The Great Basin Center for Geothermal Energy: Past, Present and Future*

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Abstract

The Great Basin Center for Geothermal Energy (GBCGE) was established at the University of Nevada, Reno in 2000, to work in partnership with the geothermal industry to increase the uptake and development of geothermal resources in the western United States. Mechanisms to achieve this include conducting innovative research, pursing collaborative projects with industry, student projects, outreach activities and training. Research conducted at the GBCGE aims to better understand the geothermal resource potential of Nevada and the broader Great Basin, by investigating geological factors that control where geothermal resources are located in the region, and by developing new approaches for geothermal exploration to increase our discovery of 'blind' geothermal systems. In addition, we seek to understand the characteristics of geothermal reservoirs in terms of their temperature, volumes of fluid, permeability, fluid geochemistry, and fluid flow pathways, which are important factors for optimizing the development and management of geothermal resources. Notable achievements since the establishment of the GBCGE include:

- The compilation and release of geothermal datasets for the Great Basin (such as the geochemical groundwater database, geothermal favorability maps, and the Great Basin Geothermal GIS);
- development of new methods to explore for blind geothermal systems (e.g. shallow temperature surveys, remote sensing to map geothermal alteration minerals, structural favorability mapping, mercury soil gas studies);
- establishment of the National Geothermal Academy (NGA), to run annual educational courses to train the next generation of geothermal scientists and engineers (over 130 students have participated in the program to date), and
- Publication of over 50 peer reviewed articles and presentation of over 200 conference papers.

Future activities within the Center will include the ongoing release of data and products useful for geothermal explorers and resource operators, focused research to address the key challenges facing the geothermal industry in the Great Basin, community outreach, and training through the NGA. Anticipated future research directions include a focus on reservoir characterization and modeling, to better understand the dynamics of geothermal reservoirs in the Great Basin. In addition, the Center is currently involved in the US Department of Energy's FORGE (Frontier Observatory for Research in Geothermal Energy) initiative that aims to develop a site for operation and testing of Engineered Geothermal System technologies. In Phase 1 of FORGE, the Center has been involved in two of the five candidate sites: West Flank of Coso (California) and Fallon (Nevada). Both projects are being led by Sandia National Laboratories. Phase 1 is to be completed in June 2016, and the sites that will continue into Phase 2 of FORGE will be selected and announced in the following months.

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Blackwell, D.D., M.C. Richards, Z.S. Frone, J.F. Blair, M.A. Williams, A.A. Ruzo, and R.K. Dingwall, 2011, SMU Geothermal Laboratory Heat Flow Map of the Conterminous United States: Web Accessed January 15, 2017, http://www.smu.edu/-/media/Site/Dedman/Academics/Programs/Geothermal-Lab/Graphics/SMUHeatFlowMap2011_CopyrightVA0001377160_jpg.ashx?la=en

GREAT BASIN CENTER FOR Geothermal Energy

University of Nevada, Reno

nbmg

The Great Basin Center for Geothermal Energy: Past, Present and Future

Dr. Bridget Ayling; Director, Assoc. Prof.

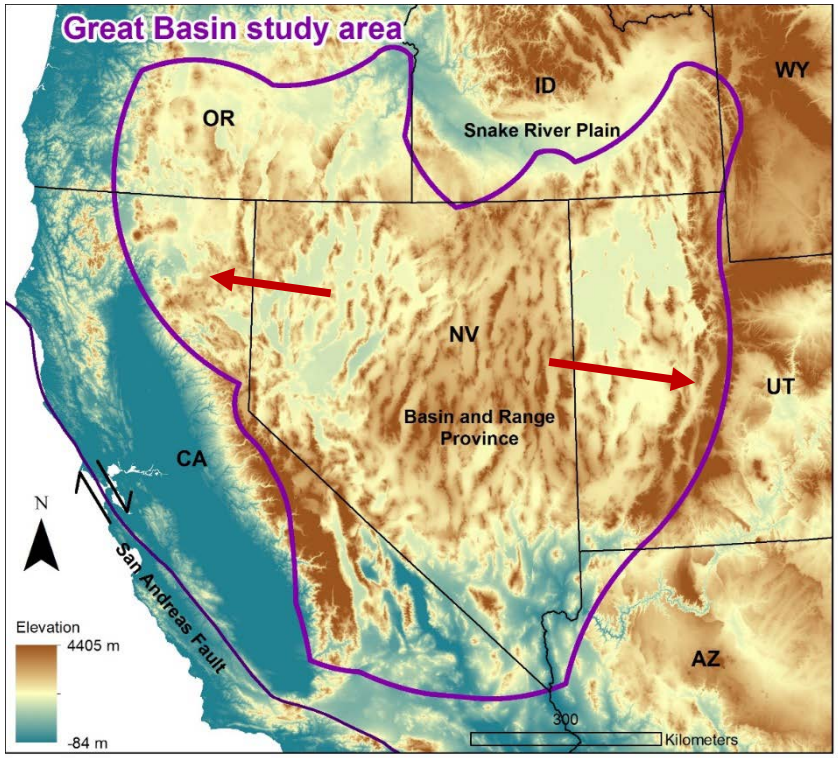




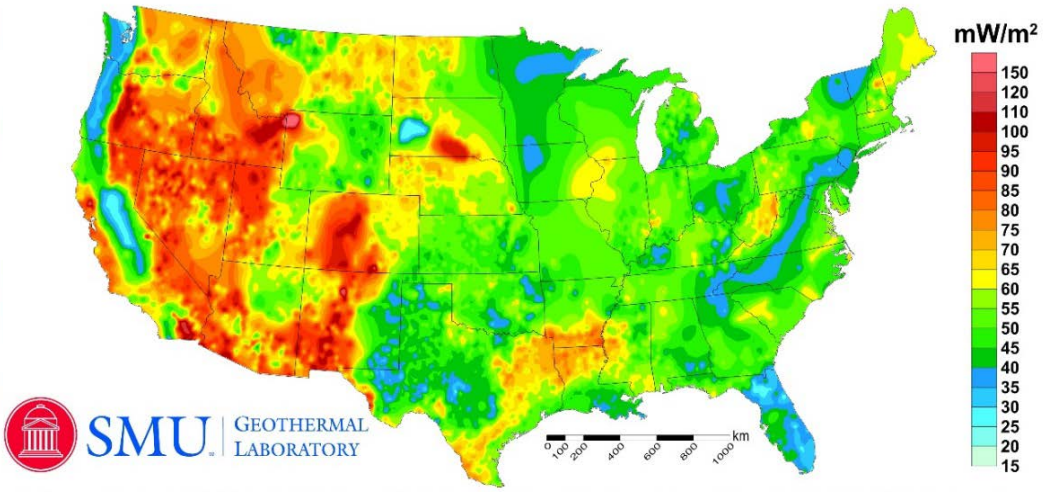
Talk outline

- Geothermal in Nevada and the Great Basin:
  - Current use, Potential and Challenges
- GBCGE – What? Where? When? Who are we? What do we do?
- Achievements of the Center:
  - Research
  - National Geothermal Academy
  - Datasets
- Current projects the Center is involved in:
  - Nevada Play Fairway Project
  - FORGE at Fallon

