Geothermal Gradient Data For Utah

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ABSTRACT

The Utah Geological Survey compiled information from exploratory temperature-gradient boreholes from a variety of publicly available sources including the Southern Methodist University Geothermal Laboratory, U.S. Geological Survey, recently released industry data, and internal unpublished reports. The data consist of 979 records for 952 boreholes throughout Utah, formatted for use with geographic information systems. Also included are detailed descriptions of the database sources and data-field parameters. The information will be available sometime during summer 2004 for general use through the Utah Geological Survey in both hard copy and digital formats.

Introduction

Thermal methods for geothermal exploration involve the measurement of subsurface temperature at specified depths in exploratory boreholes. Using temperature-depth measurements, geothermal explorers or researchers can determine thermal gradients and (when coupled with other down-hole data) heat flow. These down-hole temperature measurements comprise one of the most important geothermal exploration method for direct detection of geothermal resources. Other geophysical techniques are considered as indirect methods, and can only suggest the possibility of a geothermal system at depth. Temperature logs of boreholes are made by lowering a sensitive thermistor probe -- capable of measuring temperature differences of about 0.01°C -- on a conductor cable, recording probe resistance, and converting resistance data to temperatures at specified depths in the borehole. Small temperature logging units for shallow boreholes (< 1,000 meters [3,280 ft]) can be highly portable, mounted to a hand-crank cable reel. More sophisticated, deep-hole units are truck mounted with several thousand meters of conductor cable connected to electronic recording gear and a motor-driven winch (Wright, 1991).

During the 1970s and early 1980s, the energy industry and government agencies actively explored areas within the western United States for geothermal potential. One exploration method involved the drilling of numerous, shallow, thermal-gradient boreholes for heat-flow studies. As interest in geothermal development decreased during the late 1980s and 1990s, several companies no longer viewed these data as proprietary. The companies, in conjunction with the U.S. Geological Survey (USGS), released thermal-gradient and other geophysical data to the general public. The USGS, and also Southern Methodist University (SMU) Geothermal Laboratory, made much of this information available via the Internet. In Utah, the Utah Geological Survey (UGS) and other state agencies, under cost-share agreements with federal agencies, also compiled geothermal information including results of thermal-gradient drilling. These data were commonly recorded in internal reports or merely within agency files, but were not broadly distributed.

Regional heat-flow studies have shown the mean heat flow for the Basin and Range Province to be about 86 mW/m^2 and the mean heat flow for the Colorado Plateau to be about 59 mW/m^2 (Maria Richards, 2003, SMU, written communication based on the work of Blackwell and others, 1991; and Morgan and Gosnold, 1989). Henrikson (2000), using 88 new heat-flow measurements from Utah, showed that corresponding mean heat-flow values for the new sites are about 91 mW/m^2 in the Basin and Range and about 62 mW/m^2 in the Colorado Plateau.

Sources of Data

Thermal-gradient data were derived from various sources including the aforementioned heat-flow database compiled by and maintained through the SMU Geothermal Laboratory. In addition, thermal-gradient data for Utah were extracted from several unpublished state-agency reports, as described previously, and from the work of Henrikson (2000).

In addition to data extracted from published documents, the SMU thermal-gradient data for Utah were derived from a number of sources including Amax Geothermal, Phillips Petroleum Company, and Chevron Geothermal. CalEnergy Inc. reportedly purchased the subsurface temperature data from the Chevron/Phillips projects. The U.S. Department of Energy acquired part of this subsurface temperature data set for the Idaho National Engineering and Environmental Laboratory (INEEL). Working with INEEL, USGS personnel inventoried and digitized the CalEnergy data, and then combined this data set with miscellaneous data from Geothermal Resources International, Aminoil USA, Amax, and data from other companies acquired earlier by INEEL. The USGS later posted all of the data on the Internet (Sass and others, 1999).

The data as received by the USGS and SMU were in a variety of formats and units, and most locations were listed by section, township, and range. They were primarily copies of field data sheets, but some were in interpretive reports, and others were analogue temperature-depth plots at various scales. Gradient values shown in the database were obtained directly from the field data sheets or plots. These were usually based on a visual straight-line fit of the data from the lowermost section of the hole.

SMU also included thermal-gradient data from a number of published documents, which are listed in the "References and Data Sources" section of the UGS study (Blackett, in press). Similar but previously unpublished information, provided by Republic Geothermal Inc. (1977) and made available through the University of Utah Energy and Geoscience Institute (EGI), were also folded into the data set. Thermal-gradient data compiled by Henrikson (2000), describing new heat-flow determinations in Utah, were also incorporated. Several dozen records were also extracted from UGS files and Reports of Investigation publication series. These are also listed in the "References and Data Sources" section of the UGS study. Overall, the UGS augmented the SMU/USGS-maintained thermal-gradient dataset for Utah, consisting of 617 boreholes, including data from 335 additional boreholes to create the current database containing 979 records for 952 boreholes. Also, the UGS effort included using copies of the raw Amax temperature profiles (acquired through EGI) to check and correct entries where necessary.

Data Content and Organization

The temperature-gradient data for all 952 boreholes will be depicted on a 1:750,000-scale map, and also contained in an accompanying spreadsheet file. Figure 1 (in this paper) is a small-scale general map of Utah showing the locations of temperature-gradient boreholes included in the database with patterns depicting relative gradient magnitudes. The final product, released through the Utah Geological Survey, will include a larger-scale (1:750,000), more detailed map illustrating:

(1) Geography and physiography,
(2) Borehole locations with relative gradient magnitudes and designations, and
(3) Locations of thermal wells, springs, and geothermal areas (from Blackett and Wakefield, 2002).

