INTERPRETIVE GEOTHERMAL GRADIENT MAP OF COLORADO

COLORADO GEOLOGICAL SURVEY

Description of the Colorado Geothermal Gradient Database

GRADIENT DATABASE COMPILATION AND CALCULATION

Well and drillhole data were assembled from various data sources and gradient values were calculated for each datapoint in accordance with the methodology described in the Interpretive Geothermal Gradient Map of Colorado report text and depending on the data source type.

Bottom-hole temperature data
Gradients calculated from bottom-hole temperatures include those records with the data source designation "BHT - Dixon" and "BHT - CGS/MJS". "BHT - Dixon" data were calculated using data compiled from two sources 1) "Dixon, J., 2002, Evaluation of bottom-hole temperatures in the Denver and San Juan basins of Colorado: Colorado Geological Survey Open-File Report 02-15, 41 p." and 2) "Dixon, J., 2004, Evaluation of bottom-hole temperatures in the Canon City Embayment, Hugoton Embayment, North Park, Paradox, Piceance, Raton, and Sand Wash basins of Colorado: Colorado Geological Survey Open-File Report 04-1, 44 p."

"BHT - CGS/MJS" data were calculated by the Colorado Geological Survey from bottom-hole temperature data extracted out of M.J. Systems' Log Sleuth software.

Drill-stem test data
Gradients calculated from drill-stem test data include those with the data source designation "DST - IHS". "DST - IHS" data were calculated using data assembled from IHS Energy's PI Dwights software.

Temperature-log data
Gradients calculated from temperature log data include those points with the data souce designation "CGS - MS45/Log" and "CGS - other/Log". "CGS - MS45/Log" data were calculated by the CGS from temperature logs acquired by the CGS for the Interpretive Geothermal Heat Flow Map of Colorado publication.

"CGS - other/Log" data were calculated by CGS using additional temperature log data.

Other data sources
Gradient datapoints with the designation "CGS - MS45/other HF databases" were assembled by others from various heat flow data references and have unknown calculation methods.

"CGS - MS45/other HF databases" is data included in the CGS publication Interpretive Heat Flow Map of Colorado and were assembled from two heat flow database sources: 1) "Blackwell, D., and Richards, M., 1989, Regional heat flow database (Colorado), SMU Geothermal Lab - Geothermal Data Files, data file: Color89.csv, <http://www.smu.edu/geothermal/georesou/colorado.htm> Accessed May 3, 2006." and 2)

"International Heat Flow Commission, Global Heat Flow Database, International Association of Seismology and Physics of the Earth's Interior, site Provided by the University of North Dakota, data file: USA.xls, <http://www.heatflow.und.edu> Accessed May 3, 2006."

Background well data
Background well information was extracted from the Colorado Oil and Gas Conservation Commission (COGCC) oil and gas well database (http://cogcc.state.co.us/) downloaded on June 30, 2008 using API number to include with the calculated gradient values. Some API numbers were not present in the COGCC database and therefore these points only contain some of the background information.

DATABASE FIELD DESCRIPTIONS

Well_Name - Well or borehole name; composite of Facility name and number attributes

Operator_Name - Well or borehole operator name

Facility_Name - Facility (well) name

Facility_Number - Facility (well) number

API_Number - American Petroleum Institute (API) unique well identifier

Gradient_C_km - Calculated vertical geothermal gradient value in degrees Celsius per kilometer. Gradient values were calculated in accordance with the methodology discussed in the Interpretive Geothermal Gradient Map of Colorado report text depending on the data source type. The gradient data source type is indicated in the "Gradient Data Source" attribute field. Bottom-hole temperature and drill-stem test data employed a gradient calculation method by linearly interpolating between the Gradient Reference Depth of the bottom-hole or drill-stem test temperature measurement and the calculated ground surface temperature. Gradient values for temperature log gradient values were generated by a best-fit method to a temperature-logged borehole section. If temperature log data is present for multiple borehole sections then the average gradient of these sections is used.

Gradient_Reference_Depth_m - Reference depth below the surface over which the gradient value was calculated. For gradients calculated from bottom-hole temperature data, this depth represents the total borehole or well depth; for gradients calculated from drill-stem test data this represents the mid-point depth of the deepest drill-stem test; for gradients calculated from temperature log data this depth represents the deepest log interval available.

Total_Depth_m - Total borehole or well depth, if available.

Gradient_Data_Source - Type of data source from which gradient was calculated. Gradients calculated from bottom-hole temperatures include those records with the designation "BHT - Dixon" and "BHT - CGS/MJS"; gradients calculated from drill-stem test

data include those with the designation "DST - IHS"; gradients calculated from temperature log data include those points with the designations "CGS - MS45/Log" and "CGS - Other/Log". Gradient datapoints with the designation "CGS - MS45/other HF databases" have various calculation methods because they were assembled from several heat flow databases by other researchers.