Geothermal potential in the Great Basin

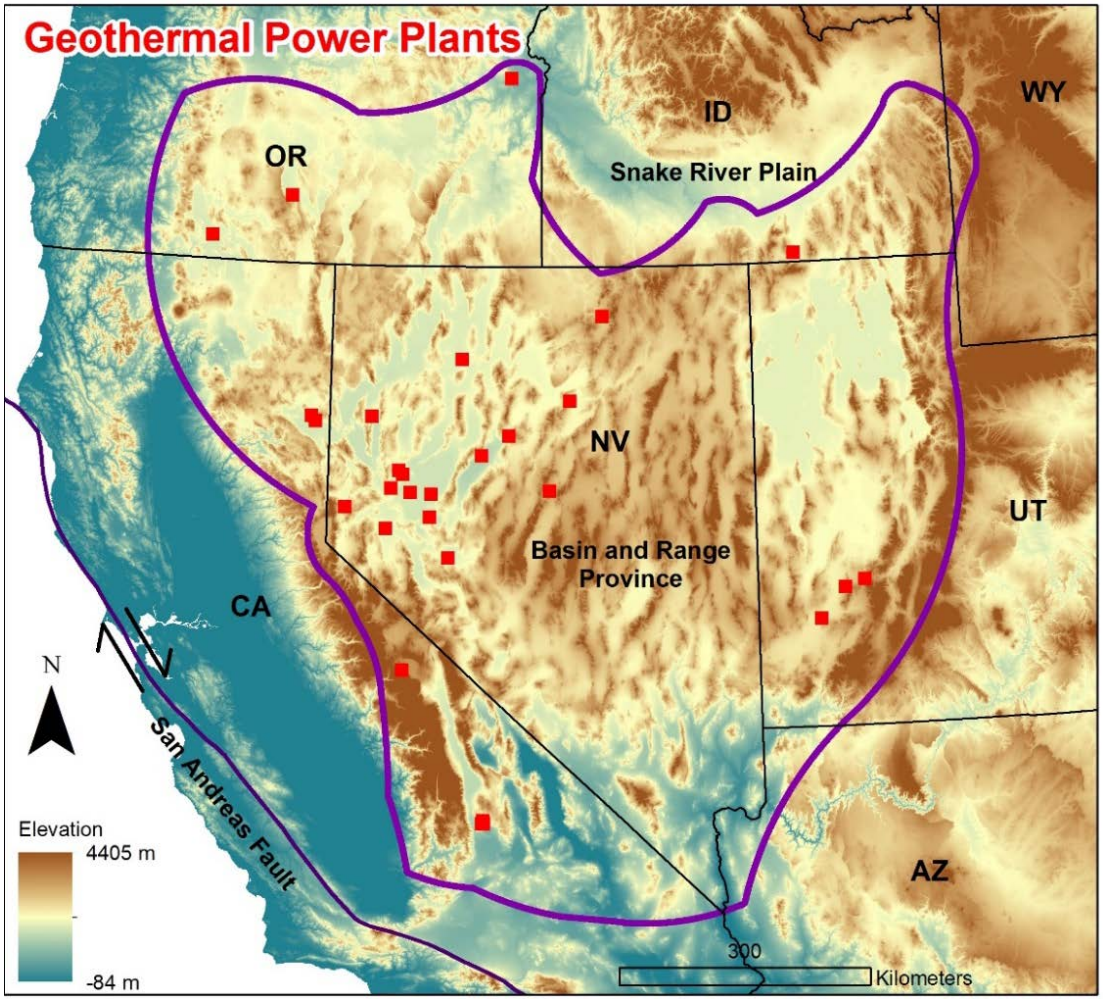


- Transtensional-extensional setting
- Characterized by elevated heat flow
- Significant geothermal potential: USGS estimated 30,000 MWe of undiscovered hydrothermal resources in the Western USA

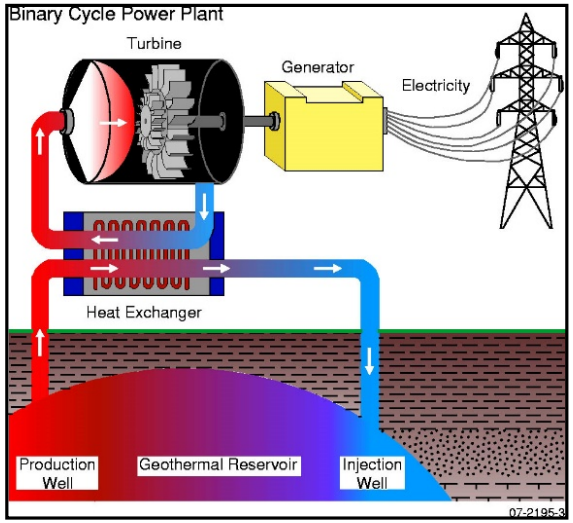


Reference: Blackwell, D.D., Richards, M.C., Frone, Z.S., Batir, J.F., Williams, M.A., Ruzo, A.A., and Dingwall, R.K., 2011, "SMU Geothermal Laboratory Heat Flow Map of the Conterminous United States, 2011". Supported by Google.org. Available at http://www.smu.edu/geothermal.

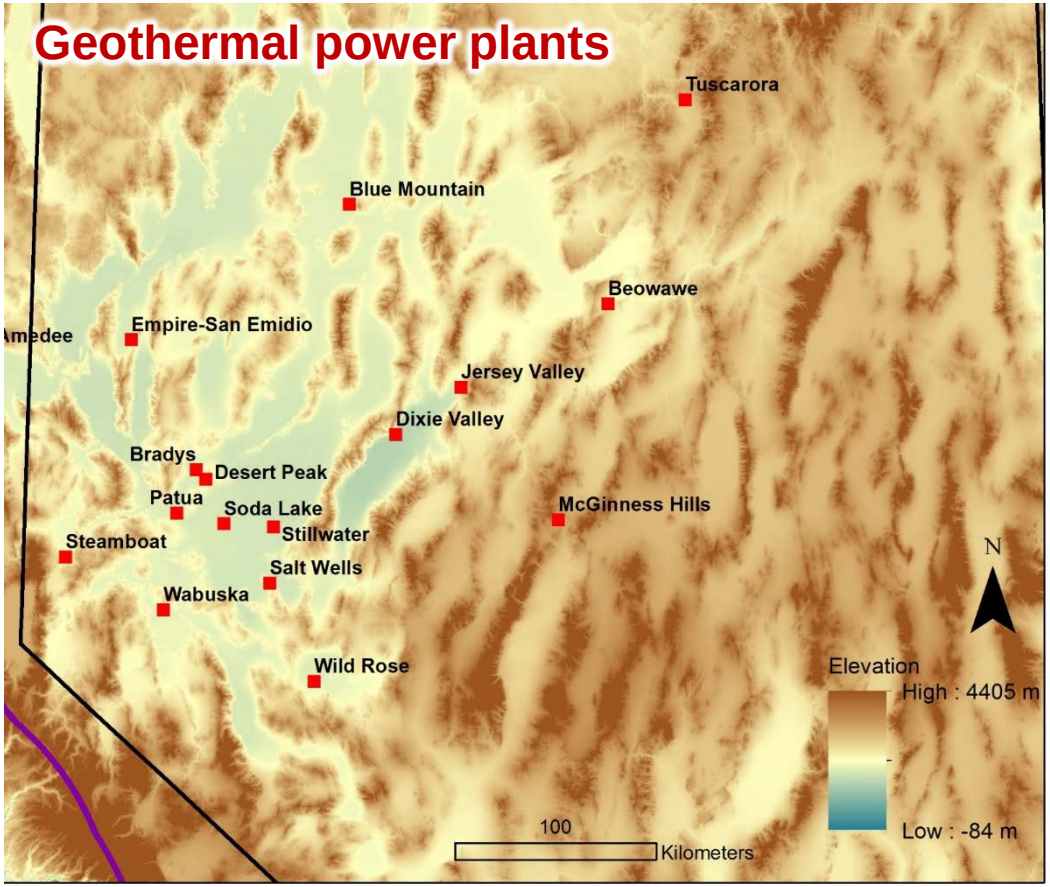
Geothermal electricity in the Great Basin



