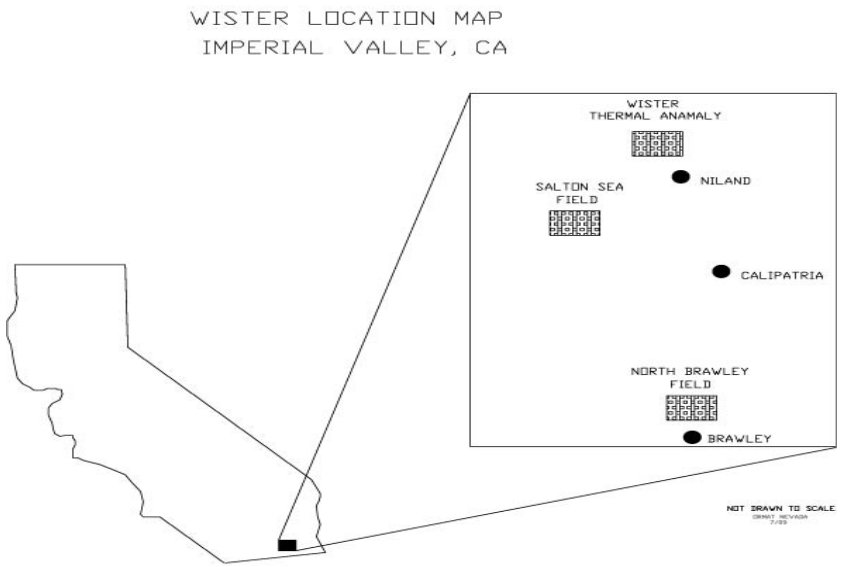


This presentation does not contain any proprietary, confidential, or otherwise restricted information

Conducting a 3D Converted Shear Wave Project to reduce exploration risk at Wister, CA

June 2011

Principal Investigator
Skip Matlick
Ormat Nevada Inc.
Innovative Technologies

Overview Slide

- TIMELINE
- Project start date October 2009
- Project end date Planned Q2 2011, Real Q4 2011
- Percent complete 55%

- BUDGET
- Total project funding $8,525,515
- DOE share $4,475,015
- Ormat share $4,050,500
- Spent $3,936,612 (49%)

Relevance/Impact of Research

CHALLENGES

Conduct a 3C 3D (converted shear wave) seismic survey to reduce exploration risk by characterizing fault and fracture geometrics at Wister, CA, a blind geothermal resource.

BARRIERS

Shear wave response is weak.

KNOWLEDGE GAPS

Weak P-wave and converted shear wave reflectivity.

Structural dips were greater than anticipated.

Unknown shear wave velocity field prior to survey and drilling.

Relevance/Impact of Research

APPLICATIONS

If 3D 3C seismic surveys could define open fractures in the Imperial Valley, then exploration/development drilling costs would be greatly reduced.

INNOVATIVE GOALS

Seismic survey in the Imperial Valley.

3D 3C recording and processing.

Using S-wave data to define open fractures.

GOALS

Confirm 50MWe of geothermal energy capacity.

Validate a new exploration method for geothermal resources.

Scientific/Technical Approach

- PROJECT SUMMARY
- Awarded grant October 2009.
- Forwarded modeled seismic response December 2009.
- Design survey and requested quotes January 2010.
- Selected acquisition and processing companies February 2010.
- Permitting delays resulted in recording 3D 3C survey July 2011.
- Processed and interpreted P-wave data September 2010.
- Delayed S-wave processing until after well was drilled to record dipole sonic log. Dipole S-wave velocities used for processing.

Scientific/Technical Approach

- Submitted Stage 1 report September 2010.
- Selected first well location using P-wave data September 2010.
- Drilled first Well 12-27 October-December 2010.
- Reprocessed P-wave data January 2011.
- Submitted Annual Report January 2011.
- Processing and interpretation of S-wave data May 2011.
- Select site for second well May 2011.
- Drill and test second well Q3 2011.
- Submit Final Report Q4 2011.

Wister Seismic Survey Design

- Designed by ExplorTech LLC.
- 13.2 square miles.
- 1320 ft source spacing.
- 880 ft receiver spacing.
- Two vibrators with 4 sweeps.

Acquisition

- Dawson Geophysical Company performed acquisition.
- Started in early July 2010 after 4-month delay to obtain BLM permits.
- Completed tribal consultation, archaeological clearance, owl avoidance school.
- Used Vibroseis sources and cableless Oyo Geospaces Seismic recorders with 3 component geophones.
- Each source point used two I/O AHV IV 60,000 pound vibrators.

