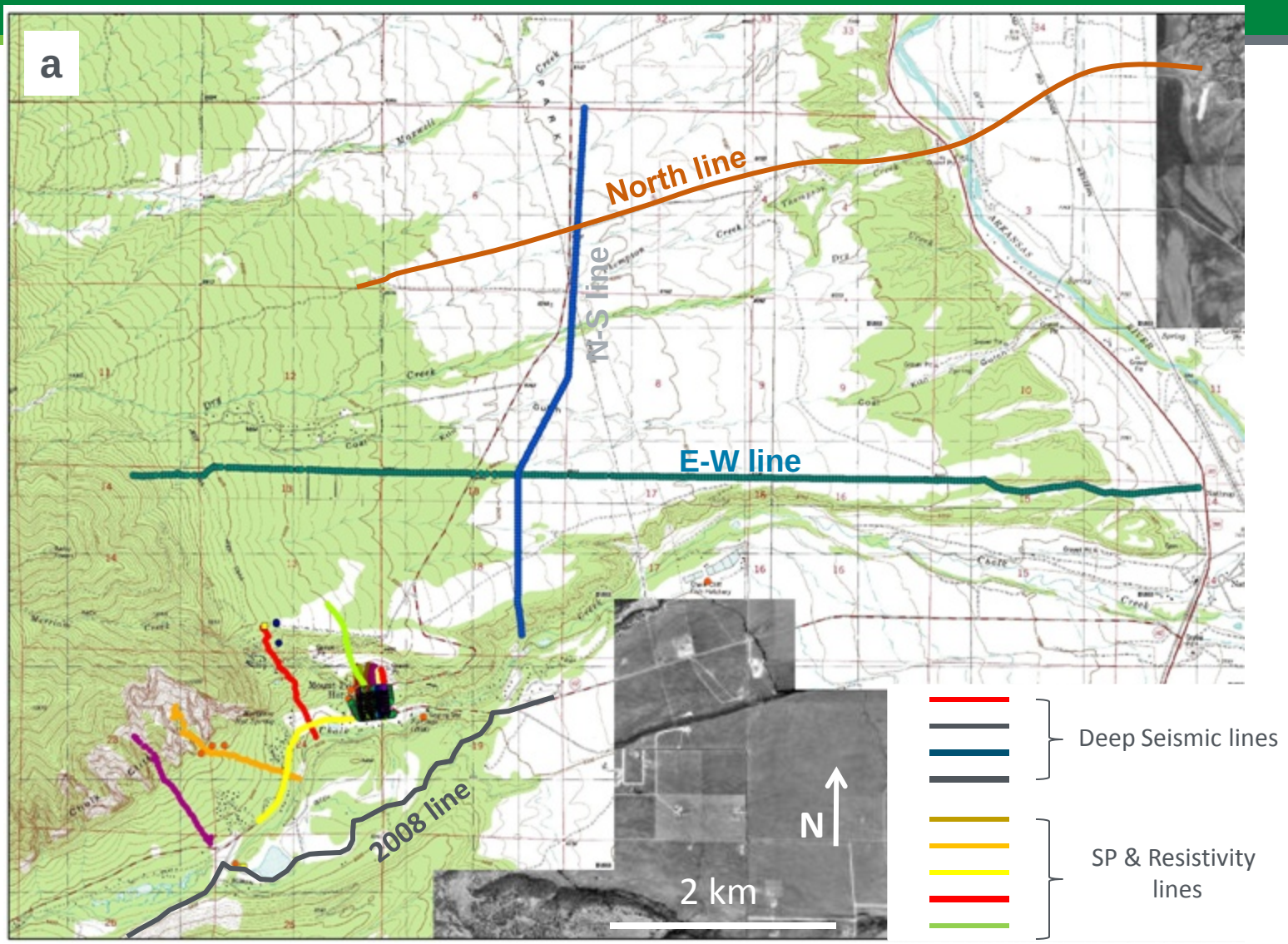
Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Collect multiple geophysical data sets	Chaffee County, Data Collected	May, 2008
Integrate and Interpret data	Interpreted	June, 2008
Collect multiple geophysical data sets	Chaffee County, Data Collected	May, 2009
Integrate and Interpret data	Interpreted	June, 2009
Collect multiple geophysical data sets	Chaffee County, Data Collected	May, 2010
Integrate and Interpret data	Interpreted	June, 2010
Drilling and development plan	Plan complete & presented	Sept., 2010
Collect multiple geophysical data sets	Vail Hot Spr., Data Collected	May, 2011
Integrate and Interpret data	Interpreted	June, 2011
Collect multiple geophysical data sets	Pagosa Springs,Data Collected	May, 2012
Integrate and Interpret data	Interpreted	June, 2012
Preliminary results completed	Presented	June, 2012

