# Heat Flow Database Expansion for NGDS Data Development, Collection and Maintenance (SMU)

Project Officer: Arlene Anderson
Total Project Funding: $5,250,000 Award # DE-EE0002852
April 23, 2013

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**David D. Blackwell, SMU Geothermal Laboratory**

**Presenter Names:**
**David D. Blackwell, SMU**
**Rajanikanth Tanikella, Siemens Corporation, Corporate Technology**

This presentation does not contain any proprietary

# Project Team Members

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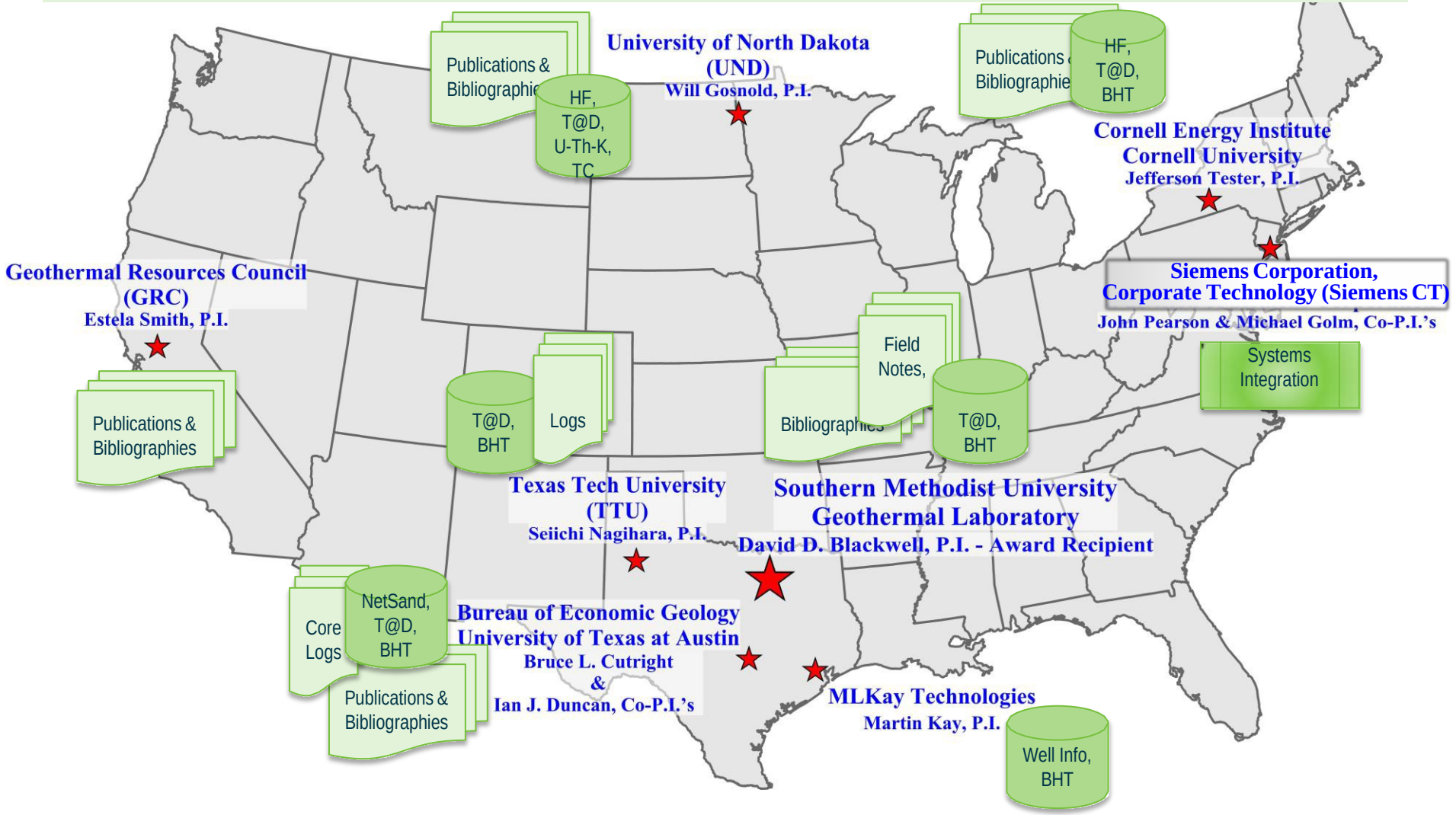
## *SMU – Siemens CT Consortium*
## *Bringing over 250 years of Geothermal Energy Expertise to the Public*



# Relevance/Impact of Research



Purpose of Project: Improve **access** to information and allow for **new interpretation** of data, thereby increasing its **usefulness** for commercial geothermal energy development

**Reasons why previous data sources were inadequate:**

- Multiple formats, layouts, units, paper versions, not searchable across multiple institutions
- Original databases difficult to visualize and/or interpret, especially for the business/industry user (generally no 'map' view)
- No current ability to 'connect' data to additional geological information
- Inconsistent standards for quality assurance or reliability of data

**Industry needs to know *where* their investment will have best opportunity for success. Thus, improving the access to and usefulness of information reduces the risk of failure.**

# Relevance/Impact of Research, Continued



**Innovative aspects of the SMU/Siemens CT project**:

- **Aggregates multiple disparate databases and libraries** from 7 organizations into a single repository
- **Spatial Map view of data points** = both intuitive to use and to interpret
- **Consistent standards** for data structure and metadata developed in collaboration with both industry experts AND non-expert users
- Show **related resources** to data points (Temperature-depth curves, publications, well logs, field notes, etc.) to support project development
- Use of **data analytics** for outlier identification and review. This in turn will improve usability and also highlights new correlations between data and/or identify data gaps for future research. [‘Reliability Code’ work]