Processing

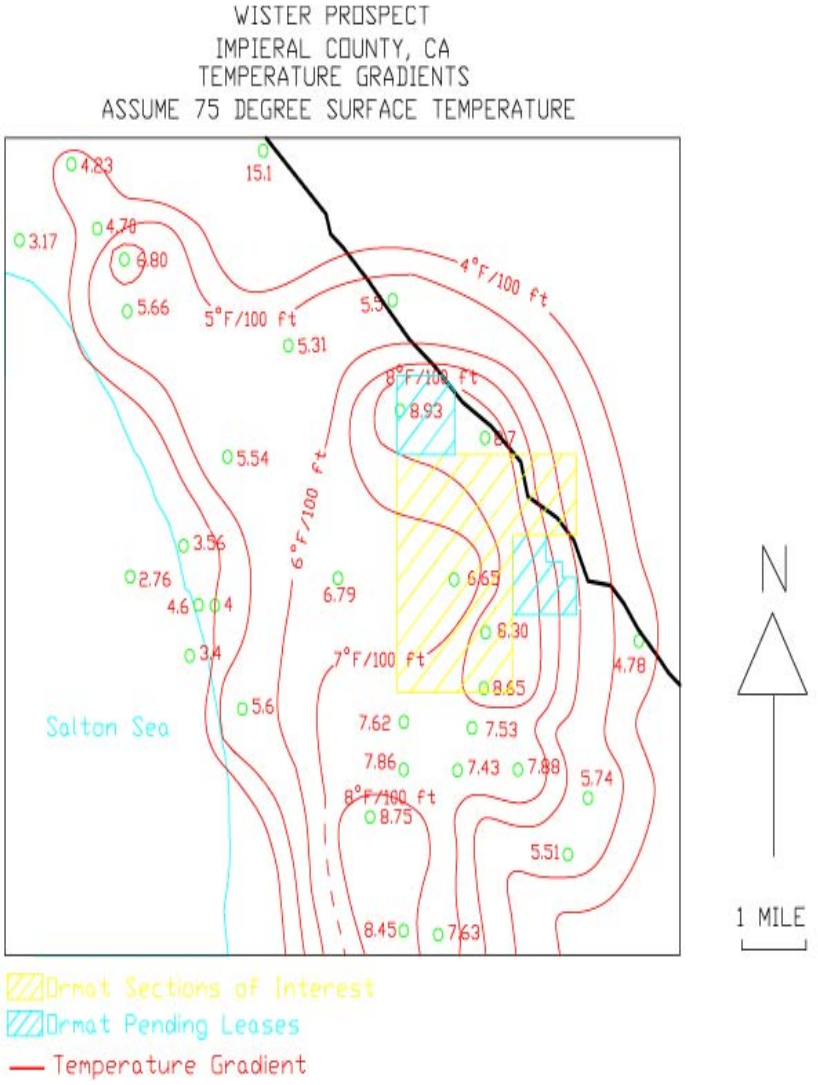
- FairfieldNodal processed P-wave data using:
- 3D binned common-point migrated stacks with 110 by 110 feet bins.
- Refraction statics.
- Receiver elevations statics map corrected surface elevations.
- Static analysis and deconvolution.
- Post-stack and pre-stack time migration.
- Early S-wave processing yielded ambiguous results.
- Delayed further S-wave process until a well was drilled and a sonic log obtained.