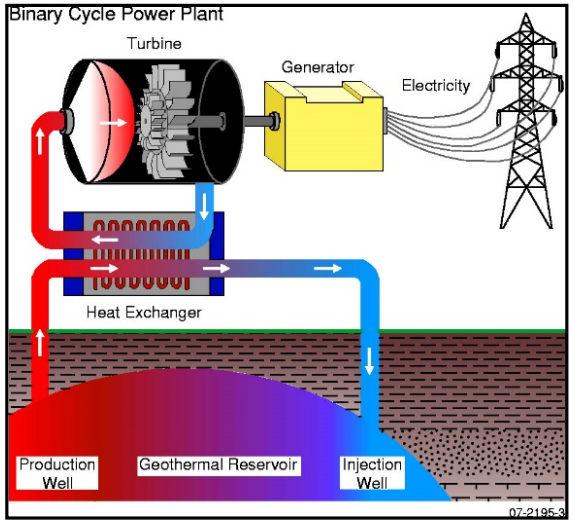
- 26 geothermal systems being utilized
- Total installed capacity:1100 MWe
- Resource temperatures: **140-270°C**
- Hydrothermal systems
- Dominantly binary power plants



Geothermal electricity in Nevada



- 16 geothermal systems being utilized (with 25 power plants)
- Total installed capacity: 674 MWe
- Resource temperatures: **150-270°C**
- Hydrothermal systems
- Dominantly binary power plants

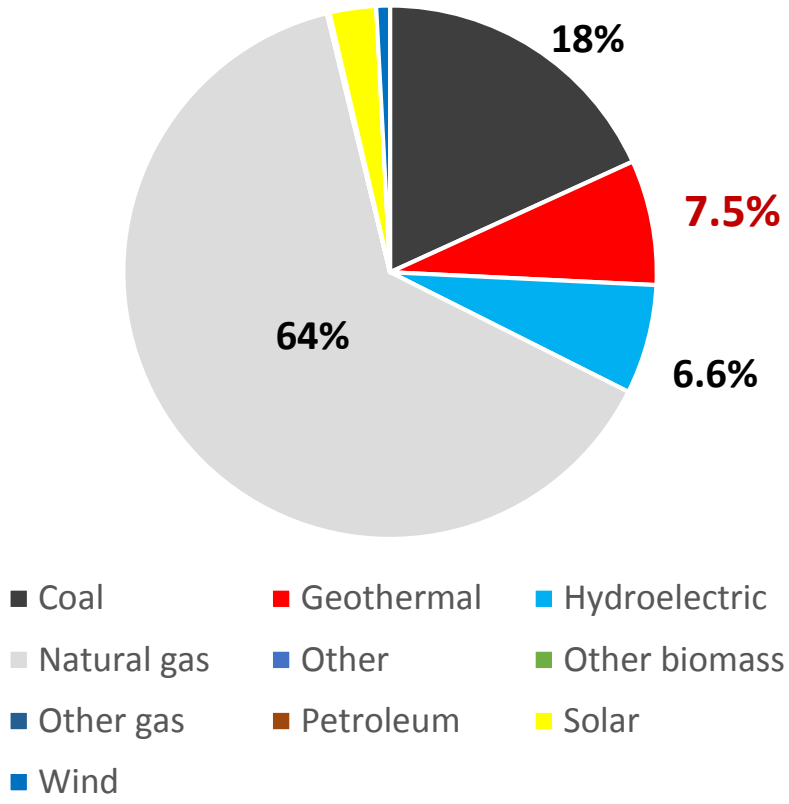


Geothermal energy in Nevada

Geothermal energy = renewable, baseload source of energy:

- an attractive option for meeting renewable energy targets
- Nevada's Energy Portfolio Standard requires that 25% of electricity sales come from renewable energy resources by 2025
- in 2014, 18.6% of Nevada's net electricity generation came from geothermal, solar, wind, and hydroelectric power sources.

Nevada's electricity generation in 2014



Current challenges for the Great Basin

Most existing known high-temperature geothermal resources were discovered via obvious surface indications (thermal features), and/or accidentally when drilling for petroleum or mineral exploration

- How can we find the currently-undiscovered geothermal resources that are likely to be 'blind'?
- How can we find new areas with sufficient temperature and permeability to host an economic geothermal system (hydrothermal)?
- Can we develop Engineered Geothermal Systems (EGS)?

The Great Basin Center for Geothermal Energy

- Currently sits within the Nevada Bureau of Mines and Geology, at the University of Nevada, Reno (within the Mackay School of Earth Sciences and Engineering, and the College of Science)
- Established in 2001
- Mission: to work in partnership with U.S. industry to establish geothermal energy as a sustainable, environmentally sound, economically competitive contributor to energy supply in the western United States
- http://www.gbcge.org/

GBCGE Affiliates

Dr. Bridget Ayling

Dr. Jim Faulds

Dr. Bill Hammond

Dr. John Louie

Dr. Mark Coolbaugh

Andrew Sadowski

Dr. Wendy Calvin

Nick Hinz

Dr. Clay Cooper

Emma McConville

Holly McLachlan

Chris Sladek

GBCGE Activities

- Conducting innovative, applied research:
  - Investigation of the geological factors that control where geothermal resources are located in the Great Basin
  - Development of new approaches for geothermal exploration to increase discovery of 'blind' geothermal systems
  - Sub-surface characterization to optimize the development and management of geothermal reservoirs
- Collaborative projects with industry to address current challenges
- National Geothermal Academy: summer short courses to train the next generation of geothermal scientists and engineers
- Data dissemination, student supervision and outreach activities

Research achievements: 2001 - present

- Geodetic measurements and strain calculations
- Remote sensing of geothermal alteration minerals
- Soil mercury studies
- Detailed structural mapping studies
- Aqueous geochemistry database
- Shallow temperature surveys
- Geothermal potential maps

In preparation: a review document collating the Center's work since it was established (lead author Lisa Shevenell)

Structural analysis

- Structural analysis and categorization of favorable structural settings in Great Basin settings and extensional settings worldwide

