The Canadian Geothermal Data Compilation

Alan M. Jessop
333 Silver Ridge Crescent NW
Calgary, Alberta, T3B 3T6

V.S.Allen
19617 Somerset Drive
Pitt Meadows, British Columbia, V3Y 2L4

Wanda Bentkowski
1648 Mayneview Terrace
North Saanich, British Columbia, V8L 5B2

Margo Burgess
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario, K1A 0E8

Malcolm Drury
Natural Resources Canada
580 Booth Street
Ottawa, Ontario, K1A 0E4

Alan S. Judge
5682 Fourth Line Road
North Gower, Ontario, K0A 2T0

Trevor Lewis
Sidney Geophysical Consultants Ltd
1107 Maple Road
Sidney, British Columbia, V8L 5P5

Jacek Majorowicz
Northern Geothermal Consulting
105 Carlson Close
Edmonton, Alberta, T6R 2J8

Jean-Claude Mareschal
Geotop, University of Quebec at Montreal
P.O.Box 8888, Station A, Montreal, Quebec, H3C 3P8

Alan E. Taylor
9379 Maryland Drive
Sidney, British Columbia, V8L 2R5

Introduction

Members of the Geothermal Group of the Earth Physics Branch (1962-1986) have undertaken a comprehensive compilation of the data generated over the last 40 years. A data system has been designed to accommodate data of many different types and different formats. The data have been assembled from several different digital data sets, paper files, and field note-books.

The Geothermal Group began on 1 March 1962 at the Dominion Observatory, later renamed Earth Physics Branch, Ottawa. The original mandate of the group was to measure and interpret terrestrial heat flow throughout Canada as part of the Upper Mantle Project. Until 1969 the group was able to drill a small number of holes each year for heat-flow measurements. Other boreholes were borrowed from mining companies and oil exploration companies. About 1972 the group acquired equipment for the measurement of heat production in rocks by radioactive elements. The resulting heat flow and heat generation data were used as indicators of properties of the crust, conditions in the upper mantle, and indicators of tectonic processes.

From about 1970 the scientific purpose was gradually replaced by geotechnical projects, but scientific geothermics was never completely forgotten. Many of these applications were prompted by the Panel on Energy Research and Development and the "Energy Crisis" of the 1970s. Others were related to efforts to find a safe way of storing nuclear waste, and the growing awareness of climate change. Geotechnical applications included:

deep permafrost mapping
frozen ground reaction
pipeline monitoring
gas hydrates
geothermal resource evaluation
shallow aquifers for ground-coupled heat pumps
rock property studies for nuclear waste disposal
analysis of water flow in fractures
hydrological analysis of sedimentary basins
climate change

In 1986 the Geothermal Group was disbanded and its members were scattered through the Geological Survey of Canada, with no provision for the preservation of the accumulated data and knowledge. The data would have been scattered and lost if the scientific and technical staff had not taken steps to ensure their preservation. From 1993 onwards members of the group have retired or moved into other fields of work. This compilation is thus the result of the efforts of volunteer scientists determined to save something of their efforts and of the expenditures by tax-payers over 24 years of the Geothermal Group and the 18 years since the group was disbanded.

The applications listed above are quite sufficient to justify preservation of the data. Future uses of the data and the needs of the users cannot be predicted. The data are preserved in the form of original observations, with no selection or correction of any kind. The authors make no judgement of the data. Supporting detail is included to permit the user to make judgements of quality and of the options for selective use. References to papers and reports where interpretations have been published are included.

Organisation of the data

The files are arranged in a hierarchical system. The primary file is the **SITE FILE**. A list of sites with names of drillers, locations, total depth, and dates of drilling. Each well or borehole has an eight-digit **UNIQUE HOLE NUMBER (UHN)**.

The secondary files are **LOG FILES**. Each log file lists logs of one type. Each log is allocated a **LOG NUMBER,** which is associated with the **UHN**. The log file also includes information on date, method of measurement, and estimates of reliability of the data.