Interpretation

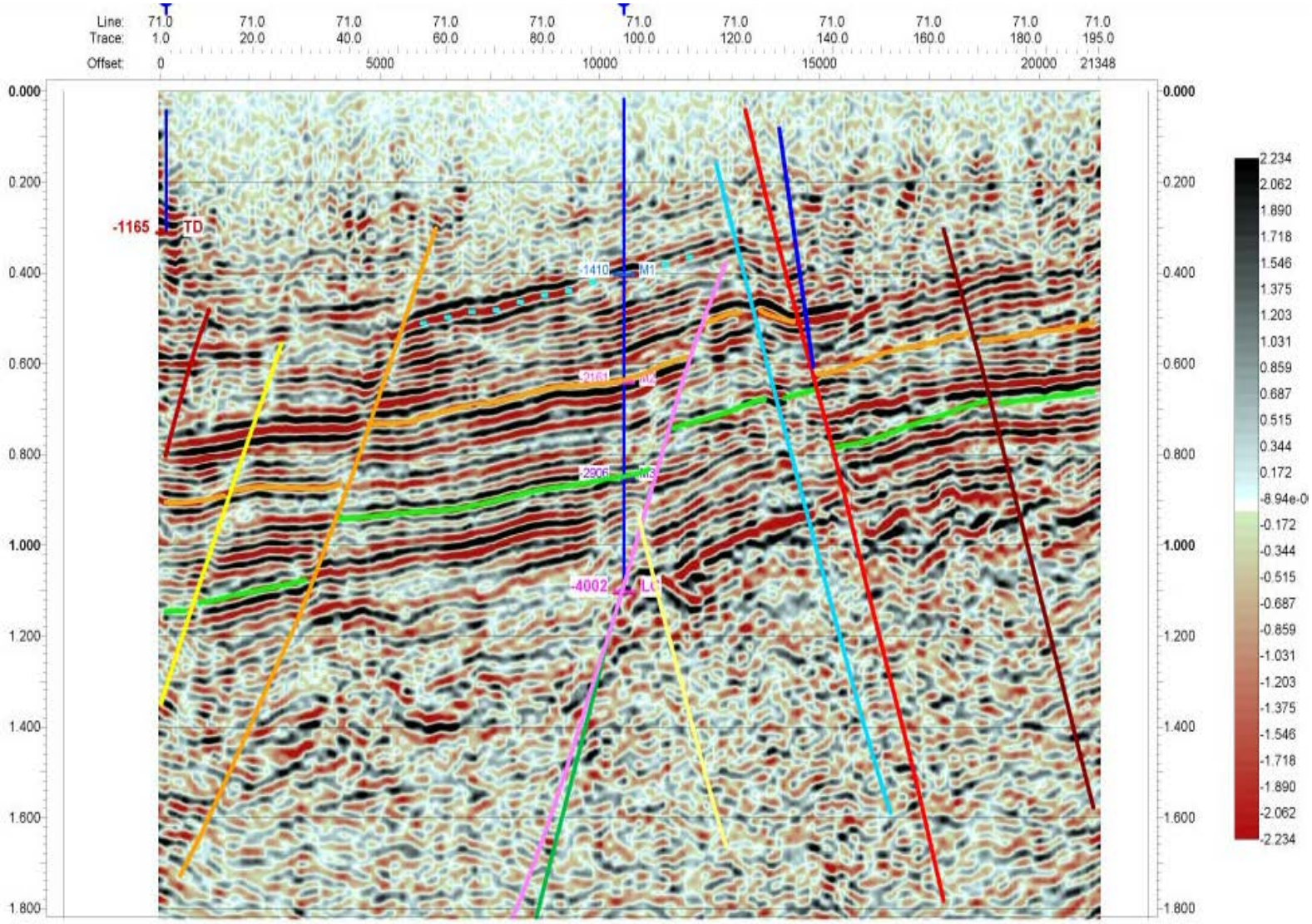
- ExplorTech LLC provided interpretation.
- SMT/Kingdom workstation used for interpretation.
- Faults picked using both vertical seismic sections and horizon time slices.
- Faults were verified with fault plane maps.
- Selected reflectors were utilized to construct subsurface maps.
- All interpretations were completed in time.