→ Enhanced our ability to predict where blind geothermal systems may be located

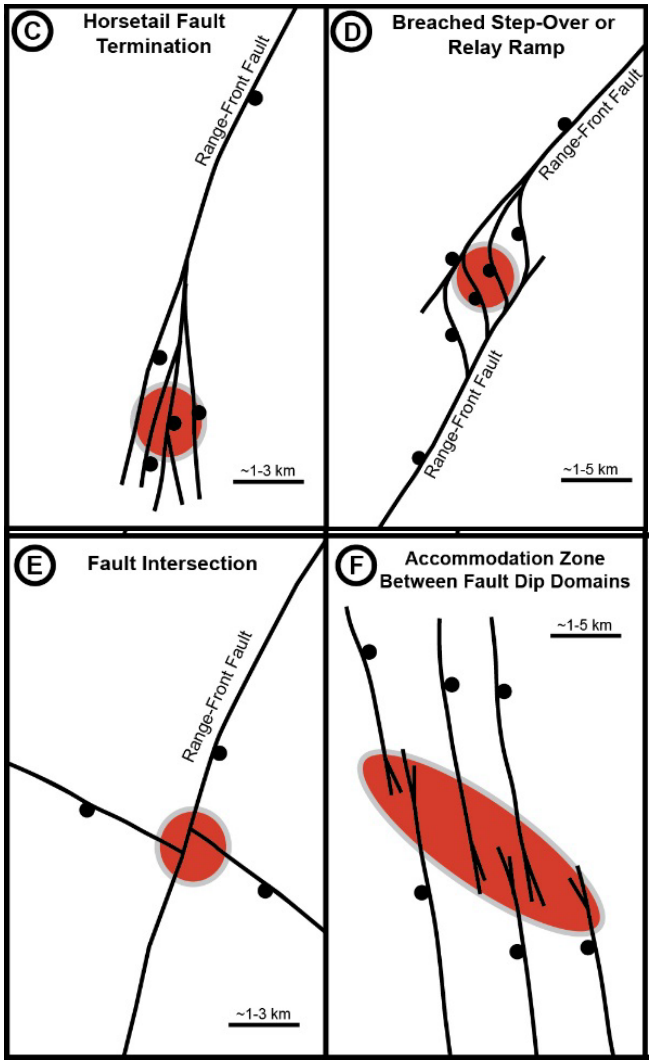
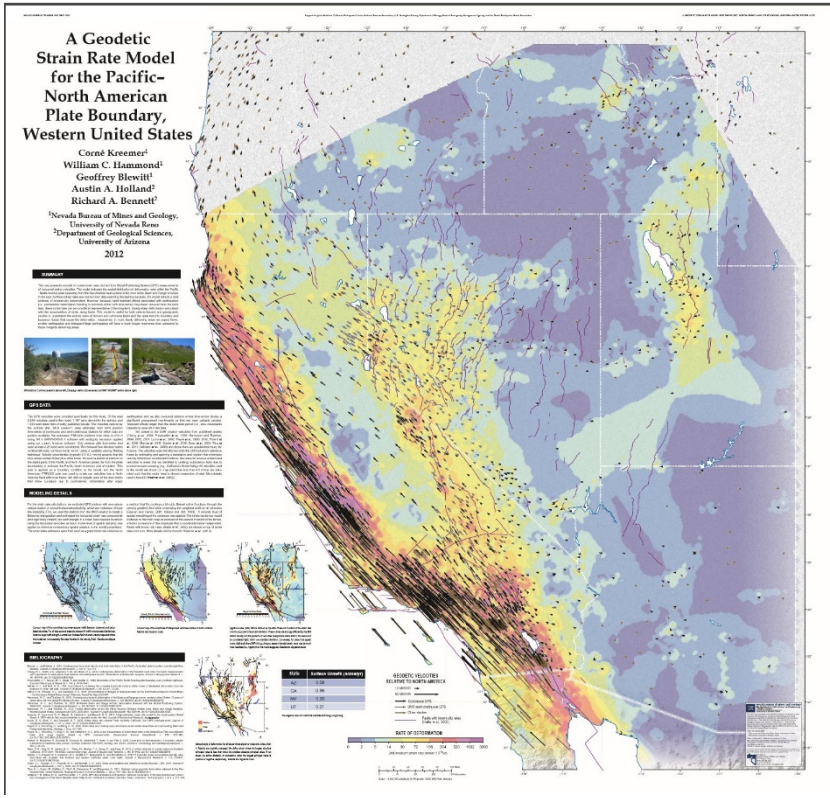


Figure courtesy of J. Faulds

Geodetic crustal strain measurements

- GBCGE initiated one of the first regional applications of geodetic crustal strain to geothermal studies – tool to map geothermal favorability
- Initial GCBGE funding helped to build the MAGNET GPS Network → improved our ability to map crustal extension on a regional scale



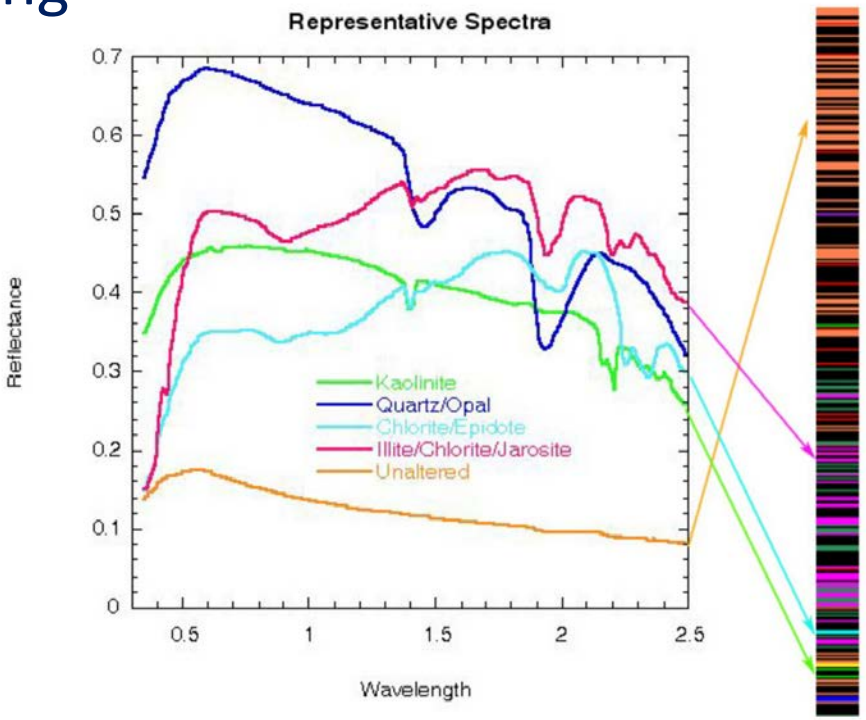
Kreemer et al., 2012

Shallow temperature surveys

Photos courtesy of
A. Sadowski, and B. Tobin

Remote sensing techniques

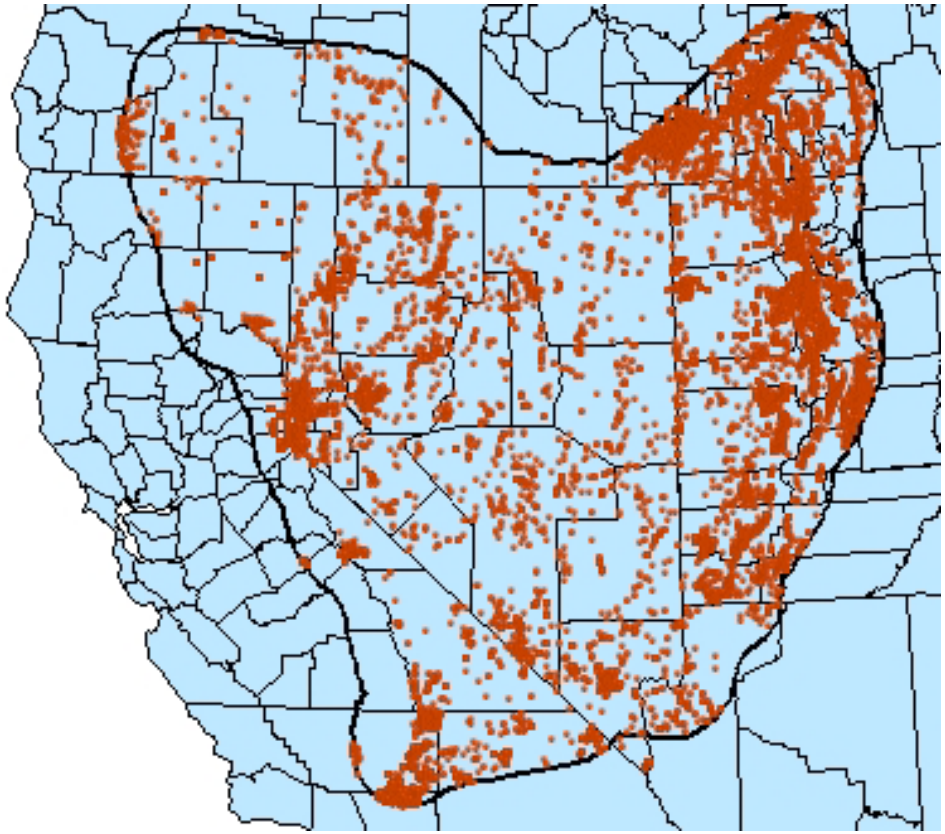
- Hyperspectral image processing techniques used to identify alteration minerals and hydrothermal deposits on a regional and borehole scale
- GBCGE pioneered work using LiDAR and low sun angle photography to identify fault scarps and association with geothermal systems



