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# Technology Commercialization Showcase 2008

## Geothermal Technologies Program

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# Agenda



- Industry Landscape
- Program Objectives
- Technology Commercialization Opportunities
- Unexploited Investment Gaps

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# Rapidly changing energy security and climate change policy is creating new market opportunities



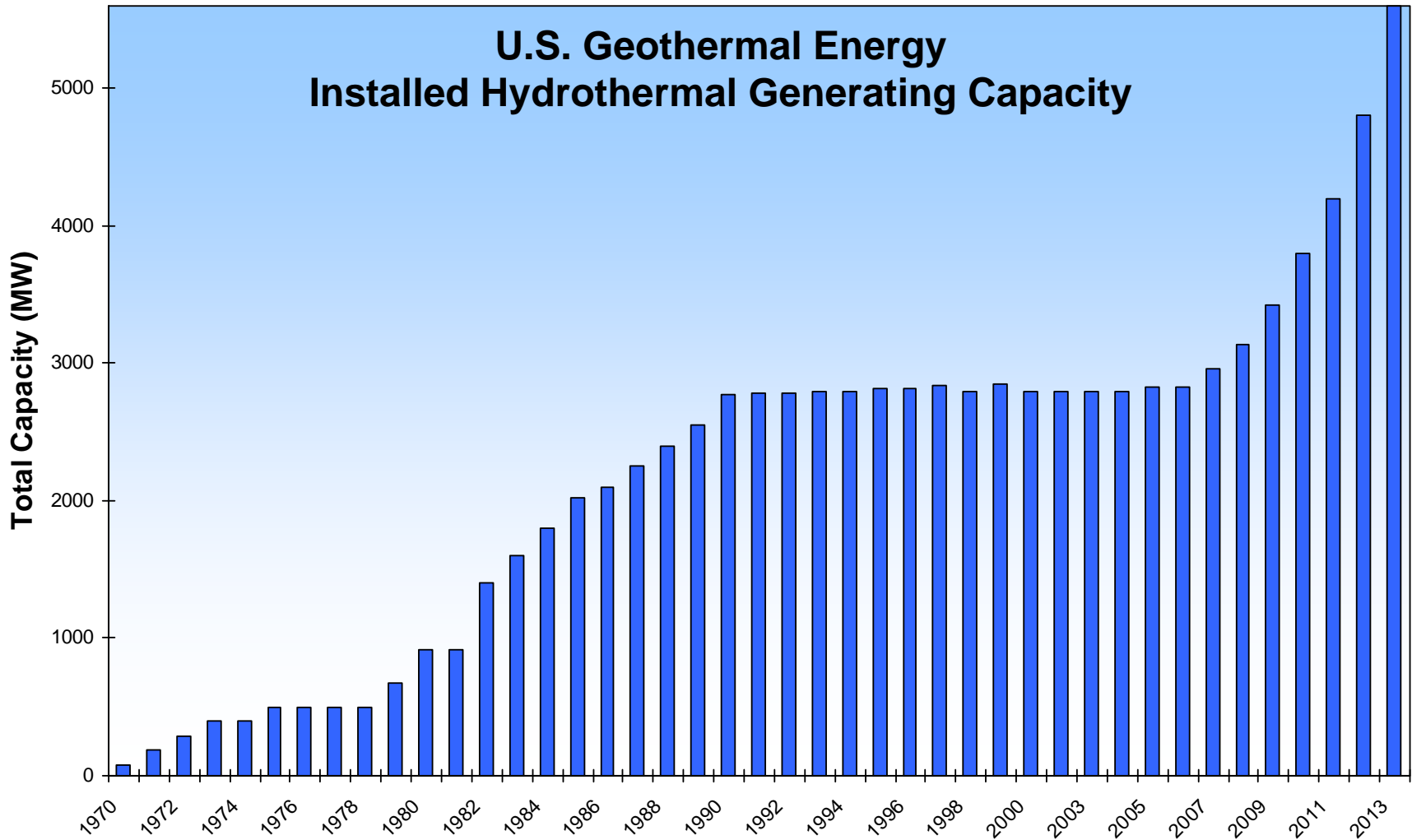
## DRIVERS

- **Energy Reliability and Security**
  - Domestic resource
  - Central station or distributed generation
  - Renewable, inexhaustible resource