- Numerous seismic sections and two horizon time structure maps were generated.

History

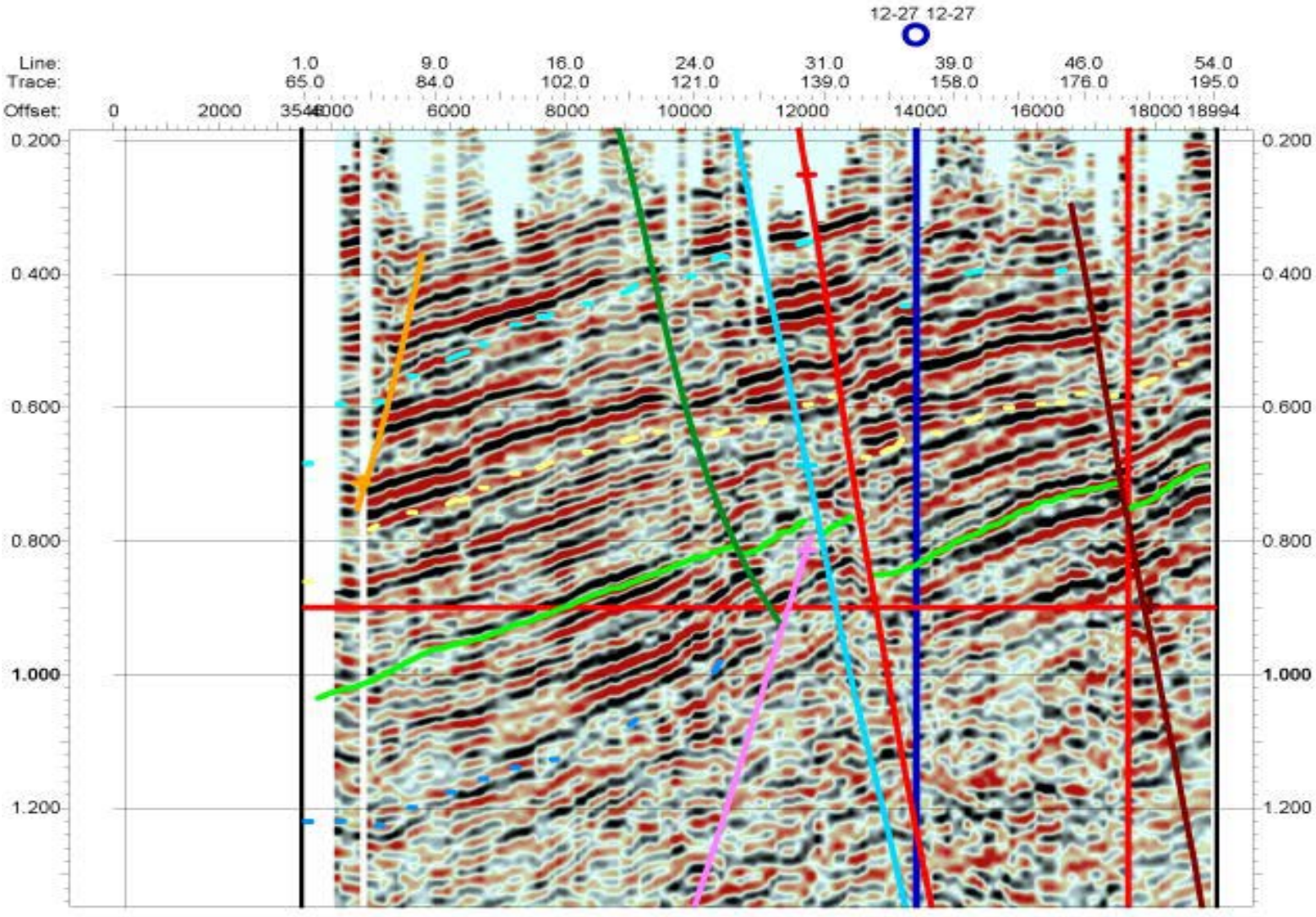
- Unocal drilled an exploration well 88-1 in 1988 based on a 8ºF/100 ft temperature gradient anomaly.
- At 3942 ft, a large fracture was intersected and the well bore collapsed preventing testing.
- Measured 342ºF at 3926 ft.