# Relevance/Impact of Research, Continued



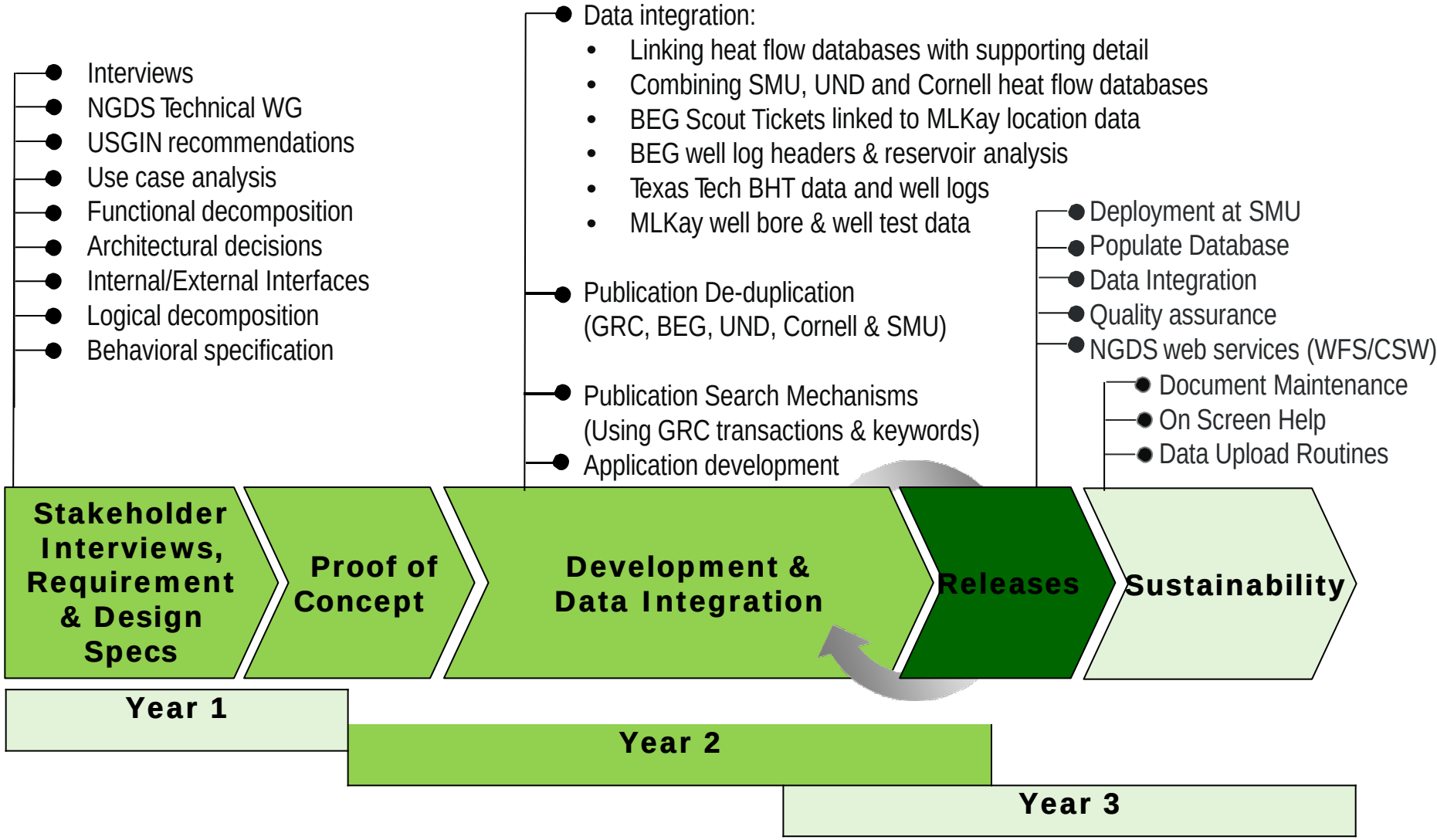
Quoted From Scientific American Article of 2/25/2013 by William Ferguson:

Yet geothermal wells need to be drilled in the right place. Without data on the distribution and quantity of geothermal energy in the upper part of the earth's crust or a volcano as a reference point, wells may not produce much energy at all. To date, two to five out of every 10 geothermal wells prospected end up dry. [Susan] Petty says that, in terms of the available exploration data, the geothermal industry is in the same place oil and gas companies were during the early 1900s. Wells cost between $2 million and $5 million, meaning geothermal investors risk losing millions on poor odds, Petty says. “The risk involved in geothermal prospecting sets the industry apart from other renewables.”