Example Results

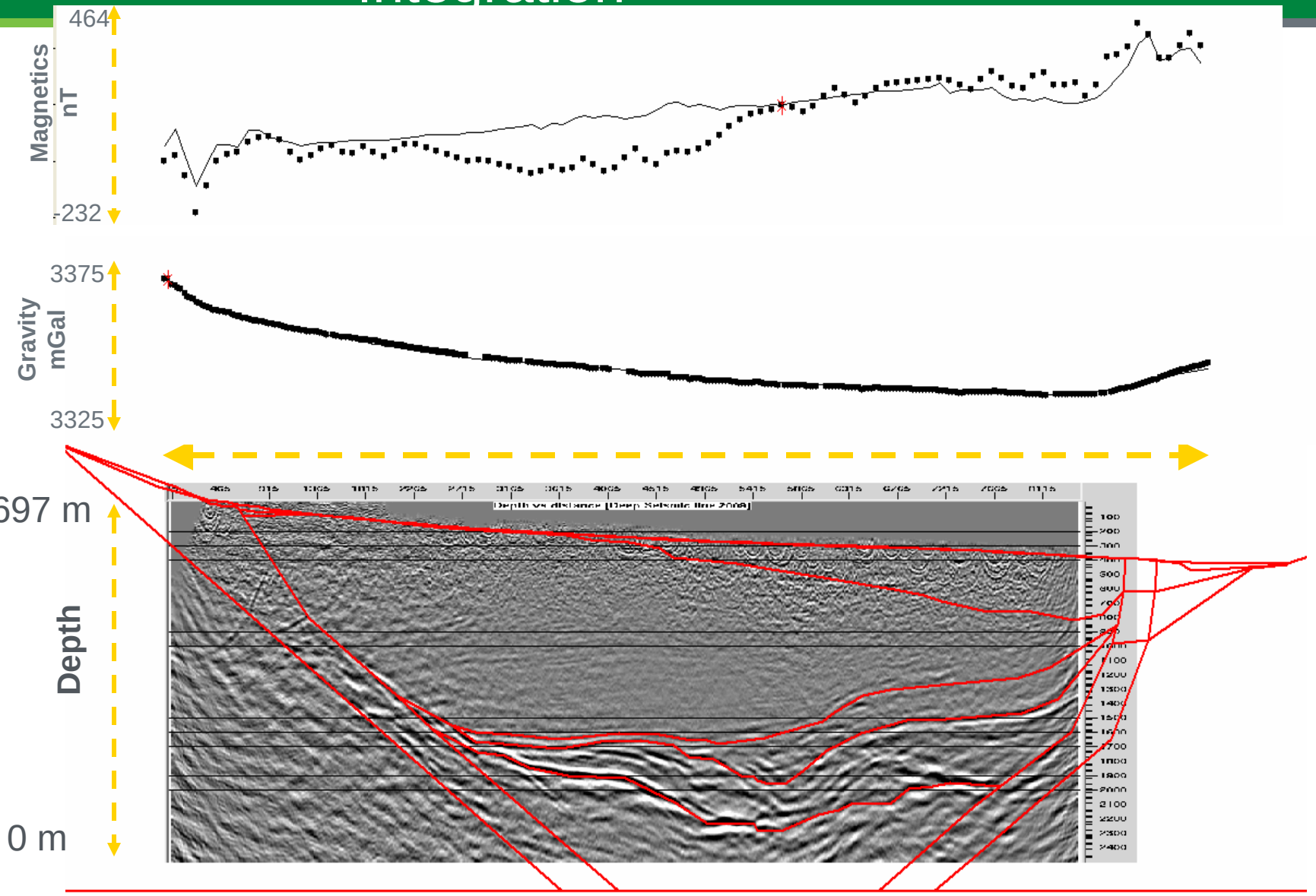


4±1 x10³ m³/day thermal water upwelling