- **Air Quality**
  - Avoided greenhouse gas emissions, especially carbon where 100,000 MW avoids 0.12 GT/Y C emission (Source: DOE Carbon Task Force)
  - This is equivalent to reducing coal use by about 10% in the year 2050, assuming 50% efficient coal powered generation

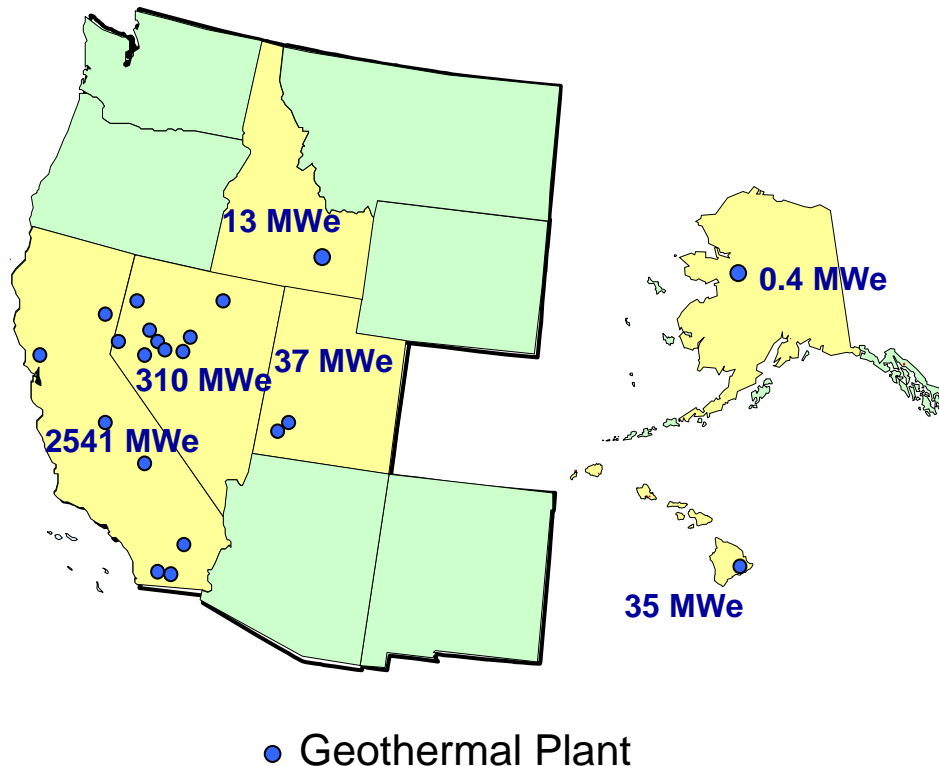
## OPPORTUNITIES

- **Economic Development, listed per 100,000 MW installed**
  - Component manufacturing – 640,000 person year jobs
  - On-site construction – 310,000 person-year jobs
  - Operations and maintenance – 74,000 person-year jobs
  - Every geothermal dollar spent has a 2.5 dollar return into the U.S. Economy (Source: Geothermal Energy Association)