***“The risky nature of the business could soon change, however.”***

# Scientific/Technical Approach





# Scientific/Technical Approach, Continued

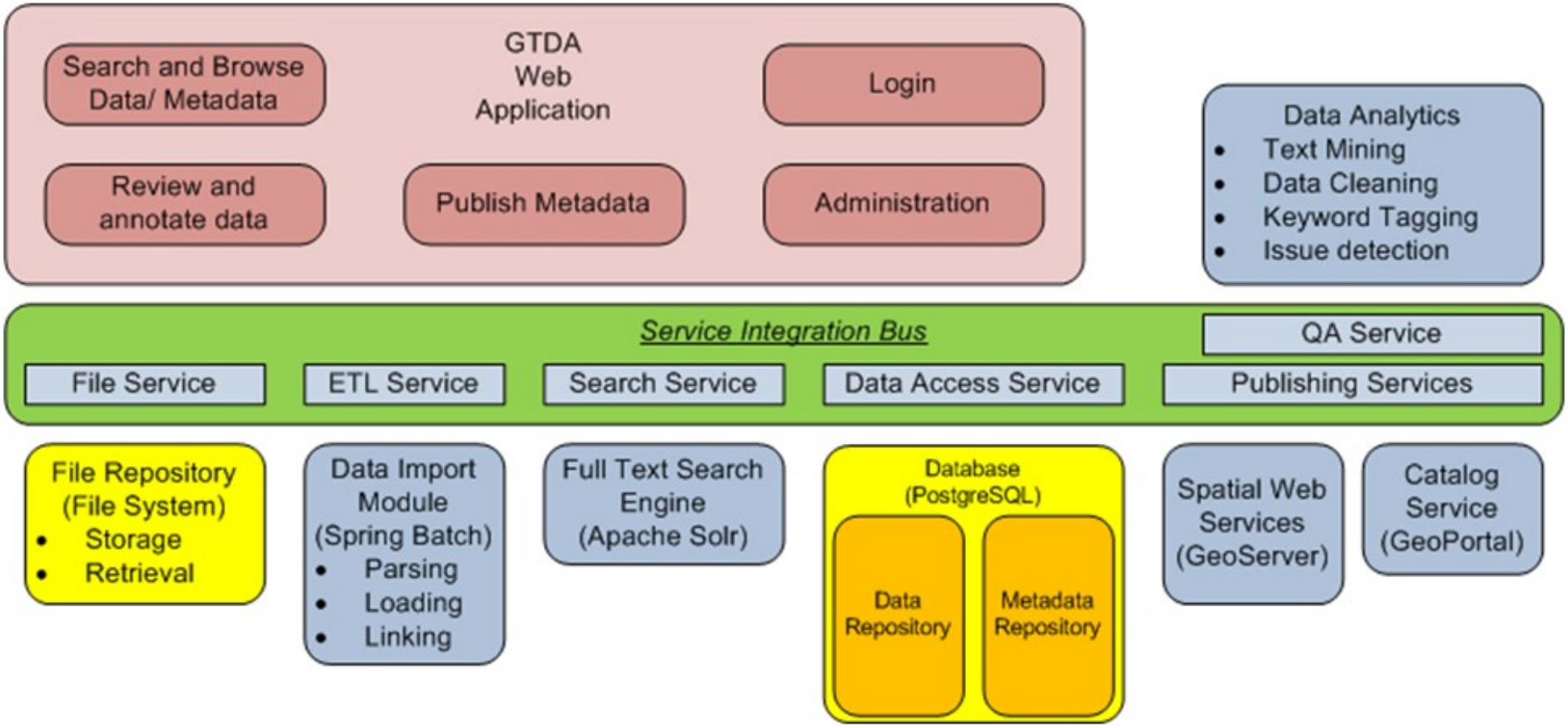


Aggregated Data from 6 institutions will be made available via multiple mechanisms:

1. Via an interactive web based interface (developed for internal use by 6 data contributors, but will be available to public) http://geothermal.smu.edu
2. Via Web Feature Services (WFS) for consumption by applications. 10 key templates to be supported.
3. Via Catalog Services for the Web (CSW) – publications and data discoverable via catalog.

## Geothermal Data Aggregation (GTDA) Architecture

### No major changes to primary components



# Accomplishments, Results & Progress

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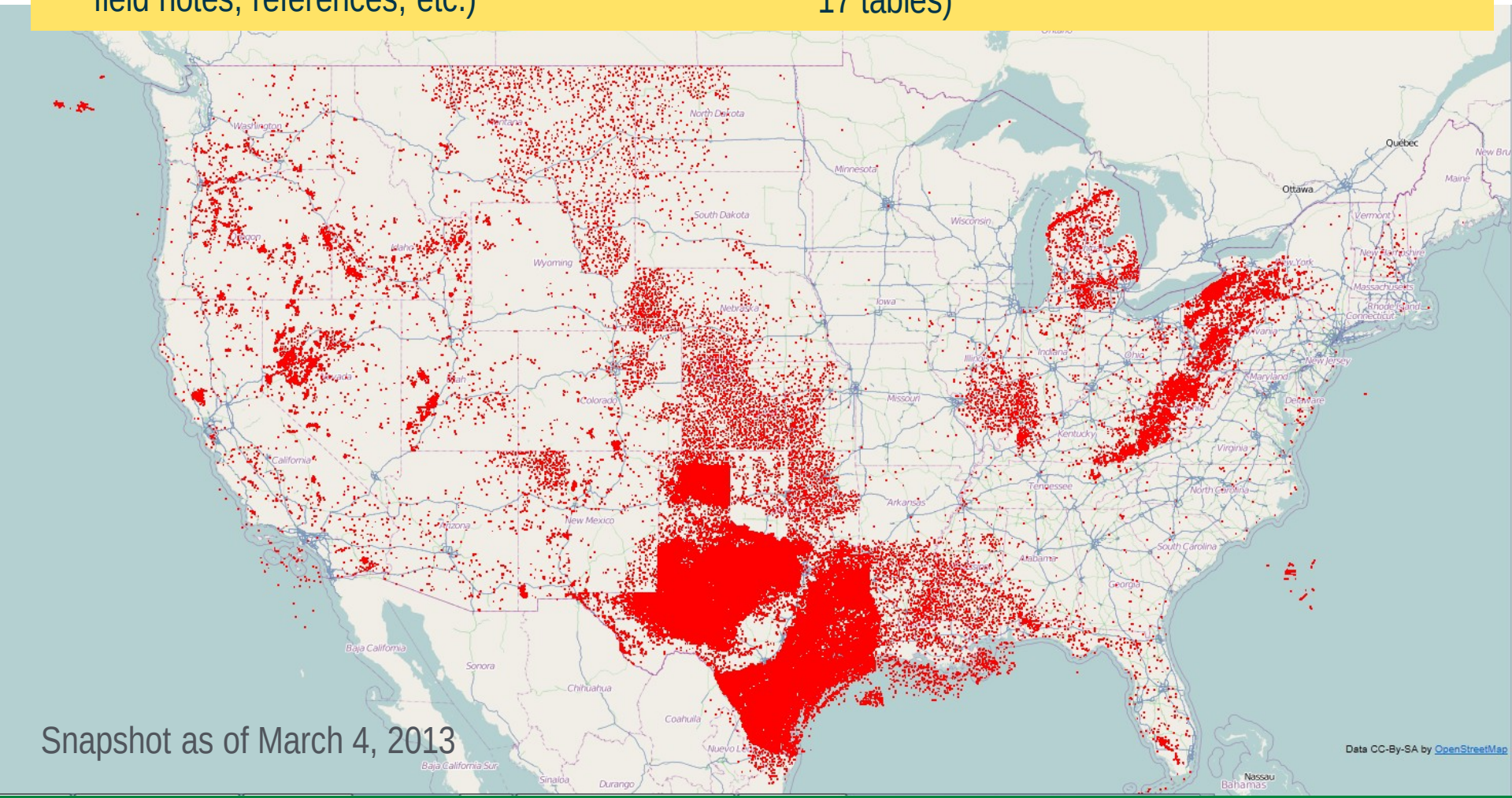
## Data, Data, and More Data….*After* Integration:

- ~56,000 site-related files (T-D curves, well logs, field notes, references, etc.)
- ~375 Gigabytes of data
- 895,830 wells (data in ~250 columns across 17 tables)




Snapshot as of March 4, 2013

# Accomplishments, Results and Progress, Continued (Updated 4/18/13)

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## Data, Data, and More Data….*After* Integration:

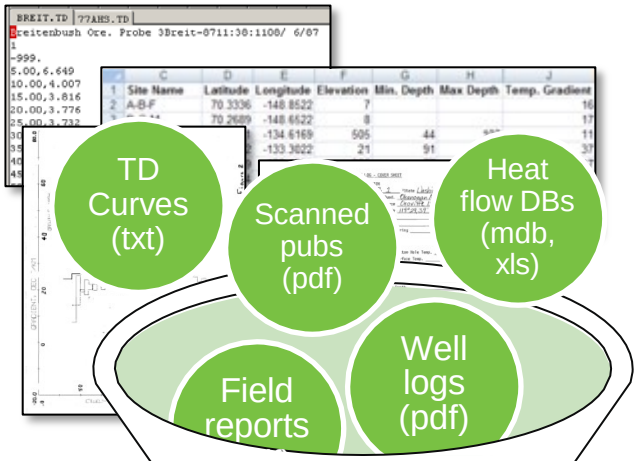
- 113,016 bibliography entries and 24,822 publication PDFs de-duplicated & indexed
- ~515 Gigabytes of data
- ~118,000 site-related files (T-D curves, well logs, field notes, references, etc.)
- 902,395 wells (data in ~250 columns across 22 tables)

| Providers | Data | Count | Size | Columns |
|---|---|---|---|---|
| SMU | Heat flow | 10,620 wells | 9M | 62 |
| SMU | BHT | 35,563 wells | 8M | 42 |
| SMU | Field Notes | 2,046 files | 1.99G | NA |
| SMU | TD Curves | 4,014 files | 14M | NA |
| SMU | AMAX Reports | 29 pdfs | 2.9G | NA |
| BEG | Well Data | 29,743 wells | 10M | 92 |
| BEG | Reservoir Data | 137 reservoirs | 100K | 62 |
| BEG | Well Logs | 4,5381 files | 57G | NA |
| Cornell | Heat flow | 8,920 wells | 4M | 51 |
| Texas Tech | Well Data | 8,200 wells | 5M | ~80 |
| Texas Tech | Well Logs | 46,083 files | 178G | NA |
| MLKay | gse10 | 133,184 wells | 30M | 24 |
| MLKay | Well bore | 1,008,323 wells | 206M | ~200 |
| MLKay | Injection/Disposal | 99,204 | 73M | 67 |
| UND | Thermal Conductivity, Heat Production, TD Data | 8 files, 522 wells | 5M | NA |

| Providers | Data | Count | Size |
|---|---|---|---|
| BEG | Bibliography | 28,259 entries | |
| Cornell | Bibliography | 1,003 entries | |
| GRC | Bibliography | 32,925 entries | |
| SMU | Bibliography | 2,025 entries | |
| UND | Bibliography | 620 entries | |
| Other | Bibliography | 42,576 entries | |
| BEG | Publications | 397 pdfs | 20.8G |
| Cornell | Publications | 611 pdfs | 878M |
| GRC | Publications | 12,050 pdfs | 215G |
| SMU | Publications | 254 pdfs | 5G |
| UND | Publications | 125 pdfs | 0.98G |
| Other | Publications | 11,385 pdfs | 33G |

Green = data in the system
Grey = data in progress
Snapshot as of April 18, 2013

## Functioning Use Cases




- Automated linking of structured and unstructured data
- transformation into integrated data format
- full-text indexing
- data quality analysis

SMU Node ('GTDA')

Browse by Data Type, Location, or Contributor

Filter by Attribute
- Location,
- Temperature,
- Drill Depth, etc.

View Related 'Linked' Data: Heat flow, T-D , Field Notes, pubs, etc.

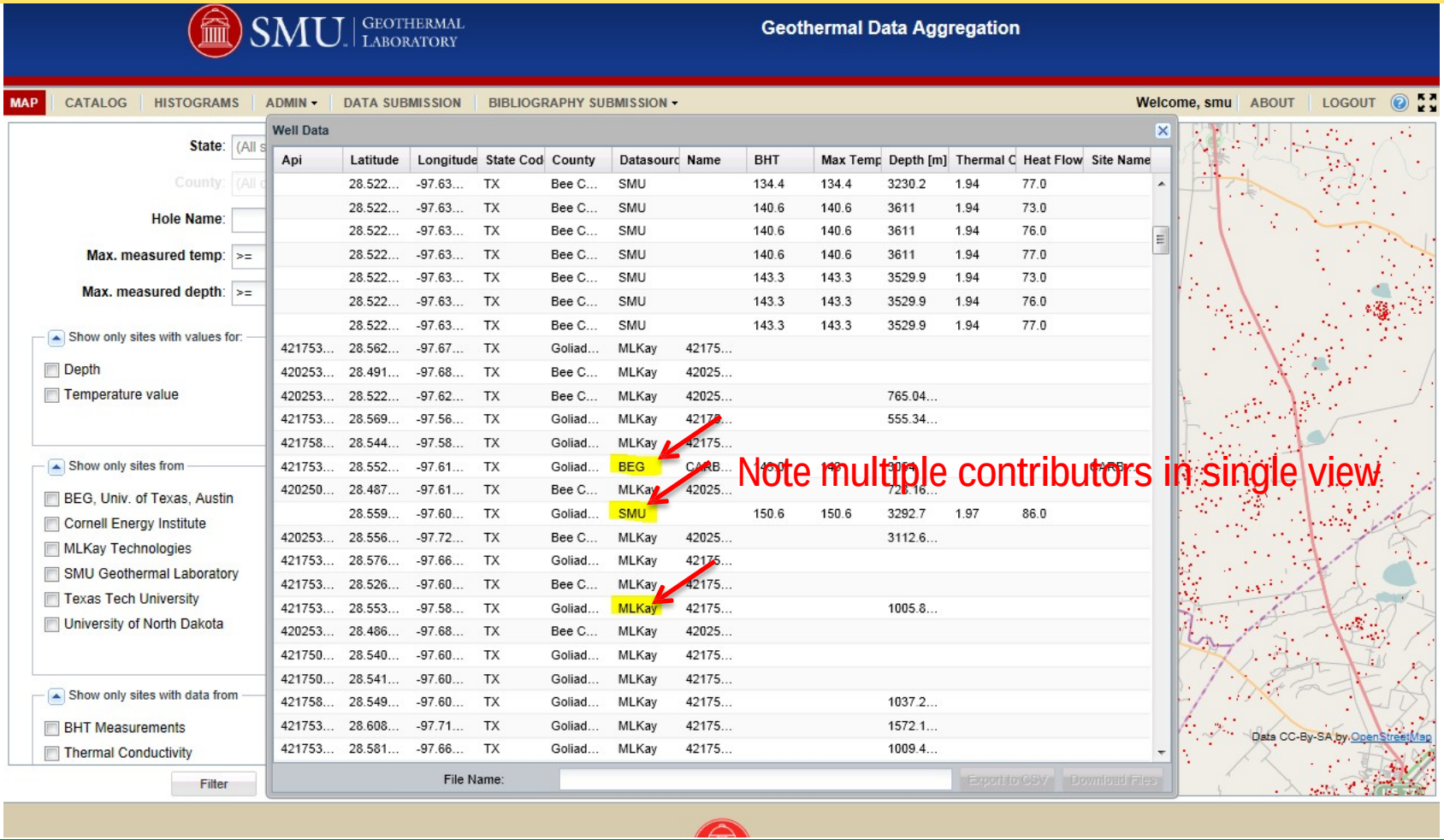
Curating
- Add comments
- Add additional data
- Publish to NGDS

# Accomplishments, Results and Progress, Continued



## Data integrated from multiple contributors in single view:

'Bounding Box' results from very small area near Bee/Goliad Texas County Line.
CSV file download of the results =19,030 rows and 858,722 cells of data from 147 possible columns.