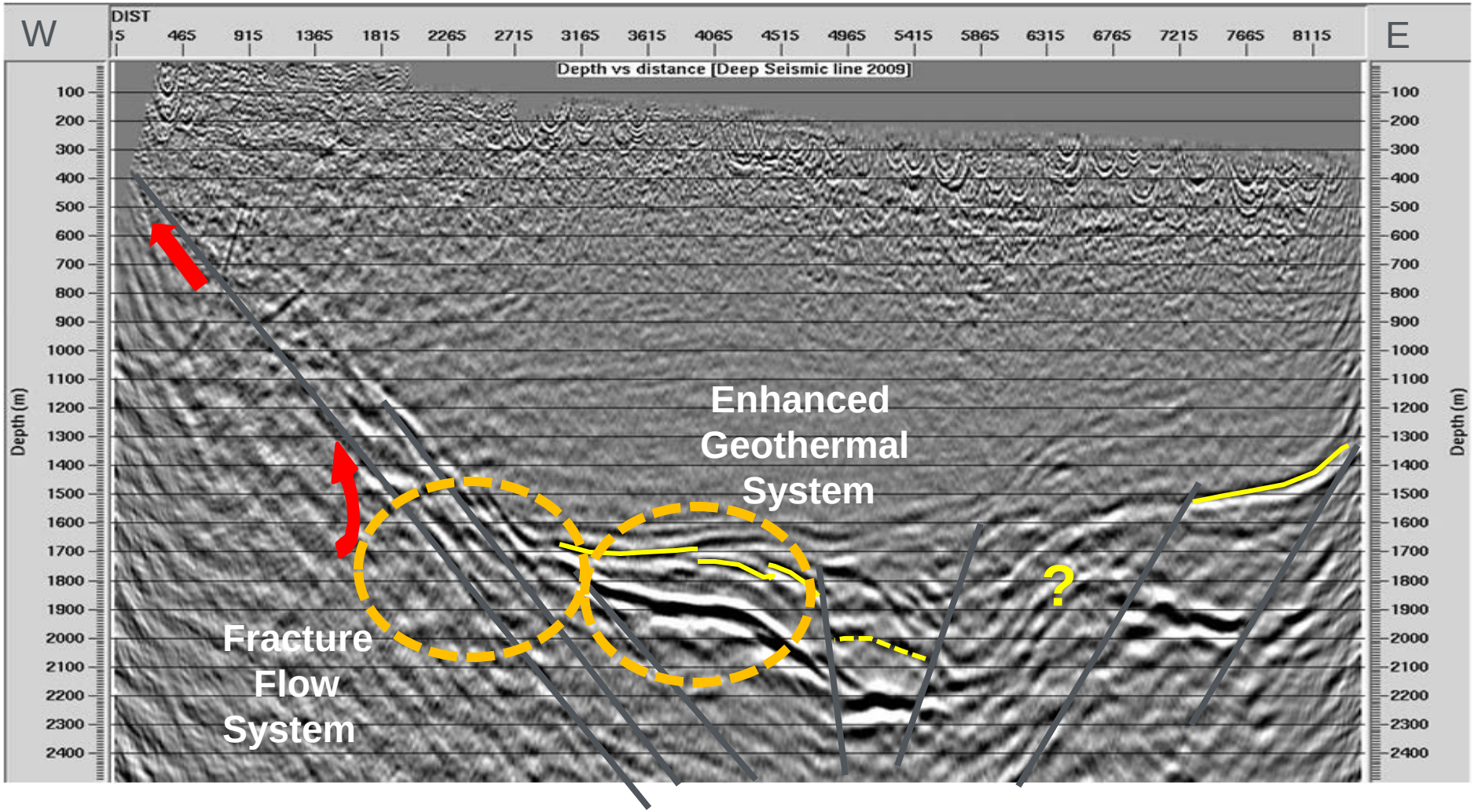



a
North line
N-S line
E-W line
2008 line
N
2 km
Deep Seismic lines
SP & Resistivity lines

