SMU Bottom Hole Temperature (BHT) Heat Flow Data Contribution

Last Modified April 6, 2021

Instructions:

1. Fill out the 2nd sheet in this file as described below (you can paste your data directly in). Be cautious to not introduce any extra empty rows or columns. It may help to select all columns to the right and delete them. Although they appear empty, they might (due to an idiosyncrasy of some spreadsheet programs) be recorded as having valid data in them which will cause the import to fail.

2. Cells will be colored red if they are in error (for example, a non-numerical value where a number is expected, or a malformed date) or yellow if they exceed the specified length limit (where a limit applies). These indicate that the values may cause an error during import. Correct these where possible. A Carriage Return may not register as red, but will exceed the maximum size for a cell and will cause the import to fail.

3. Because the conditional formating that colors the cells in error described in step 2 applies to the whole worksheet, it introduces 'empty' rows when saving the file in comma separated value (.csv) format. Thus, after entering your data and correcting any colored cells, return to this "Instructions" tab and press the button below to remove these 'empty' rows.

4. Save the "Data Entries" sheet in csv format.

5. Submit the csv file at http://geothermal.smu.edu/. Select 'Submit Data Sets'. Use pull-down to specify which of the two BEG datasets you're uploading. Browse to find the saved csv file from step 4. Note you will need to also need to browse to find and include the .txt file with your CSW (Catalog Services for the Web) information. You should verify that the contact information and abstract for the dataset is current. Note that the CSW information is also called 'distributor.txt' from the screen where you are uploading.

Data will not be published until you go to the 'review' tab, and choose to 'publish' the data. This is also within 'Submit Data Sets'.

Note: Portions of the "Data Entries" worksheets in this spreadsheet are protected to prevent inadvertent reordering. To make changes disable the protection on it.

Column	Column Name	Format	Description
A	database	string	SMU Geothermal Lab - Google BHT - Heat Flow. SMU Geothermal Lab - Alaska BHT from Batir et al. 2016. SMU Geothermal Lab - Texas 2020 SMU Geothermal Lab - Snake River Plain 2020 GPFA-AB = Geothermal Play Fairway Analysis of the Appalachian Basin (Jordan et al. 2016), Cornell University (2016) AASG_Thermed_AllTempsThicksConds.xlsx. Two well records modified by Smith (2019) Exploratory Spatial Data Analysis for the Appalachian Basin (Smith-ESDA-2019)
B	api	string	API Number is a unique well identifier containing 10 digits. 2-digit state code+3-digit county code+5-digit well permit number, padded with leading zeroes.
C	permit	string	Permit number is the same as the last 5-digits of the API number.
D	longitude	decimal	Longitude in decimal degrees (-xxx.xxxx), west of Prime Meridian, WGS84 datum. The first 4 decimals are what determines if a well is duplicate of another.
E	latitude	decimal	Latitude in decimal degrees (xxx.xxxx), north of the equator, WGS84 datum. The first 4 decimals are what determines if a well is duplicate of another.
F	surface_interval_id	string	Unique well identifier within database, **-BHT-######-@ where ** is 2 letter state abbreviation, BHT indicates Bottom Hole Temperature value, ###### is a 6-digit number for each state assigned by SMU, @ is a single letter used for multiple inputs for one location, i.e., -c is the third line of inputs for the site. When entering into map search funtion, do not use last letter. Also do not use letter for related resource uploads.
G	depth	decimal	The Depth in the well of the recorded temperature (meters) .
H	uncor_bht	decimal	The Temperature value measured and recorded during well logging, usually extracted from the well log header (C°).
I	harrison_correction	string	The amount of correction to the temperature measurement because of the drilling impact on the well fluids. GPFA-AB sites did not use a Harrison Correction, rather a corrected value based on other related parameters described in Jordan et al. 2016.
J	bhtcorrected_temp	decimal	"Correction" is added to the "Measured BHT" value to determine the corrected value then used for calculating other parameters (°C).
K	surface_temp	decimal	Mean annual near ground surface temperature (°C)(for SMU Geothermal Lab this is NOT air temperature); Gass, 1982, OIT Geo-Heat Center Bulletin.
L	harrison_gradient	decimal	Temperature gradient from the surface to the BHT, {[(Corrected BHT-Surface Temp)/Depth]*1000} (°C/km). GPFA-AB sites did not use a Harrison Correction, rather a corrected value based on other related parameters described in Jordan et al. 2016.
M	reference_data_set	string	The reference for the data used in collecting and calculating the data. No "/" of "\" at the end of the line. ||Author notes on well.
N	state	string	2-letter state abbreviation for the state where the well is located.
O	k_source	string	Reference for the conductivity value or model used for conductivity determination. If the AAPG COSUNA Maps were used then a section code is included.
P	k_section	string	AAPG COSUNA section (name-number) |**NOTE:** include in k_source column information here too.