# Accomplishments, Results and Progress, Continued

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surface_site__api
surface_site__site_name
surface_site__source_id
surface_site__site_owner
surface_site__lease_name
surface_site__field
surface_site__county_id
surface_site__latitude
surface_site__longitude
surface_site__plss_meridians
surface_site__township
surface_site__range
surface_site__section
surface_site__section_part
surface_site__other_location_name
surface_site__elevation_gl
surface_site__elevation_df
surface_site__elevation_kb
surface_site__surface_temperature
surface_site__shape
surface_site__dataset_id
surface_site__basement_depth
surface_site__average_heatflow
surface_site__tectonic_province
surface_site__well_type
surface_site__plugged
surface_site__shut_in_date
surface_site__block
surface_site__feet_from_survey
surface_site__section_block_survey
surface_site__hole_open
surface_site__fresh_water_converted
surface_site__district
surface_site__lithology
surface_site__comment

bht_measurements__id
bht_measurements__bht
bht_measurements__bht_corrected
bht_measurements__bht_correction_type_id
bht_measurements__bht_depth
bht_measurements__bht_timestamp
bht_measurements__drill_date
bht_measurements__time_since_circulation
bht_measurements__estimated
bht_measurements__dataset_id
bht_measurements__run_number
casing__id
casing__dataset_id
casing__casing_size_inches
casing__casing_depth
casing__liner_inches
casing__liner_top
casing__liner_base
casing__choke_mm
casing__casing_weight
casing__casing_top
casing__casing_left
casing__file_date
interval__id
interval__dataset_id
interval__top_depth
interval__bottom_depth
interval__interval_length
interval__water_volume
interval__bhp
interval__producing_reservoir
interval__duration_hours
notes__id
notes__notes
notes__dataset_id

thermal_conductivity__conductivity
thermal_conductivity__conductivity_se
thermal_conductivity__conductivity_sample_type_id
thermal_conductivity__conductivity_nb_samples
thermal_conductivity__conductivity_measurement_method
thermal_conductivity__conductivity_sample_shape
thermal_conductivity__sample_width
thermal_conductivity__sample_height
thermal_conductivity__sample_length
thermal_conductivity__density
thermal_conductivity__density_uncertainty
thermal_conductivity__dataset_id
thermal_conductivity__resistance
thermal_conductivity__porosity
well_dates__id
well_dates__dataset_id
well_dates__compl_date
well_dates__drl_compl_date
well_dates__water_injection_nbr
well_dates__elevation
well_dates__elevation_code
well_info__id
well_info__dataset_id
well_info__commodity
well_info__well_id
well_info__permit
well_test__id
well_test__dataset_id
well_test__well_info
well_test__g10_id
well_test__g10_rrcid
well_test__g10_tst_date
well_test__g10_dly_gas
well_test__g10_dly_cond
well_test__g10_dly_wtr

well_test__g10_shut_cd
well_test__g10_flow_press
well_test__g10_bhp
well_test__g10_shut_press
well_test__g10_opr
well_test__g10_wh_pres_test_date
heat_flow__id
heat_flow__publication_source_id
heat_flow__bht_measurements_id
heat_flow__precision_log_id
heat_flow__thermal_conductivity_id
heat_flow__heat_generation_id
heat_flow__interval_order
heat_flow__interval_top_depth
heat_flow__interval_bottom_depth
heat_flow__gradient
heat_flow__gradient_se
heat_flow__gradient_corrected
heat_flow__gradient_corrected_se
heat_flow__gradient_correction_type_id
heat_flow__heat_flow
heat_flow__heat_flow_se
heat_flow__heat_flow_corrected
heat_flow__heat_flow_corrected_se
heat_flow__heat_flow_quality_code_id
heat_flow__heat_flow_quality_method_id
heat_flow__lithology_information_id
heat_flow__notes_id
heat_flow__dataset_id
heat_flow__heat_generation
heat_flow__heat_generation_se
heat_flow__heat_generation_nb_samples
files__file_name
files__file_path_internal
files__file_path_external

# Accomplishments, Results and Progress, Continued

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## Related Data items (TD curves, field notes, pubs, etc.) linked in single view:

SMU GEOTHERMAL LABORATORY — Geothermal Data Aggregation

Details for Site OR-00027

Well Details

**Site Information**

| | |
|---|---|
| Well Name: | OR-00027 |
| Latitude: | 43.1547000 |
| Longitude: | -124.2200000 |
| API: | no data |
| Other Location Name: | BANGERT |
| Owner: | no data |
| Lease: | no data |
| County: | Coos County |
| State: | Oregon |
| Well Type: | no data |
| Surface Temperature: | no data |
| Elevation: | 34 |
| Data Provider: | SMU |

**Drilling Information**

| | |
|---|---|
| Depth Reading #0: | no data |
| True Vertical Depth #0: | no data |
| Depth date #0: | no data |
| Logs Available: | Yes |