Calvin et al., 2010

Regional aqueous geochemistry

- Great Basin Groundwater Geochemical Database
- Version 3.0 contains data for 47,500 samples from 16,855 sites in 15 data tables.
- Geochemical signatures demonstrated as a viable exploration tool



Student support and research outputs

- Over 75 undergraduate students supported on GBCGE-funded projects
- 33 MSc and 5 PhD students
- Nearly $18M awarded to 148 projects proposed and completed by GBCGE researchers
- 56 peer-reviewed papers; 242 conference publications; 5 book chapters; 11 geological maps generated from these projects

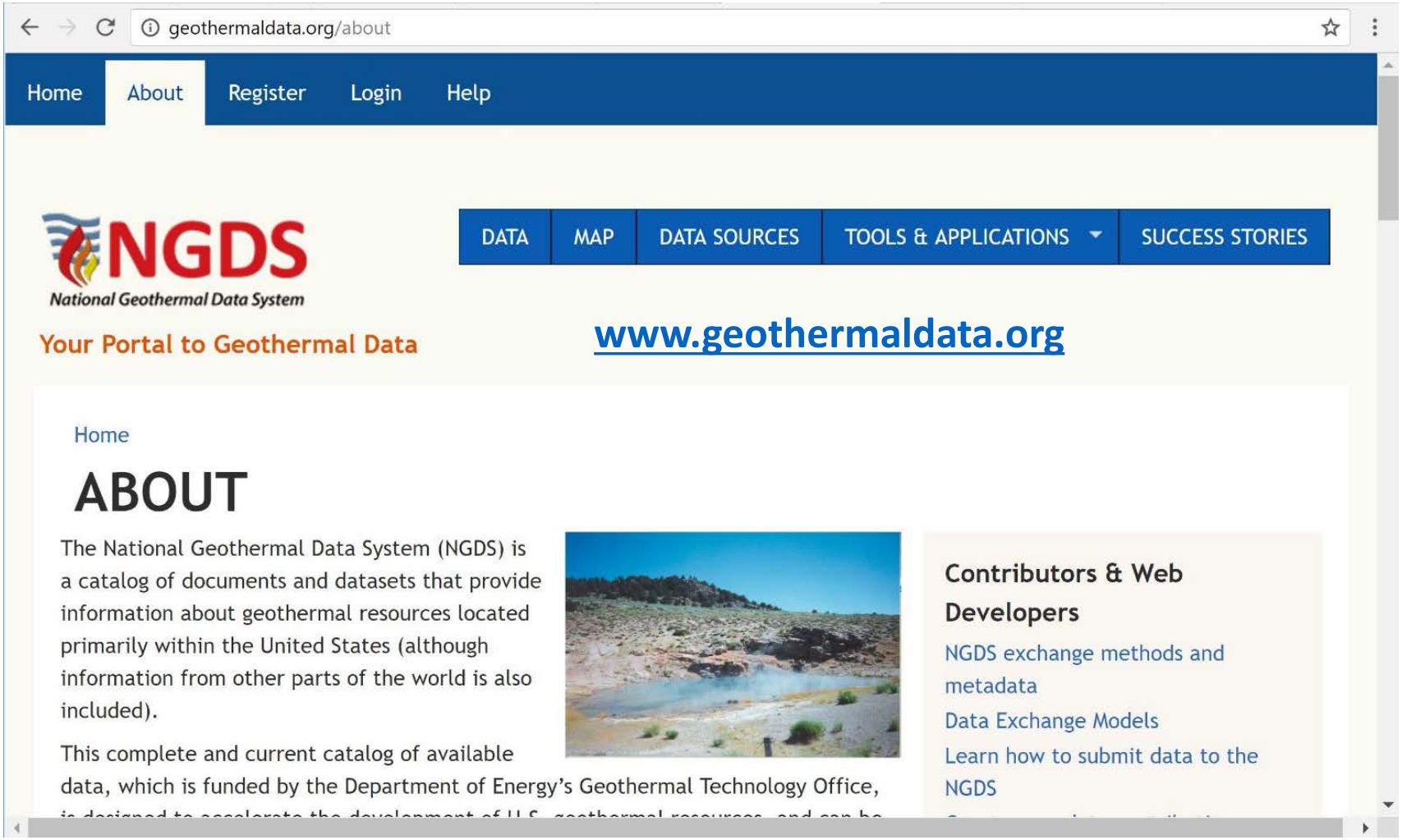
National Geothermal Academy

- The first national geothermal education program
- Initiated in 2010; training offered 2011-2014
- Several modules offered
- 138 students attended from 23 countries
- Instructors from industry, national labs and academia to help train the students in multiple disciplines.
- Funded by DoE grants in the early years. Self-supporting in final year. This model will be explored for the 2017 NGA