"BHT - Dixon" data was calculated using data from the Regional Heat Flow Database for Colorado by Blackwell and Richards (1989). "BHT - CGS/MJS" data was calculated by the CGS from data extracted out of M.J. Systems' Log Sleuth software. "DST - IHS" data was calculated using data assembled from IHS Energy's PI Dwights software. "CGS - MS45/Log" data was calculated by the CGS from temperature logs acquired by the CGS for the Interpretive Geothermal Heat Flow Map of Colorado publication. "CGS - MS45/other HF databases" is data included in the CGS publication Interpretive Geothermal Heat Flow Map of Colorado and was assembled from two heat flow databases which compiled data from various references: 1) Blackwell and Richards (1989) Regional Heat Flow Database for Colorado and 2) International Heat Flow Commission, Global Heat Flow Database. Heat flow data are generally acquired from temperature logs. The original heat flow data for these points can be found in the CGS publication Interpretive Geothermal Heat Flow Map of Colorado. "CGS - Other/Log" data was calculated by CGS using temperature log data.

Bottom_Hole_Temp_C - Bottom-hole temperature measurement in degrees Celcius.

Drillstem_Test_Temp_C - Drill-stem test temperature measurement in degrees Celcius from IHS Energy - PI/Dwights.

Completed_Formation - Completed geologic formation

Surface_Elevation_m - Calculated surface elevation in meters from 30-meter resolution digital elevation model (DEM) based on locational coordinates provided for datapoint.

Mean_Air_Temp_C - Mean annual air temperature in degrees Celcius (+/- 1.1 deg C) extracted from PRISM climate model GIS data. Air surface temperatures at each well were derived from the PRISM model data from Oregon State University (Daly, C., and Gibson, W., 2006, United States average monthly or annual minimum, maximum, and mean temperature, 1971-2000, <http://www.climatesource.com/us/fact_sheets/meta_tmin_us_71b.html#7> Accessed September 3, 2008.). This model was used to generate contours of mean annual air surface temperature for Colorado at intervals of 2ºF. The air surface temperature at each well site was then determined from these contours using GIS techniques and the geographical coordinates of each well. Three degrees Celsius was added to each calculated air temperature to give the ground surface temperature at each site to compensate for the difference between air and ground temperatures associated with radiative ground heating and other effects.

Ground_Surf_Temp_C - Calculated ground surface temperature in degrees Celcius used in the calculation of gradient values for bottom-hole temperature and drill-stem test data. The

ground surface temperature was calculated from the mean annual air temperature by adding 3 degrees Celcius to each calculated air temperature to compensate for the difference between air and ground temperatures associated with radiative ground heating and other effects.

Latitude - Latitude in decimal degrees (North American Datum 1983)

Longitude - Longitude in decimal degrees (North American Datum 1983)

UTM83_X - Easting coordinate in meters (Universal Transverse Mercator, North American Datum 1983, Zone 13N)

UTM83_Y - Northing coordinate in meters (Universal Transverse Mercator, North American Datum 1983, Zone 13N)

Basin_Tectonic_Province - Oil and gas basin or tectonic province where point is located

Field_Location - Oil and gas field or other description of point location

County - County name where point is located

Township - PLSS township number and direction where point is located

Range - PLSS range number and direction where point is located

Section_Number - PLSS section number where point is located

Qtr_Qtr - PLSS section quarter-quarter where point is located

Meridian - PLSS applicable meridian

Feet_E_W - Point location distance, in feet, from the east or west PLSS section line

Direction_ E_W - East or west PLSS section line from which the point location distance is measured

Feet_N_S - Point location distance, in feet, from the north or south PLSS section line

Direction_ N_S - North or south PLSS section line from which the point location distance is measured

Well_Bore_Status - Oil and gas well or borehole status, from COGCC database with the following status code definitions:
    Abandoned (AB)
    Active (AC)
    Abandoned location (AL)
    Comingled (CM)

Domestic well (DM)
Drilling (DG)
Dry and abandoned (DA)
Injecting (IJ)
Permit to deepen for injection (PD)
Plugged and abandoned (PA)
Producing (PR)
Shut In (SI)
Temporarily abandoned (TA)
Unitized (UN)
Verbal Intent to plug (VP)
Waiting on completion (WO)
Permit (XX)

Status_Date - Date of oil and gas well or borehole status designation

Spud_Drilled_Date - Spud date (date of drilling commencement) from COGCC database or other drilled date provided

Temp_3000ft_F - Projected temperature in degrees Fahrenheit at a depth of 3,000 feet below ground surface based on datapoint gradient value, used in creation of Plate 3

Temp_6000ft_F - Projected temperature in degrees Fahrenheit at a depth of 6,000 feet below ground surface based on datapoint gradient value, used in creation of Plate 3

Temp_10000ft_F - Projected temperature in degrees Fahrenheit at a depth of 10,000 feet below ground surface based on datapoint gradient value, used in creation of Plate 3

Depth_212F_ft - Projected depth in feet below ground surface to boiling water (212 degrees Fahrenheit) based on datapoint gradient value and assuming standard atmospheric pressure, used in creation of Plate 3

Temp_3km_C - Projected temperature in degrees Celsius at a depth of 3 kilometers below ground surface based on datapoint gradient value

Temp_5km_C - Projected temperature in degrees Celsius at a depth of 5 kilometers below ground surface based on datapoint gradient value