**Well Thermal Information**

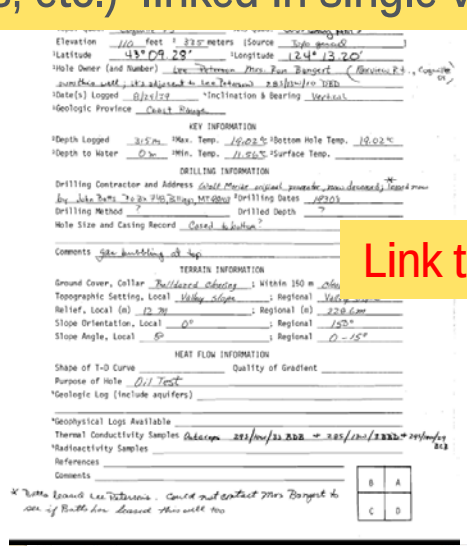
| | |
|---|---|
| Maximum Temperature (°C): | 19.02 |
| Site Heat Flow: | 42.0 |

| Interval # | Top depth | Interval Bottom Depth | Gradient Corrected | Gradient Corrected SE | Thermal Conductivity | Thermal Conductivity SE | Heat Flow | Heat Flow Corrected | Heat Flow SE |
|---|---|---|---|---|---|---|---|---|---|
| a | 150.0 | 315.0 | 30.9 | no data | 1.3 | no data | 42.0 | 40.0 | no data |

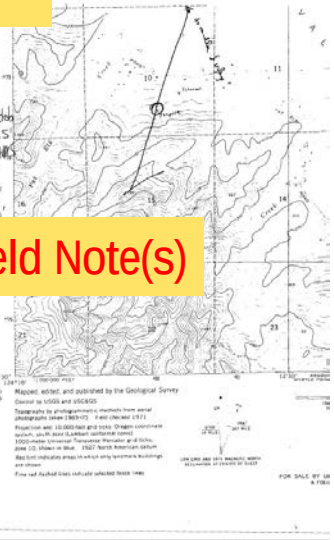
**Related Information**

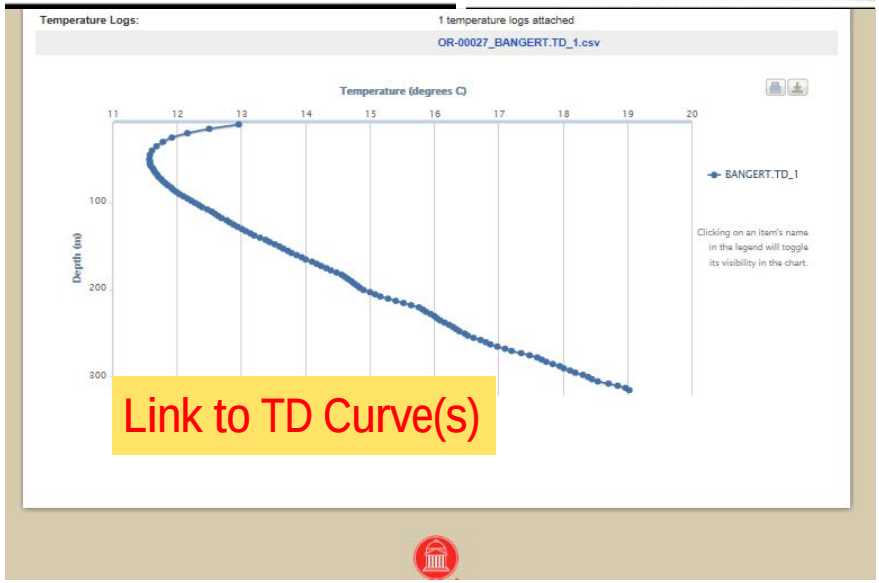
| | |
|---|---|
| Related Resources: | 1 related resources attached |
| | OR-00027_BANGERT.FN.pdf |
| Re | 1 References attached |
| | Heat Flow in the Oregon Cascade Range and its Correlation with Regional Gravity, Magnetic, and Geologic Patterns<br>Blackwell, David D.; Steele, John L.; Frohme, Michael K.; Murphy, Charles F.; Priest, George R.; Black, Gerry L.<br>U.S. Geological Survey 1989 142-170 |
| Field Notes: | 1 notes attached |
| | OR-00027_BANGERT.FN.pdf |

Link to Reference(s)




Link to Field Note(s)

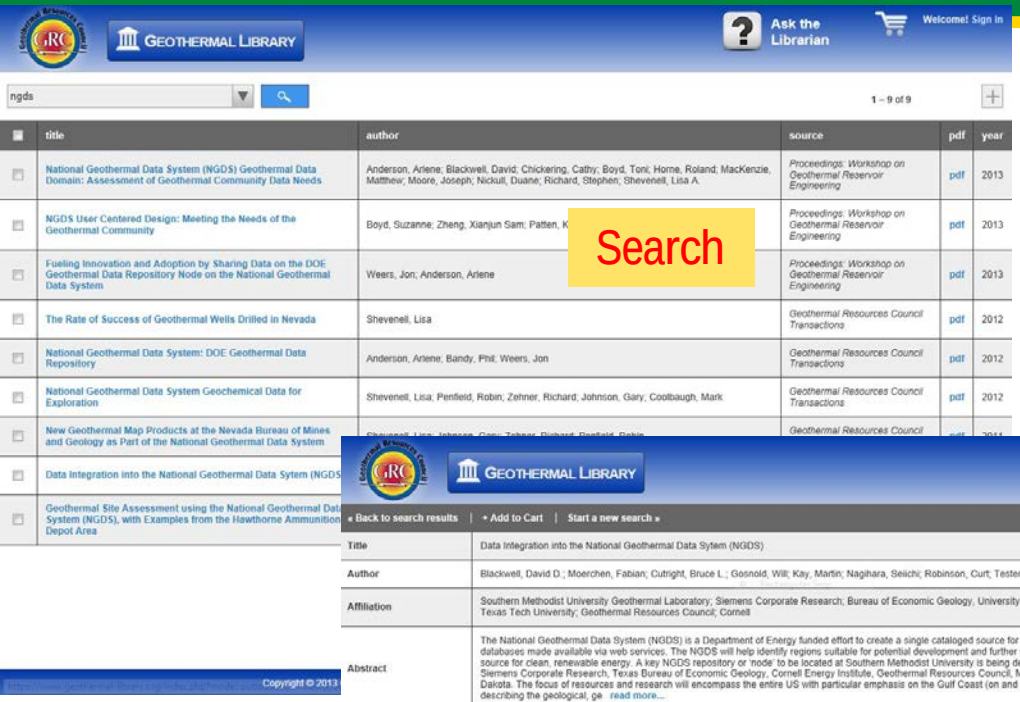



Link to TD Curve(s)

# Accomplishments, Results and Progress, Continued







SMU Node (GRC + BEG + UND + Cornell + SMU)

- Full-text search for publications
- download PDFs (on server or via URLs) or bibliographic
- Reference links from heat flow data
- soon-to-be discoverable via CSW
- Working on improving order of search results