# Closing the geothermal capacity gap is a large market opportunity



# Hydrothermal energy landscape - opportunities for continued expansion



## U.S. Market

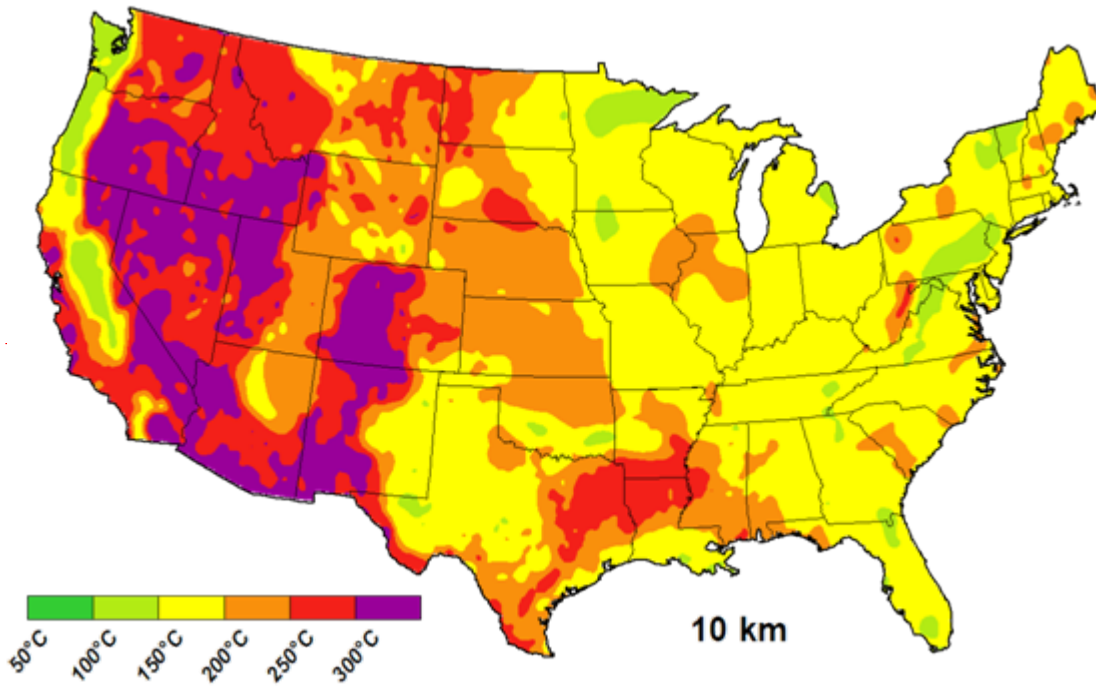
- Installed capacity of 2,900 MW (GEA)
- Total of 86 new projects in 12 states (GEA)
- Additional 3,300 MW will be developed by 2012 (GEA)
- Oil and gas co-production potential of 5,000 MW in 7 states (Texas Gulf Coast Plain alone)
- Tax credits: \$0.02/kWh production tax credit or 10% investment tax credit (expires 12/31/08)

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EGS resources are ubiquitous – leading to more capacity, more jobs, and more money



(map at 30,000 foot depth)

### 100 GW of Geothermal Capacity Means:

- 500 Power Plants (200 MW/plant)
- 100,000 Wells (>3km depth)
- 300 Rigs (100 wells/rig)
- new employment boom
- \$1.4B in Royalty (50% federal land)

These projections were based on historical knowledge and reflect cumulative impacts.