Q	resistance	decimal	Thermal resistance calculated based on the depth of the BHT data from the lithologic model (m^2*K/W).
R	k	decimal	Thermal Conductivity (W/m*K) calculated using K=Depth/Resistance.
S	q_calculated	decimal	Heat Flow (mW/m^2) for individual BHT values calculated using Q=K*Gradient. For GPFA-AB calculated using the model described in Smith and Horowitz (2015) [in Jordan et al. (2016)], and the Monte Carlo uncertainty analysis described in Smith (2019).
T	quality	string	For BHT Data: BHT-C: Many wells nearby with similar values ±10%; BHT-X: Single data source with no method to confirm accuracy of temperature or unreliable conductivity values. Other defined codes may be added. For GPFA-AB sites the standard deviation of the mean heat flow was computed from the Monte Carlo uncertainty analysis described in Smith (2019).
U	basement_depth	decimal	Depth to the base of the sedimentary section with in a basin; it is used to scale the lithologic model for thermal resistance determination (meters).
V	correction	string	Reference for the type of BHT correction used; SMU primarily used the Harrison Correction with a few wells given no correction. The Forster correction was considered helpful for the wells in the Denver Basin area, but not used to be consistent across the database. See Dingwall and Blackwell 2011 GRC paper for details on Forster corrected data. Whealton et al. (2015) describe the correction applied in the Appalachian Basin.
W	bht_well	decimal	Number of BHT interval data points included within a single well for heat flow calculation.
X	well_ave_hf	decimal	Final determined heat flow value for a single well based on the most accurate value used or if multiple values then an average (mW/m^2).
Y	file_number	string	State file number for well
Z	operation_name	string	Name of the operator or company| Well Name
AA	drilling_start	date	Date drilling began in MM/DD/YYYY format; no leading '0'
AB	drilling_complete	date	Date drilling began in MM/DD/YYYY format; no leading '0'
AC	tsc	decimal	Time Since Circulation, time in hours recorded on some well log headers of when mud circulation stopped and logging began.
AD	state_plane_meter_x_coordinate	string	Location data that is state specific and part of the original well location details.
AE	state_plane_meter_y_coordinate	string	Location data that is state specific and part of the original well location details.
AF	company_name	string	Company owning the well at time of well logging.
AG	well_type	string	Type of well as identified by the original data source (oil, gas, water, dry, etc.). Include the word 'well' eg ., oil well.
AH	well_status	string	Status of well as identified by the original data source (producing, closed, plugged & abandoned, etc.).
AI	field_name	string	Name of the oil and gas field, as identified by the original data source.
AJ	formation	string	Producing formation or deepest formation drilled, as identified by the original data source. Includes Formation Tops data when available.
AK	elevation_measured	string	Elevation measured from Kelly Bushing, Drilling Floor, Ground Level, etc.
AL	elevation_ft	decimal	Surface elevation at wellhead (feet).
AM	elevation_m	decimal	Surface elevation at wellhead (meters).
AN	county_name	string	Name of county where the well is located. Do NOT Include the word 'County'. e.g. Freestone, NOT Freestone County
AO	surface_id	string	Database identifiers for the well surface location.
AP	bottom_id	string	Database identifiers for the well in-ground end location; this is important for multi-drilled legged wells.