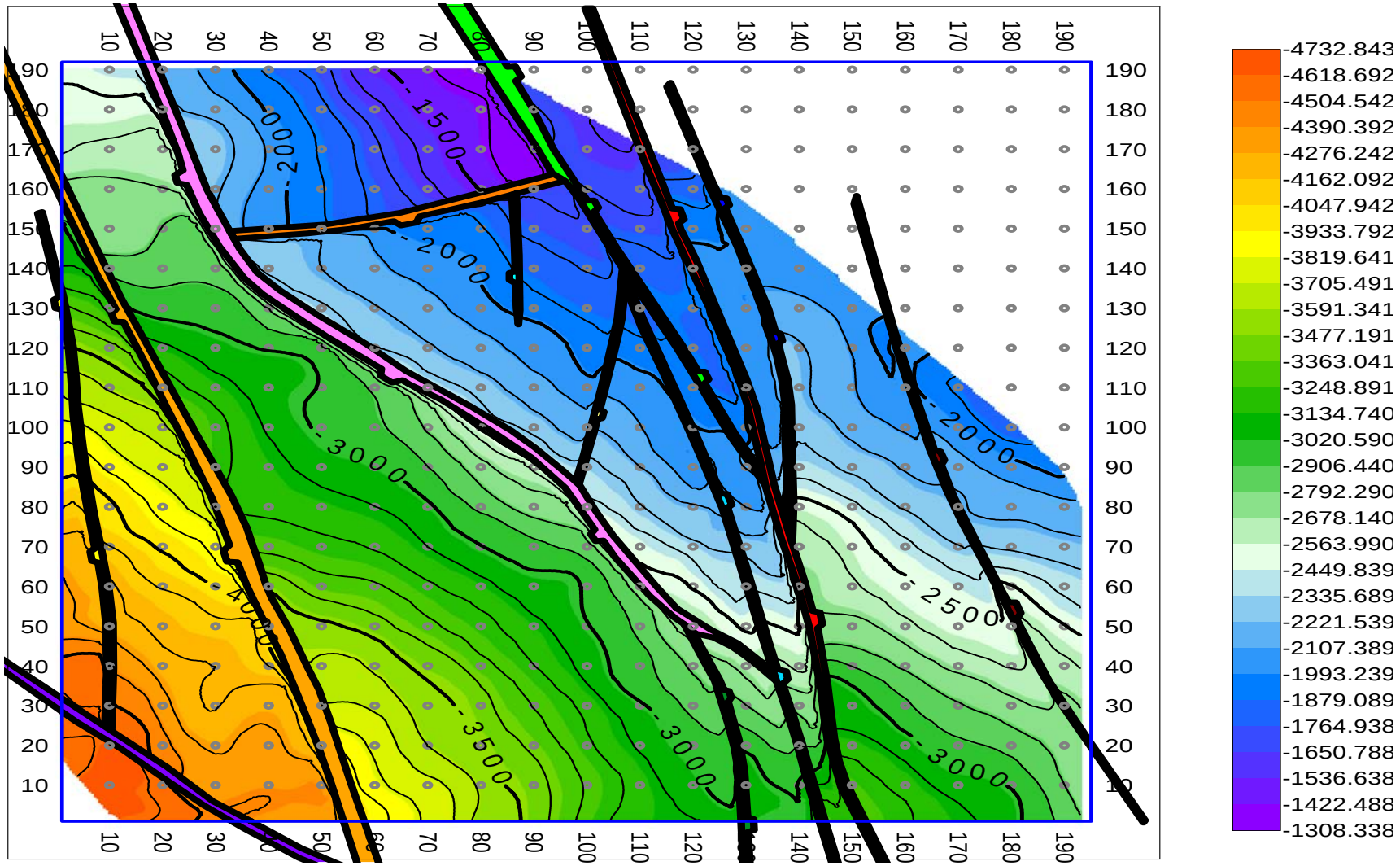
Well 88-1 Seismic Section



Well 12-27 Seismic Section



Horizon Time Structure Map

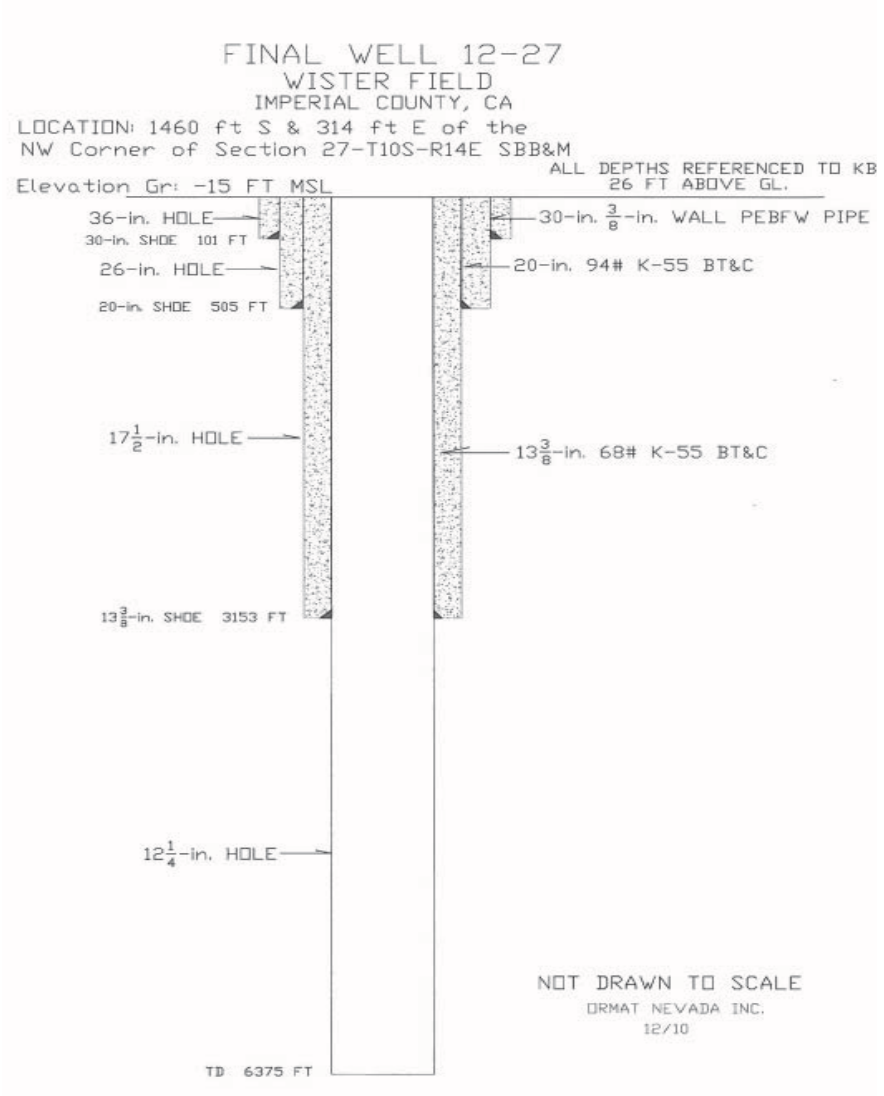


Selection of first well

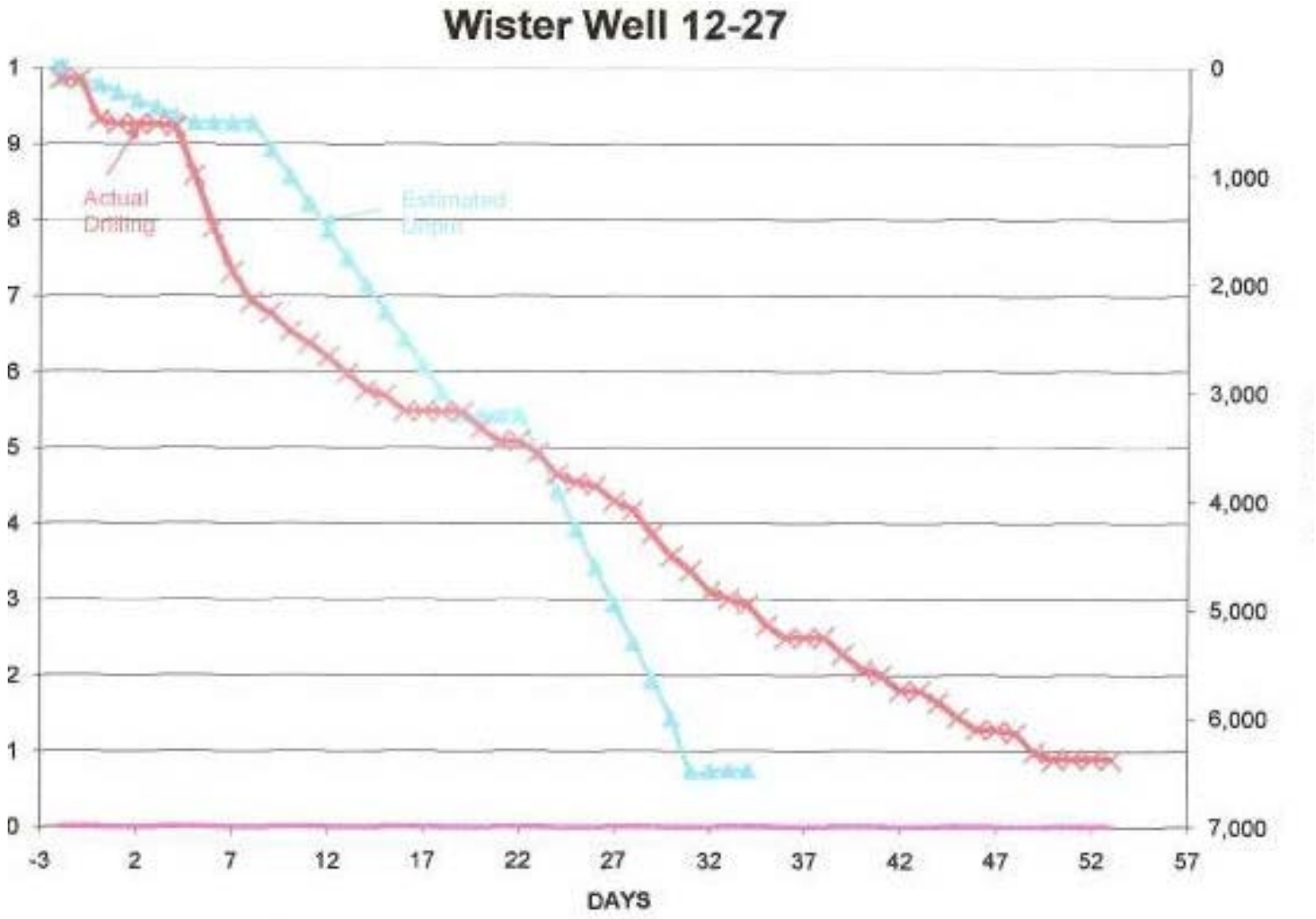
- Ormat compared seismic data and maps with available permitted drilling sites.
- The NW striking fault pair corresponded with the thermal anomaly.
- These two normal faults offered a double drilling target in the 6000-6500 ft range.

Well 12-27

- Drilled to 6375 ft KB.
- 20-in. casing cemented at 505 ft KB.
- 13-3/8-in. casing cement at 3153 ft KB.
- 12-1/4-in. open hole to TD.
- Injection test showed rate of only 1.5 BPM @600 psig.
- Dipole sonic log recorded.