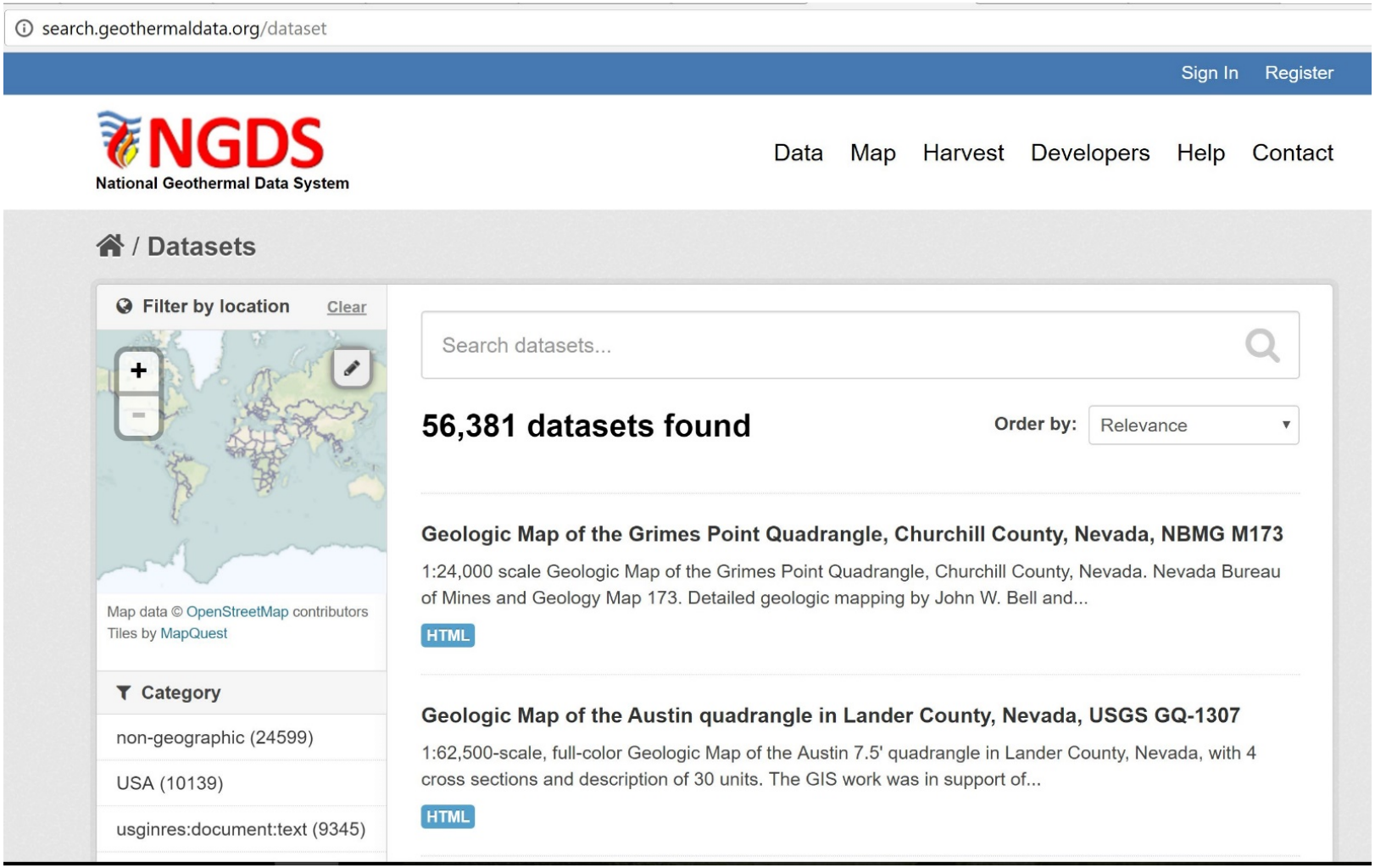
National Geothermal Academy 2017

- Geothermal drilling engineering
  - Bill Rickard (Geothermal Resource Group)
  - 1 week module, 18-23rd June 2017
- Geothermal reservoir engineering:
  - Prof. Roland Horne (Stanford University)
  - 1 week module, 26-30th June 2017

National Geothermal Data System



National Geothermal Data System



National Geothermal Data System

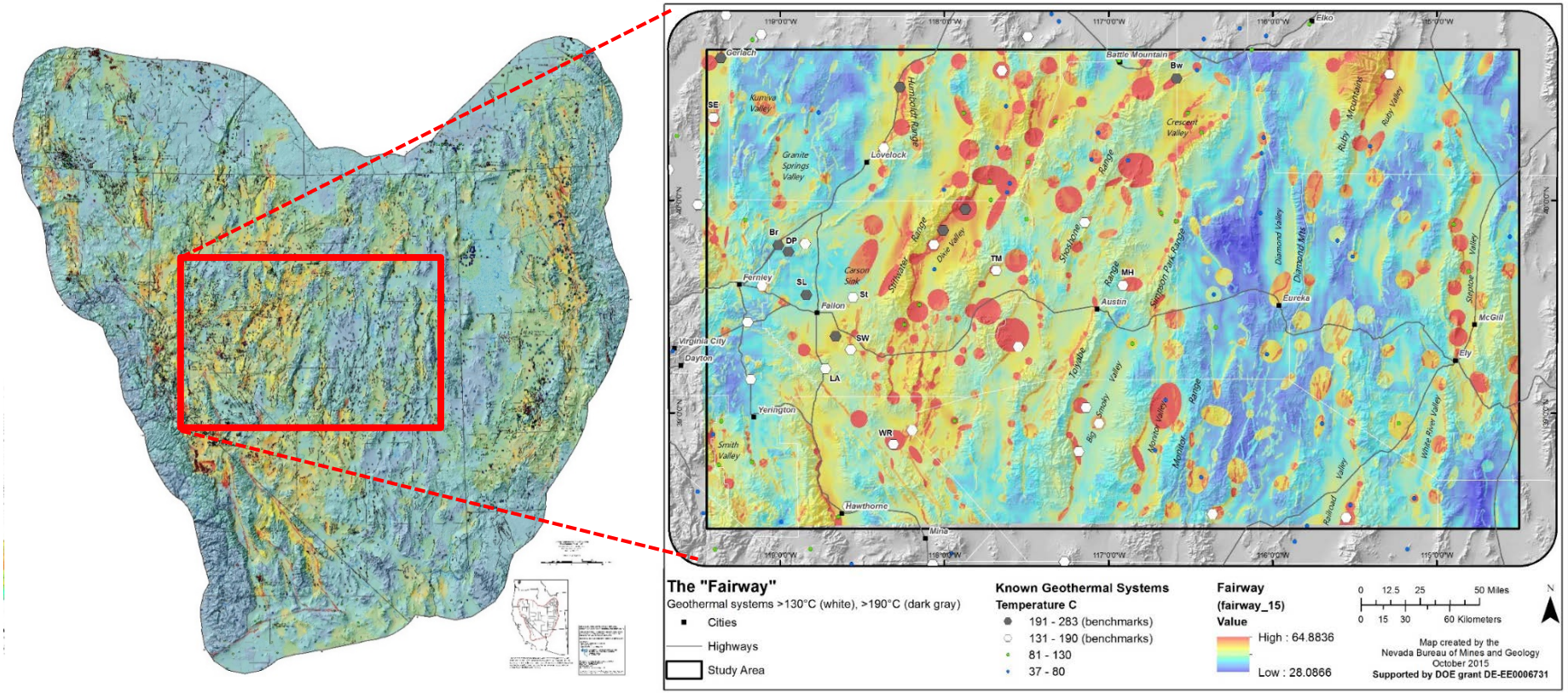
- UNR is the **western regional data hub** for the NGDS. We store, host and deliver Tier 3 geothermal datasets for NV, UT, ID, MT, SD, CO and WY.
- Data is categorized in one of three interoperability tiers; the higher the tier, the greater the level of interoperability. Tiers roughly conform to whether data can be accessed through a web service or must be downloaded or viewed as a file.
- Tier 1: Unstructured data (text, images, or sound)
- Tier 2: Structured data that does not conform to an NGDS schema
- Tier 3: Structured data that conforms to an NGDS schema