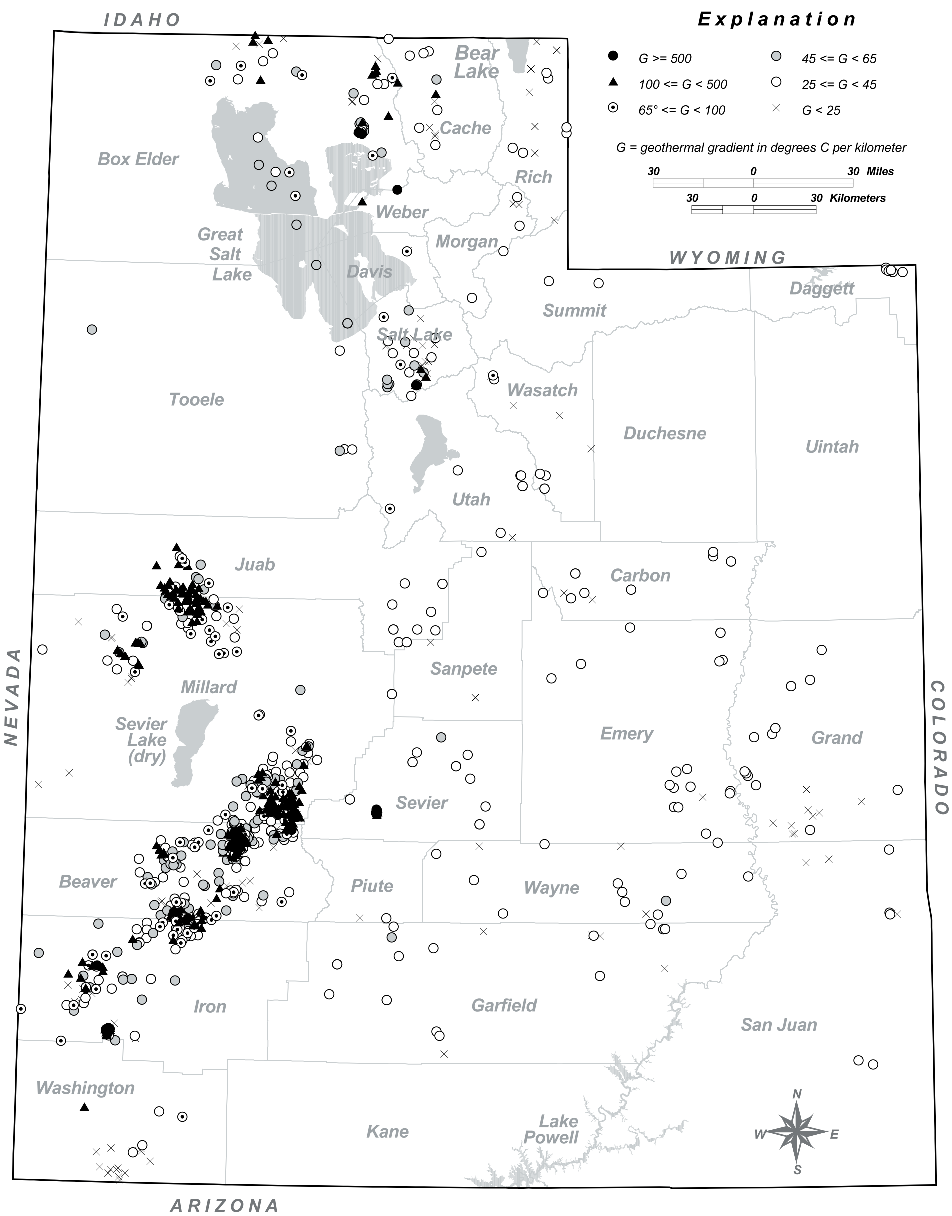

Figure 1. Locations of thermal-gradient boreholes in Utah showing relative gradient magnitudes.

The thermal-gradient data set described here will accompany the report as an MS Excel® spreadsheet. An abbreviated version of the data set will also be included as an appendix.

The following database field description are somewhat modified from the SMU Geothermal Laboratory's Web site.

REGION_LOC: Physiographic subdivision, or geographic feature where appropriate.

HOLE_NAME: Most common name or designation used.

PUB_REF: Publication (or reference) code listed within the "References and Data Sources" section.

COUNTY: County name.

MAPNO: Data point index numbers used as labels.

PROVINCE: Major physiographic province.

LAT_NORTH: North latitude in decimal degrees.

LON_WEST: West longitude (negative) in decimal degrees.

DMS_DMS: Unique identifier string consisting of degrees, minutes, and seconds of latitude then longitude.

TRS: Township, range, section, and subdivision.

UTM_E/UTM_N: Universal Transverse Mercator (UTM) coordinates in meters east and north of the Zone +12 origin.

ELEV_M: Elevation of the surface location of the hole given in meters above mean sea level.

MEAS_DATE: Measurement date of the temperature log.

DRILL_DATE: Date of hole drilling or well completion.

DRILL_DEPTH: Total drilled depth in meters.

BHT_C: Bottom-hole temperature in degrees Celsius.

WAT_TABLE: Depth to static water level in meters.

MAX_TEMP: Maximum measured temperature, in degrees Celsius, not necessarily bottom-hole temperature.

START_M/END_M: Starting and ending depths for the gradient interval, in meters.

AVGTCU: Average thermal conductivity in Watts/meter/Kelvin (*W/m/K*).

UCGRAD: Uncorrected gradient and standard error.

GRAD_CLASS: General divisions for uncorrected thermal-gradient values (within the UCGRAD data field, in ºC/km) determined in boreholes.

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