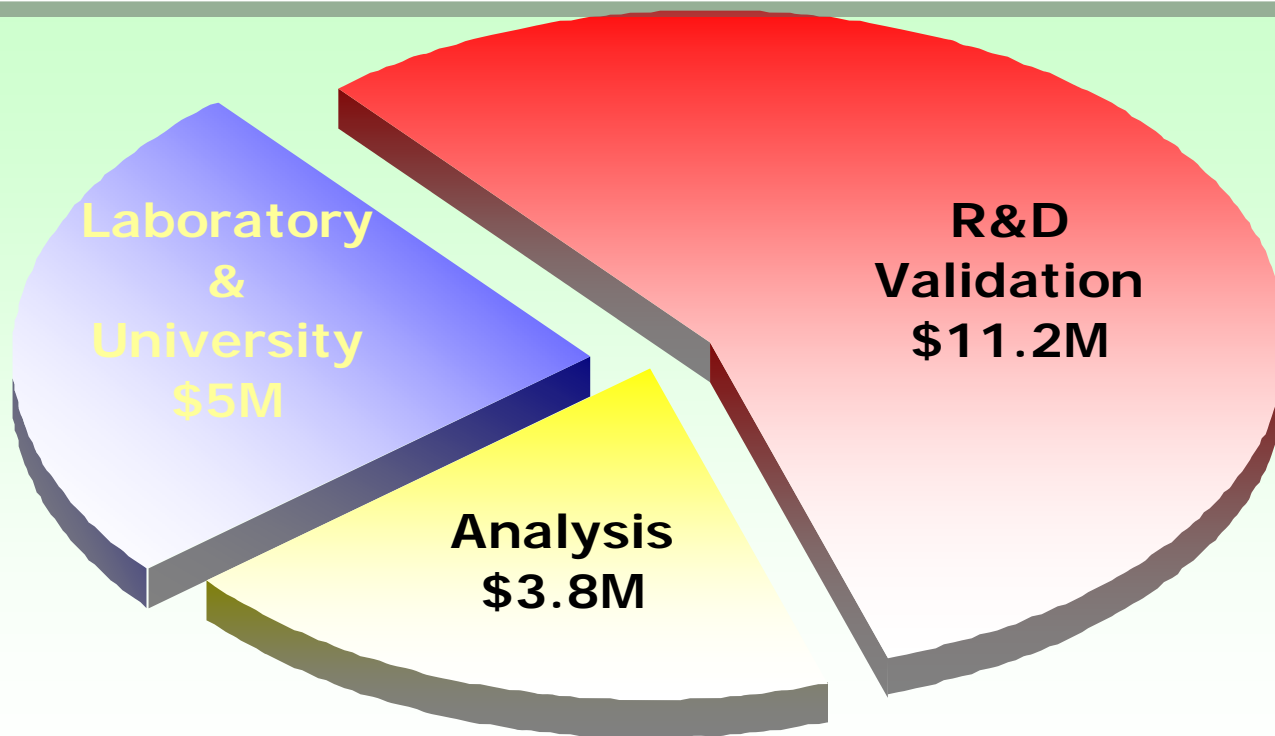
## **New EGS Geothermal Market**

- Some mining industry turning to geothermal development
- Two new players in Geothermal (US)
- Dozen new players in (Canada, Australia, the UK and New Zealand)
- Over \$400M in private equity
- New Financial Partners
  - Berkshire Hathaway
  - Goldman Sachs
  - Morgan Stanley
- Chevron – 800 lb Gorilla (not in US)

# Budget Allocation across Partners



## *FY 2008 Geothermal Program Spending Distribution*



Total \$20M

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This new approach to harnessing geothermal resources shows great promise.

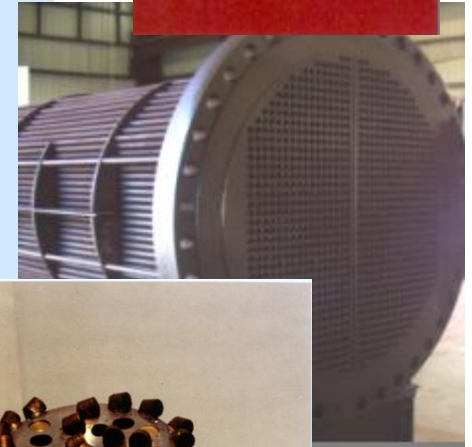


- Look to us for future opportunities
- Buy in has occurred from multiple nations
- Preliminary research predicts massive gains
- We have been successful with our R&D and deployment of hydrothermal technologies

