

## **Workshop Summary Findings**

### **Developing Higher Enthalpy Geothermal Systems in the USA**

Held October 13-16, 2013

Lake Arrowhead, CA

#### **A: Project Goals:** (Compiled by Peter Schiffman)

- Improve the economics and efficacy of base load electrical power production from sustainable geothermal resources without increasing their environmental footprint
- Explore and demonstrate the feasibility of increasing geothermal electrical power production by approximately an order of magnitude through production of ULTRA high-enthalpy geothermal fluids.
- Create a project in the United States for developing ULTRA high enthalpy resources that builds upon those already underway in Iceland (IDDP), Japan (JBBP), and New Zealand (HADES).
- Promote and enhance collaboration amongst governmental agencies, industry, and academia in the USA and internationally, to advance the capitalization and development of ULTRA high-enthalpy and sustainable geothermal resources.
- Through such collaboration, to develop multidisciplinary approaches and best practices for site selection in the exploration for ULTRA high-enthalpy geothermal resources in the USA.
- Identify site candidates in the USA where a drilling project targeting ULTRA high-enthalpy fluids has the greatest potential for transforming the ability of geothermal energy to contribute to sustainable, electrical power production.
- Explore the potential of using EGS technology to optimize electrical power production from ULTRA high-enthalpy geothermal resources.
- Develop the science and technology for ULTRA high-enthalpy exploration and development that is transferable to other Earth and Material Science applications.
- Enhance our understanding of fundamental problems in the Earth Sciences including: ore genesis, very high-temperature fluid-rock interactions, and magmatic/hydrothermal transitions.
- Educate and train the future work force and create new employment opportunities in this field of green energy, thereby enhancing the United States' competitiveness.

## **Criteria for Site Selection**

- Must be a site that likely contains ULTRA-high enthalpy resources at depths attainable by current drilling technology on the basis of existing surface and subsurface data.
- Must be a site with substantial infrastructure, access, and permitting, as well as availability to power and testing facilities.
- Must be a site with an existing operator willing to be an active partner in this project.
- Must be a site in which it is possible to maximize the scientific and technological benefit and transferability for a given capital investment.
- The initial site must be one in which this project could readily demonstrate the proof of concept that the development of ULTRA high-enthalpy resources is viable.
- Potential sites that meet the above criteria include, but are not limited to: the Salton Sea, The Geysers, Coso, Hawaii, and possibly various sites the Great Basin.

## **B: Funding and Organization** (Compiled by John Shervais)

### **Potential Funding for ULTRA Geothermal Resources**

- Industrial Partners Critical!
- Partner for any Specific Site Essential!
- Consortium of Industrial Affiliates
- Technology Transfer
- Test Bed for New Technologies
- NSF -- SEES program -- very competitive, too late for 2014
- DOE EERE -- FOA coming soon, but we won't be ready. Cost share a must = industry support
- DOE BES -- Maybe
- DOD -- Navy Geothermal Office? Possible if a military site (e.g. Coso, California)
- ICDP -- YES, but  $\leq 20\%$  Operational funding
- ARPA-E -- Energy Funding, big budget
- DARPA -- If we can provide defense justification
- Private Foundations (e.g. Elon Musk foundation) -- Maybe
- Others?

## **C: Technical Challenges** (Compiled by Dennis Nielson)

### **Research Coordination**

- Organize to promote research and technology development to benefit all high-enthalpy projects worldwide. - IGA Sponsorship? Problem of too many geothermal organizations?
- Promote technical transfer applied to other industries (e.g. Oil & Gas)
- Coordinate Political and regulatory aspects (e.g. hydrofracturing).

### **Well planning**

- Drilling Objective
- SAFETY
- Drilling Plan
  - Contingencies
  - Risk Analysis
- Completion
- Testing (Reservoir Engineering)
- Budget

### **Drilling**

- Materials Engineering
  - Casing
  - Well Head
  - Surface Handling
- Down Hole Motors, Measurement While Drilling
- Cement
- Mud –Composition and Cooling

### **Borehole Measurements**

- During Drilling
  - Measurements While Drilling to update model, Predict Borehole Depth or Approach to Magma
- Logging & Monitoring
  - High-Temperature Logging (Open hole)
    - Temperature, Gamma, Borehole Imaging, Sonic Velocity, Electrical Resistivity.....
  - Long-Term Monitoring (Reservoir Engineering)
    - Pressure, Temperature Spinner

### **Fluid Handling**

- Produced Fluid (Flowing Well)
  - Mass, Enthalpy, Gas, Chemical Composition
  - Storage, Treatment -> ReInjection?