Penetration Plot

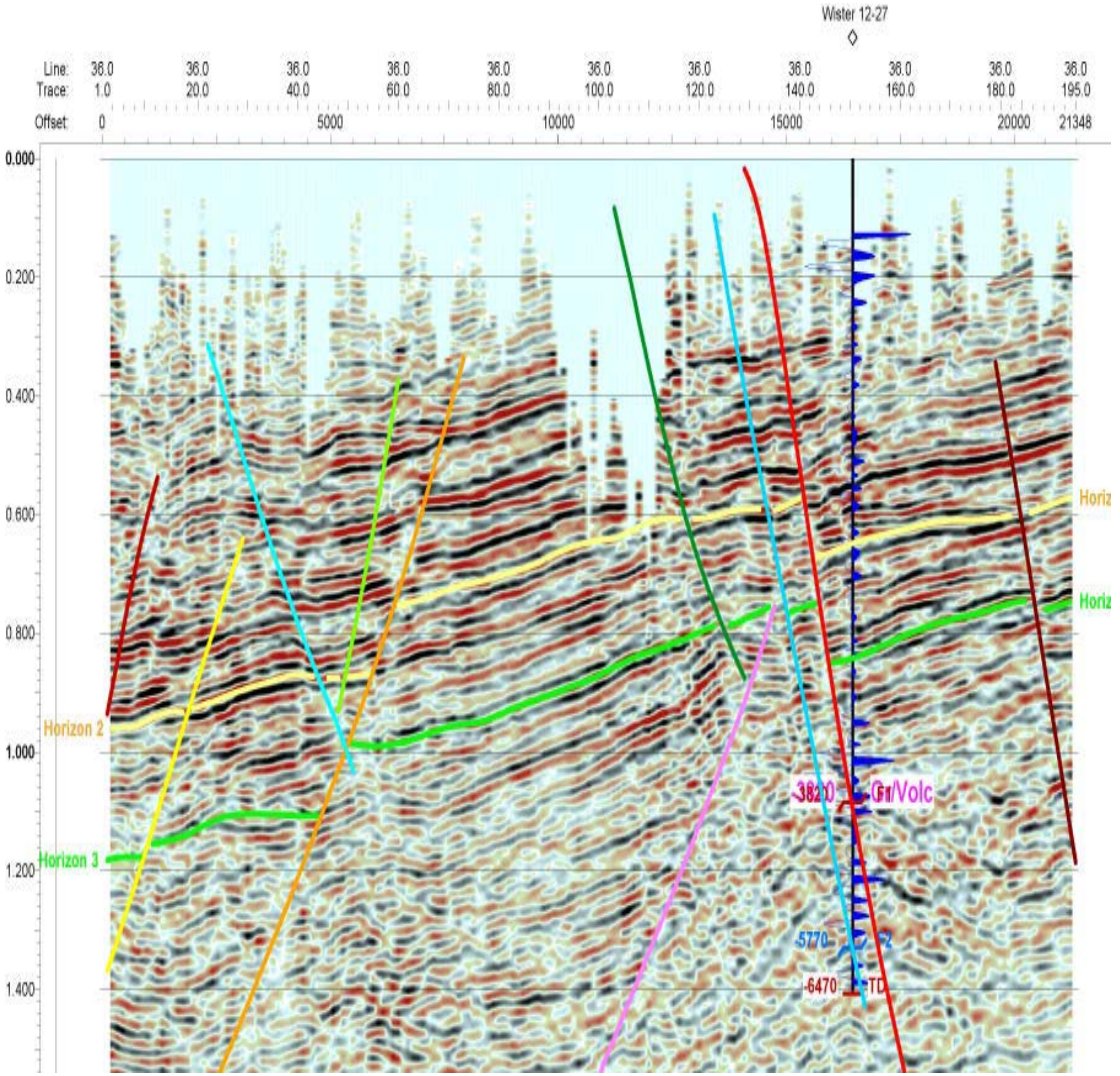


Lithology

- Entire well was mud logged.
- Between surface and 2400 ft KB, clay/claystone and sand (20%) was intersected.
- From 2400 to 3860 ft KB, claystone and sandstone (20%) was encountered.
- Below 3860 ft KB, basement rocks (mostly meta-granodiorite) was penetrated.