Current projects

Geothermal Play Fairway Analysis

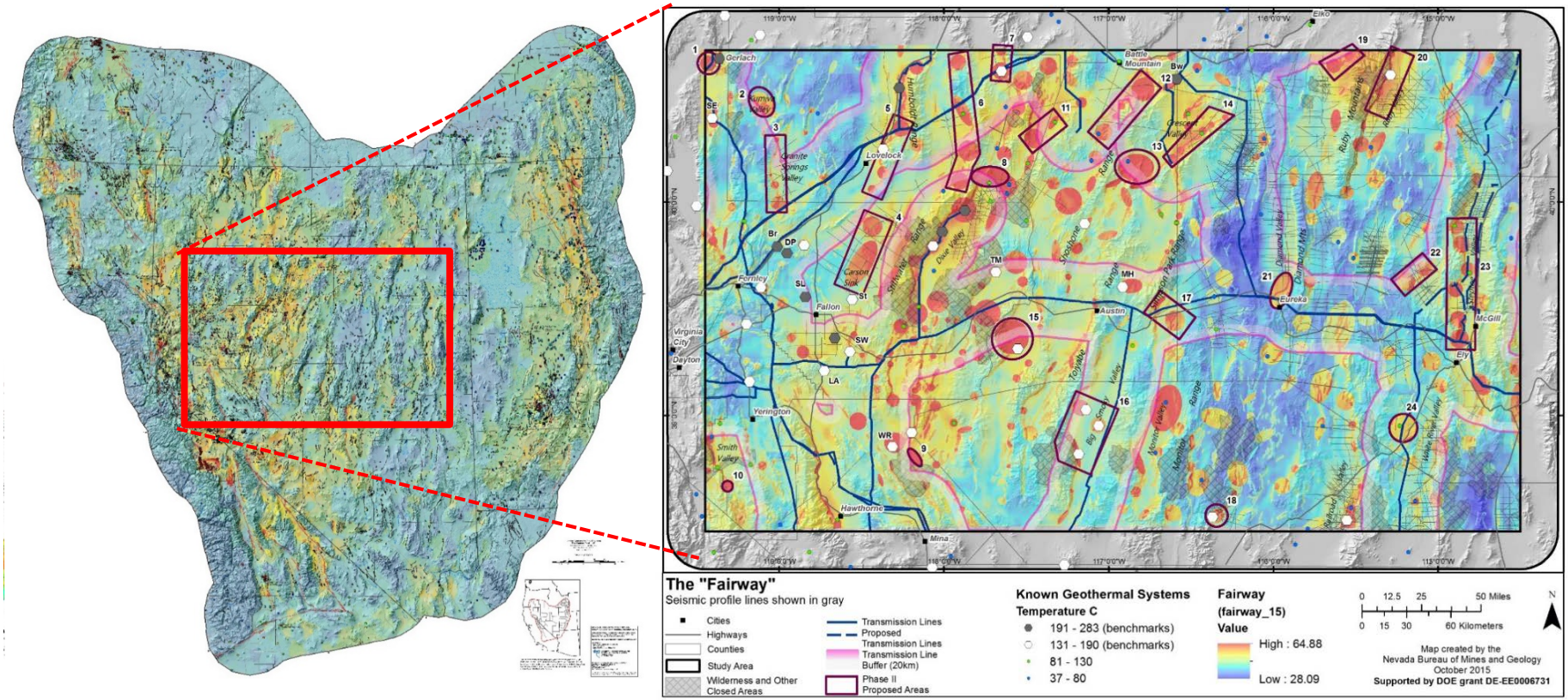
- Funded by the US Department of Energy
- Ultimate goal: improve the success rate for exploration drilling and reduce the development risk and capital cost
- Individual project aim: identify areas with high potential for hosting blind geothermal systems
  - Phase 1: Develop a workflow involving the synthesis of geological, geochemical and geophysical data to identify/predict locations that have the most favorable intersections of heat, fluid and permeability (11 sites)
  - Phase 2: collect new geological, geochemical and geophysical data for identified sites with potential to reduce uncertainty: identify drilling targets (6 sites)
  - Phase 3: drill sites that have greatest demonstrated potential to host a blind geothermal system, thus validating methodology

UNR's Play Fairway Project – Phase 1



Figures courtesy of Jim Faulds

UNR's Play Fairway Project – Phase 2



Figures courtesy of Jim Faulds

Frontier Observatory for Research in Geothermal Energy

- The Energy Department envisions FORGE as a dedicated site where scientists and engineers will be able to develop, test, and accelerate breakthroughs in enhanced geothermal system (EGS) technologies and techniques.
- Ultimate goal: make EGS **commercially viable**

EGS potential in the USA

- USGS estimates we could have >500 GWe if we can unlock the potential of EGS (total power generation capacity in the USA is ~1100 GWe)
- Prior EGS projects funded by Department of Energy:
  - Fenton Hill (NM – 1974-1995)
  - Raft River, ID (1979, 2010-present)
  - Coso, CA (1994, 2001-2005)
  - Desert Peak, NV (2009-?)
  - Newberry Volcano (2010- ?)
  - East Mesa, CA (1980)
  - Baca, NM (1981)
  - Beowawe, NV (1983)
  - Bradys, NV (2010 - ?)
  - Geysers, CA (1981, 2011-2013)
- R&D challenges: how do we safely create and maintain permeability in an engineered reservoir? Can we make it economic?

FORGE timeline

FORGE
U.S. Department of Energy

- **Phase 1:** Sites are evaluated for their suitability to host FORGE (5 sites evaluated: Snake River Plain, ID; Newberry Volcano, OR; Milford, UT; Fallon, NV; Coso, CA) (2015-2016) $2M
- **Phase 2:** Down-select to 2 sites; set up and further site characterization (Fallon, NV and Milford, UT) (2016-2018) $29M
- **Phase 3:** FORGE is operational as an R&D test site (~2018/2019)

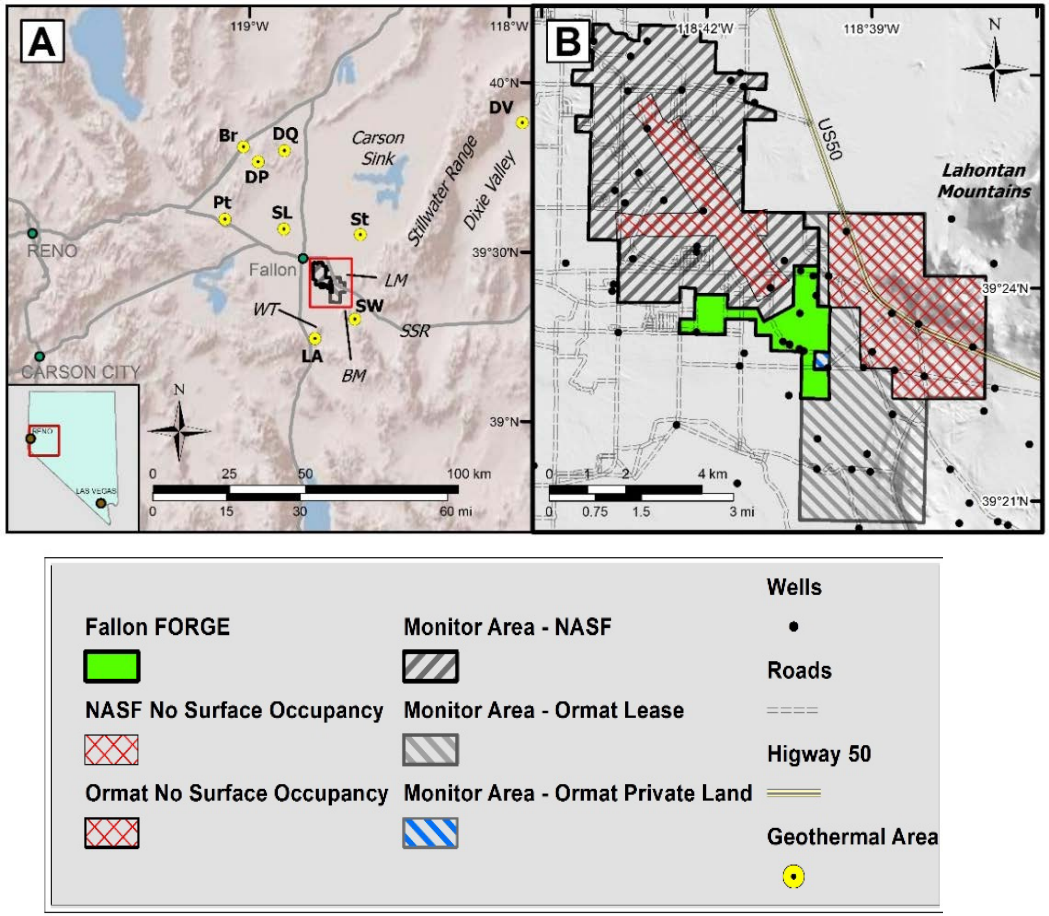
Fallon, NV: FORGE Team

- PI: Sandia National Laboratories
- 10 organizations
  - National labs
  - Academia
  - Industry
  - Geological Surveys
- Diverse team
- Several decades of collective experience in geothermal research

FORGE Phase 1 at Fallon

Demonstration of Fallon meeting the FORGE site criteria:

- Temperature (175 – 225 °C)
- Depth (1.5 – 4 km)
- Low permeability rocks ($< 10^{-16}$ m²)
- Crystalline lithology
- Appropriate stress regime
- No hydrothermal system