The tertiary files are the **OBSERVATION FILES** and contain the measured data. Each line is identified by the **DEPTH** of the observation or sample, associated with the **UHN** and the **LOG NUMBER**. Large data sets such as temperature are split into several files for ease of handling. There are data files for:

Temperature
Thermal conductivity and diffusivity
Heat generation
Rock petrology
Borehole inclination
Site topography

The compilation is as complete as it has been possible to make it. Some data are known to have been lost, and there are probably others that have been missed. The compilation of September 2004 includes data from over 1900 wells or boreholes. In total there are approximately 3400 temperature logs, 1070 conductivity logs, 380 heat generation logs, 340 logs of petrological description, 380 logs of inclination, and 70 logs of surface topography.

University groups in Canada have generated significant data sets in some parts of the country. Old data sets have been recovered from theses and other publications. Current personnel have been invited to add their data to the collection, and the University of Quebec at Montreal has contributed data from over 250 sites.

All data are expressed in SI, except where noted. Exceptions occur only where the magnitude of the quantity makes it easier to express in some multiple of an SI unit, e.g. mm instead of m for core diameter. Where depths were originally measured in feet or physical properties were measured in cgs units, they have been converted to SI.

Description of data

All files are in ASCII text format. Fields are separated by commas (,). In those files where commas may occur within a field, i.e. the Site File and the Bibliography File, fields are delineated by quotation marks (“).

Site File

There are two versions of the site file: one sorted by UHN named SITESUHN.TXT, and one sorted alphabetically by site name named SITENAME.TXT.

The Site File lists all wells, boreholes or mines where data of some kind has been obtained or sought after. Some sites have no data attached, but they are left in the list in case further data are discovered. Each borehole etc is identified by the UHN. Many mining locations or other geotechnical areas have more than one borehole, and the UHN reflects this. The first five digits of the **UHN** define the location and the last three digits indicate the number of the hole within the location. For multiple boreholes to be included in a location usually means that they are within 10 km of each other. It has been impossible to make this a rigid requirement, and some separate sites are closer than 10 km.

Location numbers of Earth Physics Branch sites were allocated in blocks of 50 as needed. These blocks have not always been rigidly observed, and not all blocks are complete. Allocations are as follows:

1 - 50	Drilled by Earth Physics Branch for scientific research
51 - 100	Borrowed from mining or oil industry
101 - 150	In mines and borrowed from industry
151 - 200	Borrowed from mining or oil industry
201 - 250	Shallow holes drilled by Earth Physics Br., Geological Survey or others
251 - 300	Drilled by oil industry in the north
301 - 350	Drilled for the Geothermal Energy Program
350 - 400	Drilled by industry in the west
401 - 450	Drilled by industry
451 - 500	Drilled for the Geothermal Energy Program
501 - 600	Shallow holes in northern pipeline corridors
601 - 650	Drilled by industry in the north
651 - 700	Drilled by industry in central and eastern regions
751 - 800	Pressure observation wells in Alberta

Other location numbers, allocated to sites of measurement by external agencies are as follows:

10001 - 10037	Various university groups
10101 - 10268	University of Quebec at Montreal
20001 - 20043	Under-water measurements
20101 - 20115	Eastern offshore sites

Columns within the Site file are as follows:

Unique Hole Number	An 8-digit number to identify the borehole
Site name	Name of site allocated by users
Operating company	The agency drilling the hole
Operator's number	The agency's number or name
Regional indicator	1:50,000 map sheet
Latitude	North Latitude in degrees and decimal minutes
Longitude	West Longitude in degrees and decimal minutes
UTM	UTM coordinates
Location accuracy	Estimated accuracy of the location (m)
Ground elevation	Elevation of the top of the hole
Total Depth	Total depth of the hole
Start of drilling	Date of start of drilling (yyyymmdd)
End of drilling	Date of end of drilling (yyyymmdd)
Abandonment	Date of well abandonment
References	Papers reporting the site
Heat flow data number	Reference to World Heat-Flow Data Collection

Latitude/Longitude coordinates have been converted to UTM coordinates using the NAD27 datum. To convert to coordinates based on NAD83 add to the northing a quantity that is about 220 min the southern part of Canada and about 180 m in the north, and add a quantity to the easting that is about +12 m in the east of a zone and about -12 m in the west of a zone. These differences vary with both latitude and longitude and for accurate conversion the correction should be calculated for each location.