GRC Website –

- Search for pubs
- view abstracts
- download PDFs or bibliographic info
- links to/from Stanford

# Accomplishments, Results and Progress, Continued

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SMU Node improves access to geothermal information, allows new interpretation of data by industry stakeholders, and furthers GTO mission of increased commercialization of geothermal energy.

| | Target/ Milestone | Results |
|---|---|---|
| FY2010 & FY 2011 | 1. Identify Relevant Data for Collection<br>2. Define System Requirements<br>3. Define Software Specifications<br>4. Demonstrate Proof of Concept Prototype | 1. Interviews Conducted and Libraries Inventoried 8/10.<br>2. User Stories Defined 9/10.<br>3. System Design Specs Documented 9/10.<br>4. Proof of Concept Demo 3/11. Ported to SMU Servers 5/11. |
| FY2012 | 1. Create production-ready version of SW.<br>2. Load SMU Heat flow data into system<br>3. Begin integrating related datasets (TD, field notes, etc.)<br>4. Begin loading additional datasets into system (in standard format)<br>5. Collect feedback and update accordingly.<br>6. Analyze data for quality issues | 1. System Loaded on SMU Servers 1/12.<br>2. SMU Data Loaded in 1/12.<br>3. TD curves linked 2/12. Field notes 3/12.<br>4. Texas Tech, Cornell, GRC, MLKay, UND & BEG 3/12 thru 3/13.<br>5. Bi-Weekly Feedback and Development Updates 2/12 – 2/13.<br>6. Results of initial QA reports shared 1/12. Ongoing Process. |
| **FY2013** | 1. Continue loading additional data<br>2. Continue integrating related data<br>3. Test interoperability of WFS<br>4. Define Quality Weighted Scale Rating System<br>5. Implement quality assurance mechanisms<br>6. Begin maintenance sustainability plan<br>7. Publish data to NGDS/Internet<br><br>**On target to complete on time, within budget.** | 1. Phase 1 Data collection & integration 96% complete.<br>2. Phase 1 Data collection & integration 96% complete<br>3. WFS for Heat Flow Initial test late 2012. Second test 2/13. Additional templates (9 more) to follow. Feb – July 2013.<br>4. Data Quality workshop held 1/12. Reliability Code for Heat Flow paper published (GRC) 10/12. MatLab Program distributed for comments 1/13.<br>5. Reliability Code implementation planned prior to public release of heat flow data via WFS (estimated 5/31/13).<br>6. Plans for ongoing systems support within SMU OIT secured 6/12. Sustainability Plan Submitted 7/12. Data Upload Routines within software to be complete 5/31/13.<br>7. WFS & CSW implementation will be complete before 9/30/13. |

# Future Directions

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| Key Activities for rest of FY2013/Project Completion | Status & Expected Completion |
|---|---|
| CSW - Publish Data to catalog for search and discovery (publications already in catalog & data via interactive interface) | 5/1/2013 |
| WFS – Complete SQL Queries, Test, and expose to NGDS | See additional slide |
| Upload Routines for Additional Contributions – Test for heat flow, temp-depth data, related resources, radiogenic heat calculations, thermal conductivity measurements, well logs, and publications) | Complete Testing by 5/31/2013 |
| Debugging – Address identified tasks, including system performance improvement | Complete by 9/30/2013 |
| Documentation - on-screen user help, including administrative capabilities, and written maintenance/update procedures for SMU Office of Information Technology | Complete by 8/30/2013 |
| Quality Assurance – Coordinate Heat Flow Reliability Code work with others and additional outlier analysis | Ongoing Effort – see additional slide |

# Future Directions – Additional Discussion WFS

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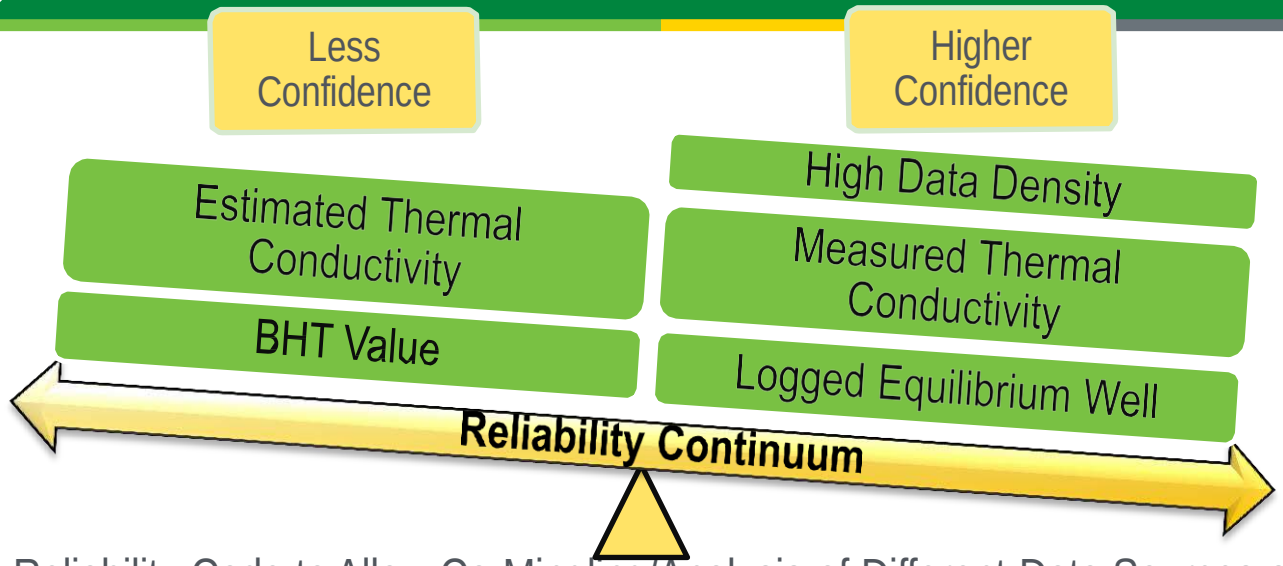
- WFS Efforts Prioritized by Top 10 Content Models to Implement
  1. Heat Flow (in testing, Feb 2013)
  2. Well Header
  3. Borehole Temperature Observation Feature
  4. Well Fluid Production
  5. Fluid Flux Injection and Disposal
  6. Thermal Conductivity
  7. Radiogenic Heat Production
  8. Reservoir Analysis (BEG) (not on http://stategeothermaldata.org/data_delivery), but we have a version from Steve in the AZGS format
  9. Drill Stem Test Observations (to become Well Test Observation)
  10. Well Log Observation

- Data for above resides in database on SMU Servers. Siemens CT writing SQL queries to pull the data and place in prescribed WFS formats. AZGS assisting with testing.
- Additional templates on stategeothermaldata.org may be supported if/when 'node in a box' is deployed.