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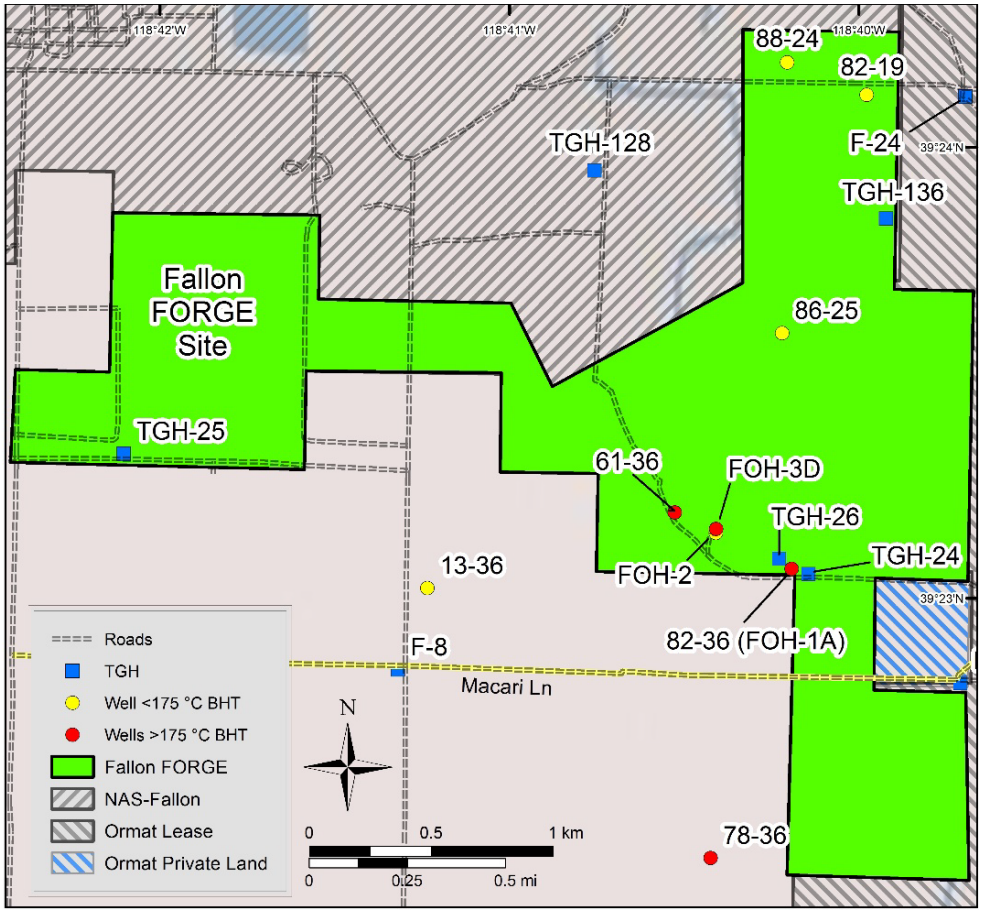
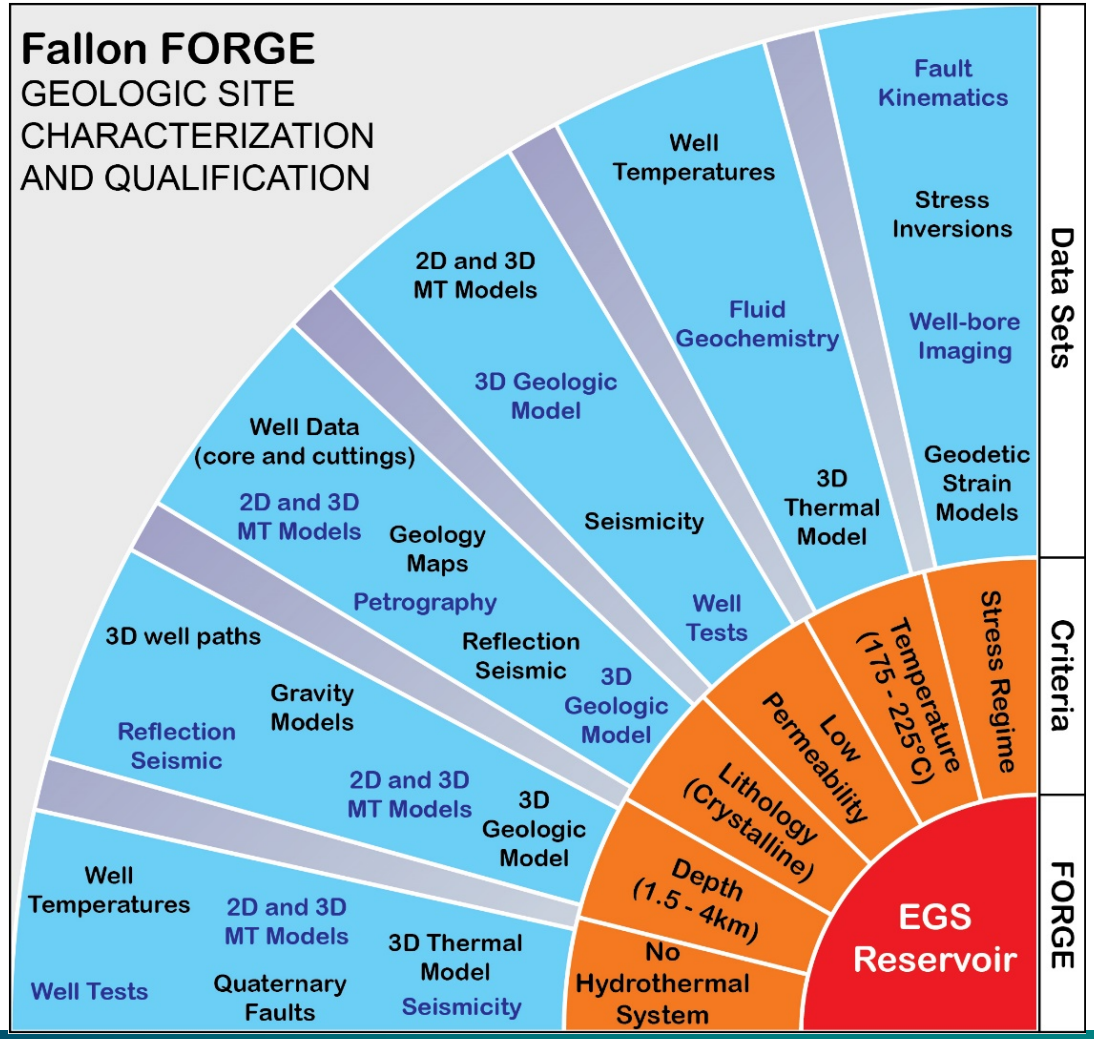


Data assimilation and synthesis

- FORGE Parameters – Data Constraints
  - Stratigraphic – Surface, wells, petrographic
  - Structural – faults, stress regime
  - Thermal Data
  - Fluid Geochemistry Data
  - Alteration Data
  - Well Flow Testing Data
  - Geophysical Data
    - Gravity and magnetic
    - MT
    - Seismicity
    - Seismic reflection



FORGE Phase 2a and 2b at Fallon

- Securing required environmental permitting (NEPA etc.)
- Additional site characterization to address data gaps, related to:
  - Obtaining baseline data sets for evaluating stimulation – including installation of a micro-seismic monitoring array
  - Precisely locating EGS targets –drilling a core hole
  - Establishing mechanical properties of potential targets
  - Selecting future drilling sites with minimal geological risk
  - Minimizing geological uncertainties

  → **Watch this space**


Thank you