Depth Seismic Section

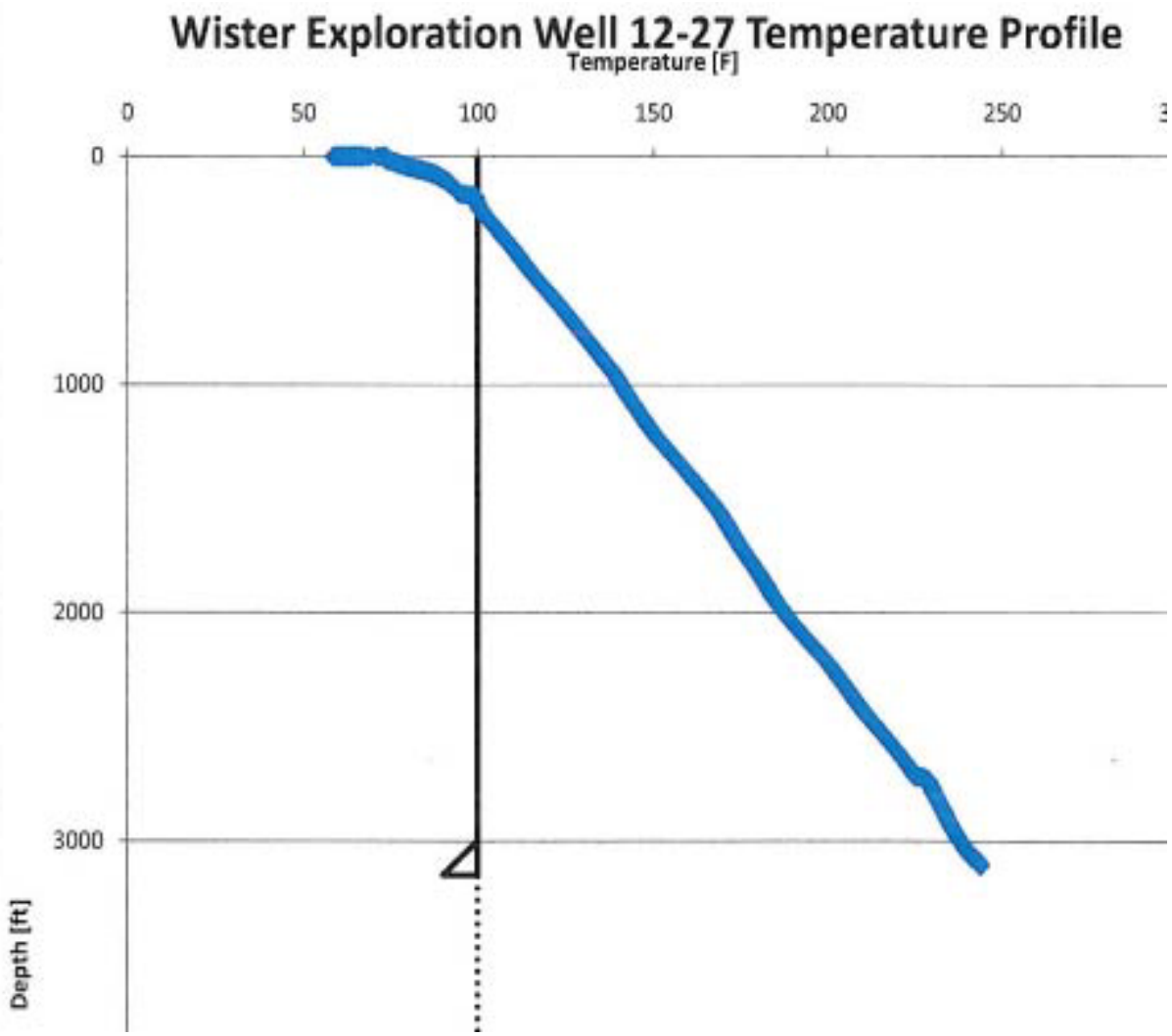
- Reprocessed P-wave data using sonic log velocities show the faults at 3820 ft and 5770 ft.



Lack of Permeability

- At 3820 ft KB, secondary minerals included epidote, silica, pyrite, and chlorite in a claystone rock.
- Claystone is not a competent rock capable of maintaining open fractures.
- At 5850 ft KB, a 50-foot wide altered felsic dike was encountered and lost circulation increased to 21 BPH.
- Apparently a volcanic dike intruded and sealed the fault zone.

Well 12-27 Temperature Plot



Future plans

- Reprocess S-wave data.
- Select second drilling target.
- Drill and test second well.

Acquired and processed 3D seismic survey.

Interpreted seismic survey.

Drilled well.

Calibrated P-wave data to well.

Began S-wave processing.

Project Management/Coordination

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- SCHEDULE
- Delayed by permits from BLM and Imperial County.
- Lack of sonic velocities vs. depth until well drilled and sonic log recorded prevented S-wave processing.
- Originally planned completion by Q2 2011, now Q4 2011.

MANAGEMENT

PI Skip Matlick

Data Sharing

DATA TYPES

Reports, maps, seismic sections, drilling histories, seismic tapes, mud logs, and electric wireline logs

- All data will be forwarded to “DOE Geothermal Data Repository”.

Mandatory slide

Collaborations

- Collaborators:

  ExplorTech LLC.

- Jobs

  48.7 full-time year-long jobs have been created to date.

Mandatory slide

Future Directions

- Interpret S-wave data.
- Select second well location and target.
- Drill and test second well in Q3 2011.
- Submit final report Q4 2011.

- MILESTONES
- Use S-wave interpretations to select second drill target. Go/no go decision planned in Q3 2011.

Summary

	FY 2010	FY2011
TARGET/MILESTONE	3D 3C Seismic Survey	
	Drill first well	
	Reprocess P-wave	
		Process S-wave
		Target second well
		Drill second well