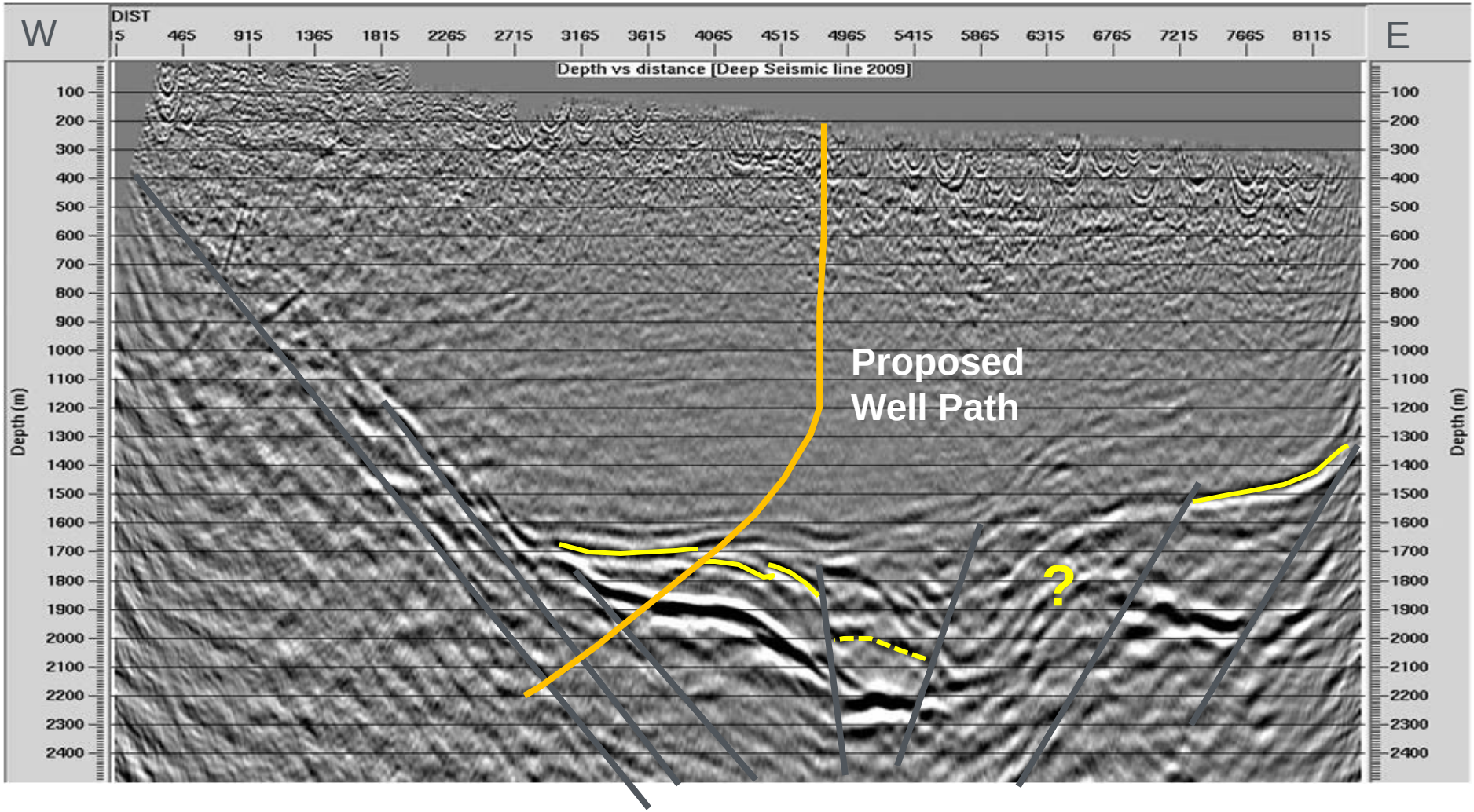
Gravity/Magnetic/Seismic Integration



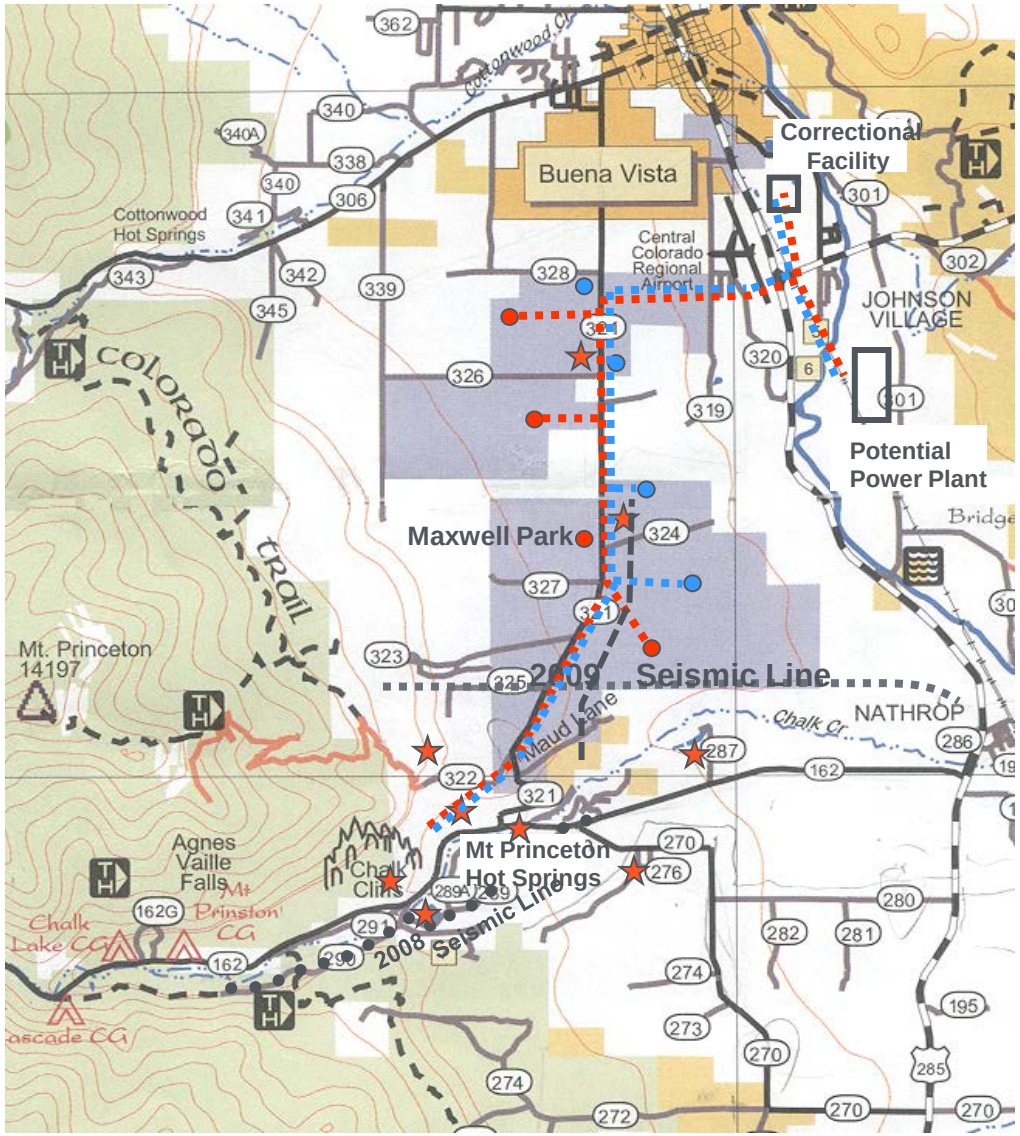
2009 E-W SEISMIC LINE



Proposed Well



Development Plan



Source: Chaffee county recreational map, 2004

Future Directions

- With DOE on this particular project - none
  - Continue related activities at Jersey Valley, Nevada (see Andre Revil, April 23)
- Continue Geothermal assessment at :
  - Pagosa Springs, CO
  - Assist with proposed drilling near Buena Vista, CO
  - Poncha Springs, CO (?)
- Continuation Goals
  - Identify hydrothermal conduits
  - Continue to train geothermal professionals

Milestone or Go/No-Go	Status & Expected Completion Date
Project Results	All Complete and Delivered

Summary

- Geothermal flow imaged and identified
- 240 new professionals trained in assessment of geothermal systems
- Drilling and distribution system outlined and presented

Project Management

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- The purpose of this slide is to provide some context for evaluating your project.
- Please prepare one overview slide containing the following information:

Timeline:

Planned Start Date	Planned End Date	Actual Start Date	Current End Date
March 1, 2008	December 31, 2012	March 1, 2008	December 31, 2012

Budget:

Federal Share	Cost Share	Planned Expenses to Date	Actual Expenses to Date	Value of Work Completed to Date	Funding needed to Complete Work
1,246,932	375,533	1,246,932	1,247,836	1,623,396	- $0 -

- Management activities:
  - Data acquired and interpreted in conjunction with field class
  - Coordinated with dozens of local agencies and individuals (slide 3)
  - 240 professionals trained
  - Similar assessment requested at other locations