SMU Geothermal Lab Notes on Data Calculations for BHT Well Sites

References for dataset

SMU-Batir 2016 Alaska: Batir, Joseph F., D.D. Blackwell, and M.C. Richards, 2016, Heat flow and temperature-depth curves throughout Alaska: finding regions for future geothermal exploration, Journal of Geophysics and Engineering, v. 13, 366-377.

SMU-Brokaw 2017 Denver Basin: Brokaw, C., 2017. Improved Thermal Conductivity and Heat Flow for the Northern Denver Basin (Order No. 10619404). Available from Dissertations & Theses @ Southern Methodist University. (1952052214).

SMU-2018 East Texas: Batir, J., M.C Richards, M. Hornbach, C.C. Pace of Southern Methodist University Geothermal Lab. 2018. Resource Analysis for Deep Direct-Use Feasibility Study in East Texas [data set with links to publication]. https://dx.doi.org/10.15121/1493734.

SMU-2020 Snake River Plain: Batir, Joseph F., M.C. Richards, M. Hornbach, D. Blackwell, and A. Kolker, 2020, Shallow Geothermal Potential of the Snake River Plain Final Report to Bureau of Land Management, paper submitted to GRC 2020 Annual Meeting, and the data uploaded to NREL Geothermal Data Repository.

SMU-2020 TX: Batir, Joseph and Maria Richards, 2020, Analysis of Geothermal Resources in Three Texas Counties, Final Report for University of Texas at Austin DOE-GTO Prime Award: DE-EE0008971 project Texas Geothermal Entrepreneurship Organization (GEO). SMU Geothermal Laboratory, Dallas Texas 75275-0395, 60 p. Data uploaded into the NREL Geothermal Data Repository

SMU-Google BHT Heat Flow: Blackwell, D. D., Joseph Batir, Zachary Frone, Junghyun Park, and Maria Richards, 2010, New geothermal resource map of the northeastern US and technique for mapping temperature at depth, Geothermal Resources Council Transactions, v. 34. Document ID 28663.

SMU-Google BHT Heat Flow: Blackwell, David, M. Richards, Z. Frone, J. Batir, A. Ruzo, R. Dingwall, and M. Williams 2011, Temperature at depth maps for the conterminous US and geothermal resource estimates, Geothermal Resources Council Transactions, v. 35. Available from http://geothermal.org.

Cornell-2016-GPFA-AB: Cornell University. 2016. Appalachian Basin Play Fairway Analysis Thermal Risk Factor and Quality Analyses [data set]. Retrieved from http://gdr.openei.org/submissions/879

Horowitz, F.G., Smith, J.D., Whealton, C.A., 2015. One dimensional conductive geothermal Python code [WWW Document]. URL https://bitbucket.org/geothermalcode/onedimensionalgeothermalheatconductionmodel.git (accessed 8.1.17).

Jordan, T.E., et al., 2016. Final Report: Low Temperature Geothermal Play Fairway Analysis for the Appalachian Basin. Retrieved from http://gdr.openei.org/submissions/899

Smith, J.D., 2019. Exploratory spatial data analysis and uncertainty propagation for geothermal resource assessment and reservoir models. Ph.D. Thesis. Cornell University, Ithaca, NY.

Smith, J.D., Horowitz, F.G., 2017. Thermal Model Methods and Well Database Organization in GPFA-AB, in: Final Report: Low Temperature Geothermal Play Fairway Analysis for the Appalachian Basin. pp. 202–234.

Whealton, C.A., Stedinger, J.R., Horowitz, F.G., 2015. Application of Generalized Least Squares Regression in Bottom-Hole Temperature Corrections, in: Final Report: Low Temperature Geothermal Play Fairway Analysis for the Appalachian Basin. pp. 130–144.

BHT correction values

If "Correction" column = Harrison; the Harrison correction was used; value rounded to nearest tenth
(-16.51213476+0.01826842109*Depth-0.000002344936959*(Depth)^2)

If "Correction" column = None; No correction was used

If depth <600 meter then correction =0

If 600 meter < depth and gradient <0; no correction was used

If depth >3807 meter then correction = 19.1 The deeper wells are expected to have longer times between drilling circulation and BHT measurements therefore the temperatures do not need as much correction. As a result, the correction is assumed to not increase at the same rate as the shallower depths.