# Hydrothermal technology accomplishments



- ❖ **PDC Bits (DOE Top 100)**
- ❖ **Binary Cycle Technology**
- ❖ **Crystallizer-Clarifier (pH modification technology)**
- ❖ **Hot Dry Rock Proof of Concept**
- ❖ Geopressured Geothermal Power Generation
- ❖ Low-Temperature Power Conversion (FY2007)
- ❖ Solid-state High-Temperature Battery (FY2006)
- ❖ Low Emission Atmospheric Monitoring Separator (FY2003)
- ❖ CurraLon Coating System (FY2002)
- ❖ Silica Recovery from Brine (FY2001)
- ❖ ThermaLoc CaP Cement (FY2000)



# Hydrothermal Technologies: High-Temperature Chip Set



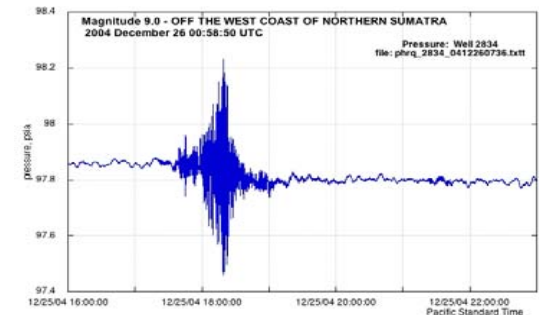
- **Problem:** High Temperature Environment.
- **Description:** 8051-based chip set with proven reliability of 5.2 yrs at 200°C; system can operate at 300+°C.
- **Impact:** Enables remote monitoring and control
- **IP position:** Copyrighted (code is burned into the chip set)
- **Status:**
  - Fully developed including educational materials
  - Used in Sandia's 250°C Pressure, Temperature & Spinner tool
- **Technology Readiness**



- Completed
- Outstanding



Monitoring a Geothermal Well



High sensitivity of tool using chip set captured hydro-seismic response of Sumatra earthquake from site in a California well

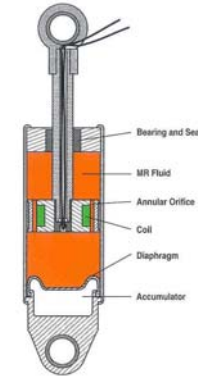
# Hydrothermal Technologies: Magneto-Rheological Fluid Damper



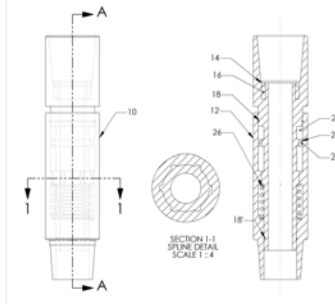
- **Problem:** Drill bits and downhole tools are susceptible to failure when subjected to excessive vibrations
- **Description:** powered and autonomously self-controlled system to mitigates downhole vibrations remotely
- **Impact:** cost reduction
- **IP position:** United States Patent No. 7036612, for drilling applications
- **Status:** Non-exclusive license granted
- **Technology Readiness**



- Completed
- Outstanding



Conventional MR Fluid Damper (truck shock absorber)



MR fluid damper drilling tool



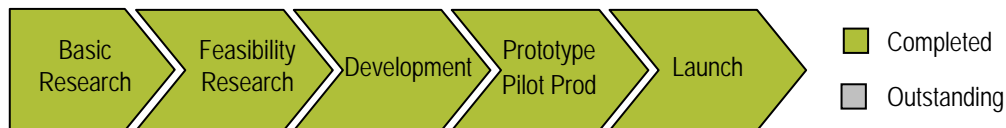
Well wall surface before (rough) and after damping (smooth)

# Hydrothermal Technologies: 2003 R&D 100 Award – LEAMS (Low Emissions Atmospheric (Metering Separator))



- **Problem:** Fluids and some gasses in some geothermal regions (e.g. the Imperial Valley) are polluting and noxious
- **Description:** safely contain and clean the atmospheric vented steam of polluting solids, liquids, and noxious gasses.
- **Impact:** Reduction in pollutants
- **IP position:** IP held by Two-Phase Engineering & Research
- **Status:** LEAMS units are currently available through Drill Cool Systems Inc.