# Future Directions – Additional Discussion Reliability Code






- Heat Flow Reliability Code to Allow Co-Mingling/Analysis of Different Data Sources and Types
  - 'traditional' heat flow sites, primarily derived from equilibrium temperature logging of wells, versus 'BHT' derived data from oil and gas industry measurements
  - Deeper well measurements versus shallower well measurements
  - Measured thermal conductivity versus estimated thermal conductivity
  - Known core log lithology versus COSUNA sections or basin cross-sections
  - Areas with large data density versus lower data density
- GRC 2012 Paper (Richards, et al.) contains additional detail
- MatLab code circulated to others for input. Will be made available freely.
- Element of published heat flow data records from SMU Node, and other nodes, if interested.

# Mandatory Summary Slide

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Significant data aggregation nearly complete. On track to complete final phases < 9/30/13 and within budget.

85% Complete & 85% Budget Spent

**Total Progress**

96% Complete

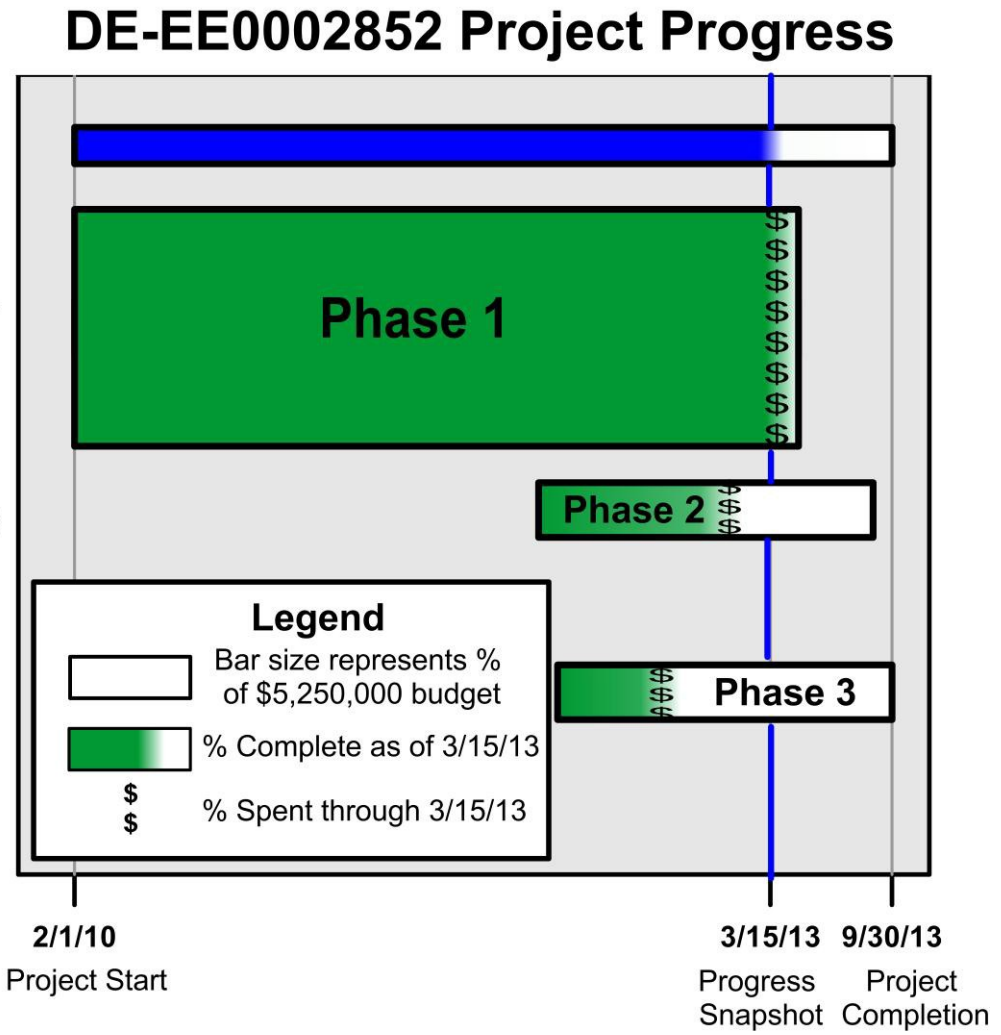
**Phase 1: Data Retrieval, Collection, Development & QA**
80% of Budget

52% Complete

**Phase 2: Transfer & Validation of Information to NGDS**
10% of Budget

30% Complete

**Phase 3: Execution of Data Maintenance Sustainability Plan**
10% of Budget



# Project Management



- No Cost Extension to facilitate interoperability with other NGDS efforts from 2/28/2013 until 9/30/2013
- Side benefit - NCE enabled additional data contributions in Spring 2013
- Project remains on target to complete within budget/time guidelines.
- Overall % work completion and budget spent both at 85%.

Timeline:

| Planned Start Date | Planned End Date | Actual Start Date | Current End Date |
|---|---|---|---|
| 2/1/2010 | 9/30/2013 | 2/1/2010 | 9/30/2013 (15% Remaining) |

Budget:

| Federal Share | Cost Share | Planned Expenses to Date | Actual Expenses to Date (est. thru 3/15/13) | Value of Work Completed to Date | Funding needed to Complete Work |
|---|---|---|---|---|---|
| $5,250,000<br>Phase 1: $4,200 K (80%)<br>Phase 2: $ 525 K (10%)<br>Phase 3: $ 525 K (10%) | n/a | $4,463,564 | $4,463,564 (85%)<br>Phase 1: $4,032 K (96%)<br>Phase 2: $ 273 K (52%)<br>Phase 3: $ 157 K (30%) | Priceless<br>$4,463,564<br>Work % Complete = Budget Spent (85%) | $786,436 (15%)<br>Work % Remaining = Budget Remaining (15%) |

- Significant Coordination with other NGDS project teams and industry - Participation in data standard formats, ontologies, and technology discussions – Feedback by academic and industry users.
- Note award has never included funding for ongoing sustainability. SMU will maintain for 10 years at no additional cost, but does not include sub-awards.