SMU-Batir2016 sites Correction: If wells were in Alaska slightly different procedures were done because of the difference in environment: If depth <1000 meters, then correction = 0

No change in correction was made for wells with depth >3807

GPFA-AB sites Correction column = WhealtonEtAl, applies a different correction equation depending on the spatial location in the Appalachian Basin. See Whealton et al. (2015) for details.

Quality Assignment

BHT-A = well site with equilibrium well temperature log

BHT-C = data points representing regional heat flow values

BHT-D = Single data source with no method to confirm accuracy of temperature, or conductivity values. The values are deep enough to be representative of regional gradients and of respective formation type.

BHT-X = data points either too shallow or outside the representative regional heat flow value by at least 10%

BHT-G = data points with heat flow values above 110 mWm-2

Heat Flow Calculations

BHT-X wells <600 meters: no heat flow calculated even for single intervals.

BHT-X wells >600 meters: heat flow calculated not confident about site value.
"Site Well HF" column calculated based on the average for the intervals taking into consideration only BHT-C quality. BHT-X and BHT-G values were NOT included in well averages, expect for GPFA-AB sites.

---If a well had only 1 measurement and it was given a BHT-X or BHT-G "Site Well HF" was left blank

2004 gridded data points heat flow calculated during the Geothermal Map of North America processing of data.

---Unless the depth was <600 meters then the value was assigned a "no value" too shallow for accuracy.

GPFA-AB sites use Smith and Horowitz (2015); Horowitz, Smith and Whealton (2015)

Thermal Conductivity Models

Ruzo Kansas Lithologic Tops based K Model	Stratigraphic column used for each well site was based on data (either measured or extrapolated) from Kansas Geological Survey files for entire state.
SMU Geothermal Lab - D.D. Blackwell	Thermal conductivity based on primary rock type at depth.
Blackwell Gulf Coast K Model	Thermal conductivity trends in "curved" manner from off-shore to on-shore with values increasing from low off-shore to highest on shore.
COSUNA section - #	Thermal conductivity determined from one or two AAPG Cosuna cross-sections. At times a well was located between overlapping cross-sections.
Blackwell Montana K Model	Thermal conductivity model related to depth to basement for eastern Montana and sediment age.
Gallardo 1989 Thesis well #	Gallardo, J.D., Empirical Model of Temperature Structure, Anadarko, Basin, Oklahoma, MS Thesis, SMU, Dallas, TX, 1989.
Batir Alaska Cook Inlet Model	Average thermal conductivity calculated using generalized stratigraphic column based on bottom lithology penetrated if known, or depth and location of well compared to Cook Inlet 2D cross section
Batir Alaska Basin Lithology Model	Thermal conductivity based on the bulk basin lithology where a well was located, all wells in a given basin will have equal thermal conductivity. Basin lithology model section given in k section
Batir Texas 2020	Crockett County primarily Anadarko Basin values; East Texas and Webb and Jackson Counties based on Pitman and Rowan 2012 LA values with some changes for consistency with the lithology in county. See Batir and Richards 2020 report UT Austin project and SMU-2018 report for NREL Deep Direct-use.

A Bullard Plot of depth versus resistance (1/thermal conductivity) for an area was used to review the values for each site. Values plotting as outliers (>10%) from the plotted group cluster were considered not useable and given an X value before assigning heat flow values.

Surface Temperatures

The surface temperatures were from the map in the paper by: Gass, T.E., Geothermal heat pumps, Geothermal Resources Council Bulletin, 11, 3-8, 1982. These are stated as being near surface ground water temperatures.

Surface Temperature sources for Alaska include:

Peterson, S. 2013, Preliminary geothermal gradient mapping in Alaska's cook inlet forearc basin, Geothermal Resources Council Transactions, v. 37, 315-320.

Center for Weather and Climate, 2011. *Climatological Data Annual Summary: Alaska* (Asheville, NC: National Centers for Environmental Information - Center for Weather and Climate, NOAA) p 87.

*Note that data from Peterson were associated with individual wells and therefore used directly. Center for Weather and Climate data were contoured and determined to be too low resolution and instead were used to estimate the potential for error associated with a 0° C surface temperature assumption.