- Injected Fluid
  - Kill Well (Fresh Water)
  - Test Well/Concept
    - Fracture Stimulation (Fresh Water)?
    - Tracers
    - Seismic Monitoring (Local Network)

## **Reservoir Engineering**

- Define the resource (temperature, pressure, fluid quality, reservoir size, permeability)
- Testing (Production test: formation properties including nature of permeability)
- Modeling (capacity, sustainability)
- Monitoring

## **Final Program**

### **A Workshop to Promote a Collaborative Initiative to Develop Higher Enthalpy Geothermal Systems in the USA**

Held October 13-16, 2013

Lake Arrowhead, CA

#### **Sunday - October 13th 2013**

- 4.00 PM - Arrival, check in, and room assignments.
- 5.30 PM - Welcome "icebreaker"
- 6.30-8.00PM - Dinner

#### **Monday - October 14th 2013**

- 8.00 - 9.00 AM - Breakfast
- 9.10 - 9.15 AM - Welcome and orientation

##### Session 1: 9.15-10.15 am. Introduction to high-enthalpy and supercritical geothermal resources

1. Wilfred Elders (UCR) "The concept of the Iceland Deep Drilling Project"- 30 minutes
2. Hiroshi Asanuma (AIST, Japan) - The Japan Beyond the Brittle Project (JBBP)." - 30 minutes

10.15 - 10.30 AM - Coffee Break

##### Session 2: 10.30-Noon. High-enthalpy geothermal programs in Iceland, Japan, New Zealand, Italy and Mexico: 1

3. Ted Bertrand (GNS,NZ) "Hotter and Deeper Exploration Science in New Zealand (HADES)- 30 minutes
4. Rosalind Archer (U of A, NZ) - "Fluid flow models at a grand scale".- 30 minutes
5. Falvio Poletto (OGS,Italy) -"Use of seismic exploration methods while drilling."- 30 minutes

Noon-1.00 PM - Lunch

##### Session 3: 1.10 -3.00 pm. High-enthalpy geothermal programs in Iceland, Japan, New Zealand, Italy and Mexico: 2

6. Heber Diez (CFE, Mexico) "Development of high-enthalpy geothermal resources in Mexico."- 30 min.
7. Georgina Izquierdo (IIE,Mexico) "Los Humeros geothermal field, Mexico." - 20 minutes
8. Viascheslav Spichak (Moscow, Russia) "Electromagnetic sounding for geothermal exploration."- 30 m.
9. Alex Schriener (CalEnergy,USA) " Drilling to 500 C: Thoughts from a development geologist." -30 min.

3.00-3.15 PM - Coffee Break

##### Session 4: 3.15- 5.00 pm. The nature of high-enthalpy geothermal systems

10. Mark Reed (U. of Oregon) "Potential sources of high-enthalpy geothermal fluids". -25 min.
11. Dennis Nielson (DOSECC drilling)- "Higher enthalpy geothermal systems." - 25 min.
12. Lilja Magnúsdóttir (Iceland/LBL) "Modeling the deep roots of geothermal systems". -25 min.
13. Sabodh Garg (Leidos)- "Modeling of high-enthalpy geothermal systems." 25 min.

- 5.30 PM - Reception
- 6.30-8.00 PM - Dinner

## **Tuesday – October 15<sup>th</sup> 2013**

8.00 – 9.00 AM - Breakfast

### Session 1. 9.10 - 10.15 am. IDDP- related scientific studies.

14. John Shervais (USU) " Mountain Home Geothermal System: mafic sill complexes in a sedimentary basin." - 30 min.
15. Peter Schiffman (UCD) "Studies of the contact zone of the intrusion in well IDDP-2. Iceland." -30 min.
16. Robert Zierenberg (UCD) "Geochemistry of sulfur in high-enthalpy geothermal systems." - 30 min.

10.15 - 10.30 AM - Coffee Break

### Session 2: 10.30-Noon. Technical challenges to drilling, completing and sampling high-enthalpy wells

17. William Rickard (Geothermal Resources Group) "High Temperature Well Drilling and Completion Challenges" – 30 min.
18. Louis Capuano (GRC & Capuano Drilling) – "The challenge of drilling deep and hot" -30 min.
19. Paul von Hirtz (ThermoChem) "Downhole fluid sampling" - 30 min.

12.00 – Group photo

12.10 -1.00 PM - Lunch

### Session 3: 1.10 -2.40 PM. Logging, permitting, etc.

20. Paul von Hirtz (ThermoChem) "Corrosive Superheated steam" - 30 min.
  21. Randy Norman (Permaworks) "New approaches to high temperature logging." - 30 min.
  22. Phil Wannamaker (UU/EGI) – "Magmatic-hydrothermal transitions in extensional regimes of USA." -30 min.
  23. Mitch Stark (Chevron) "The Geysers high-temperature zone" – 30 min.
  24. Marie Jackson (UCB) "Mineralogical analyses of altered tephra."- 30 min.
- Organization of Break Out Panels leading to writing a white paper

3.00-3.15 PM - Coffee Break

3.15 - 5.00 PM - Breakout Panels 1 – Site Selection & Scientific Goals

25. Wilfred Elders (UCR) " Organization of Break Out Panels leading to writing a white paper" -10 min.

- Breakout Panel 1 – "Site Selection & Scientific Goals" (Peter Schiffman).

- Breakout Panel 2 – "Technical challenges" (Dennis Neilson).

- Breakout Panel 3 – Strategies for collaboration and funding (John Shervais).

5.30 PM - Reception

6.30-8.00 PM - Dinner

## **Wednesday – October 16<sup>th</sup> 2013**

8.00 – 9.00 AM - Breakfast

Session 1. 9.10 - 10.00 AM - Breakout Panels 1, 2, and 3 continue

10.00 - 10.30 AM - Coffee Break, and room check out

Session 2. 10.30 –11.30 AM - Plenary Session - Reports of Breakout Panels 1, 2, and 3.

11.30 –Noon - General discussion of the way forward.

Noon-1.00 PM - Lunch

1.00 PM (or before) Departure for Airports