## Technology Readiness





# Hydrothermal Technologies: 2006 R&D 100 Award - High-Temperature Solid State Battery

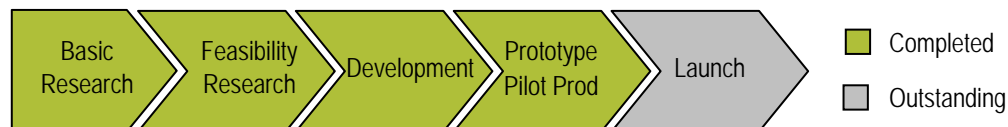


- **Problem:** lithium primary batteries do not function  $> 150\text{ }^{\circ}\text{C}$
- **Description:** The high-temperature solid state battery was developed under by a Russian researcher under the Initiatives for Proliferation Program. The R&D 100 Award was shared by Sandia National Laboratories, VNIIEF institute (Russia) and General Atomics
- **Impact:** Reduced operating cost
- **IP position:** Unknown
- **Status:** Cole Management Group is pursuing manufacturing of this battery



Intact battery (left) and one crushed at  $250\text{ }^{\circ}\text{C}$  (right) with no thermal events or outgassing

## Technology Readiness



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## **Reduce Drilling Cost**

- Zonal isolation
- High-temperature logging tools and sensors
- Seismic imaging tools

## **Reduce Number of Wells/MWe**

- Downhole pumps
- Stimulation prediction models
- Fracture characterization

## **Non-invasive Sub-surface Characterization**

- Remote characterization
- Image fluid flow
- Tracers and tracer interpretation

# Reduce Drilling Cost



**Zonal isolation** - isolate wellbore zones in high pressure and temperature environments in open (uncased) and cased holes using packers, expandable tubulars or other methods capable of providing zonal isolation

- Development of packers and associated tubular goods, valves, etc. capable of operating with differential pressures of 400 bar in wellbore diameters from 6 5/8" to 10 5/8", both drillable and/or retrievable. For drillable hardware, the device should have an indefinite operating period. For retrievable hardware, the intent is to operate for greater than 14 days.

**High-temperature logging tools and sensors** - downhole instruments to detect fractures and log or monitor temperature, pressure, flow rates, and seismic events in wellbores

- Development of tools and sensors for logging and monitoring wellbore conditions at depths of up to 10,000 meters and temperatures of up to 300° C.

# Reduce Number of Wells/MWe



**Downhole Pumps** – augment flow rates by using downhole pumps to add hydraulic head at depth

- Development of downhole pumps capable of being set at depths as great as 3 kilometers in wellbores with diameters of 6 5/8” to 10 5/8” including deviated wellbores, providing up to 300 bar added pressure at flow rates of up to 80 kg/s, and operating without workover for a performance period of three or more years

**Stimulation Prediction Models** – accurately simulate a reservoir’s response to a stimulation

- Development of stimulation prediction models capable of accurately predicting the location, spacing, and orientation of created fractures

**Fracture Characterization** – accurately detect and characterize rock mass fracture systems

- Development of fracture characterization technology capable of resolution of rock mass fracture systems at depths between 1,000 and 10,000 meters using surface or wellbore sensors, in rocks of various types and compositions

# Non-invasive Sub-surface Characterization



**Image Fluid Flow** - accurately image fluid in created and/or pre-existing fractures so as to map flow through the reservoir

- Development of fluid flow imaging technology capable of imaging reservoir fluid flow through created and/or pre-existing fractures at depths of 1,000 to 10,000 meters using surface or wellbore sensors, in rocks of various types and compositions.

**Tracers and Tracer Interpretation** – adapt or develop reservoir tracers and/or tracer interpretation techniques that provide information beyond well-to-well connectivity such as fracture surface area or fracture spacing

- Development of tracers and tracer interpretation techniques capable of being used at temperatures up to 300° C and providing information beyond well-to-well connectivity.