Log Files

There is a Log Files for each type of data. Each Log is identified by the *Log Number*, which is associated with the UHN. Each Log File has its own field for Date, Method of Measurement, and for the accuracy of the various data included. Unusual circumstances are noted in the Comments field.

Names of log files are LOGTMP.TXT, LOGCND.TXT, LOGHGN.TXT, LOGPTR.TXT, LOGINC.TXT, and LOGTPG.TXT. There is a file named FILELIST.TXT that names the site and log files.

Temperature Log File

- Unique hole number
- Log number
- Date of log (yyyymmdd)
- Method of measurement
- Depth accuracy (%)
- Temperature accuracy (K)
- Comments

Conductivity Log File

- Unique hole number
- Log number
- Date of log (yyyymmdd)
- Method of measurement
- Depth accuracy ($)
- Conductivity accuracy (%)
- Diffusivity accuracy (%)
- Density accuracy (%)
- Porosity accuracy (% error)
- Comments

Heat generation Log File

- Unique hole number
- Log number
- Date of log (yyyymmdd)
- Method of measurement
- Depth accuracy (%)
- Uranium accuracy (%)
- Thorium accuracy (%)
- Potassium accuracy (%)
- Heat generation accuracy (%)
- Comments

Rock Petrology Log File

- Unique hole number
- Log number
- Date of log (yyyymmdd)
- Method of measurement
- Depth accuracy (%)
- Mineral Content accuracy (%)
- Comments

Inclination Log File

- Unique hole number
- Log number
- Date of log (yyyymmdd)
- Method of measurement
- Depth accuracy (%)
- Inclination accuracy (degrees)
- Azimuth accuracy (degrees)
- Comments

Topographic description log file

- Unique hole number
- Log number
- Increment of grid radius (m)
- Number of radius increments
- Increment of elevation (m)
- Collar height above datum (m)

3 - Observation Files

Most observations are identified by depth. Depth means the distance from the surface measured along the borehole. If the borehole deviates from the vertical the Vertical Depth is also given if known. Many of the measurement techniques used are described in Jessop (1990)

Observation files are named: TMP00001.TXT etc, CND00001.TXT etc. , HGN00001.TXT etc, PTR00001.TXT etc, INC00001.TXT etc, and TPG00001.TXT etc.

Temperature File

- Unique hole number
- Log number
- Measured depth
- Vertical depth
- Temperature

Conductivity/Diffusivity File

- Unique hole number
- Log number
- Core depth
- Vertical depth
- Conductivity (W/mK)
- Diffusivity (in mm^2/s)
- Density (in Mg/m^3)
- Porosity (fraction)
- Sample diameter (mm)
- Sample thickness (mm)

Heat Generation File

- Unique hole number
- Log number
- Core depth min
- Vert depth min
- Core depth max
- Vert depth max
- Heat generation (in $\mu W/m^3$)
- Uranium conc. (in ppm)
- Thorium conc. (in ppm)
- Potassium conc. (in %)
- Density (in Mg/m^3)

Rock Petrology File

- Unique hole number
- Log number
- Core depth
- Vert depth
- Rock name
- Rock description
- Sections counted
- Points counted
- Grain size (in mm)
- Xenocryst size (in mm)
- Mineral (see index)
- Content (in %)
  - repeat Minl & content, total of 9

Inclination File

- Unique hole number
- Log number
- Meas depth (m)
- Inclination (degrees)
- Azimuth (degrees)

Site Topography File - in Log file

- as specified on previous page

Site Topography File - in Observation file

- Site number
- Log number
- Azimuth (degrees)
- Starting radius increment
- Elevation data (increments)
  - 15 per line

General comments on Observations

Temperature

Most temperature observations have been acquired by means of a single thermistor in a probe on the end of a cable. The cable was a four-conductor telephone cable, and it was raised and lowered by hand. Winding was stopped at intervals for measurement. The thermistor was in a small tip, diameter about 3 mm, which led the probe down the hole, so that stirring of the fluid was a minimum at the time of measurement. Thermistors were normally calibrated at least every year. Small changes were detected and thermistors with large changes were discarded.

Some logs were taken by means of fixed cables. These had thermistors at intervals. The cables remained in place from one log to the next, and so the thermistors remained at the same depths from log to log. Calibration drift could not be avoided or detected.

A few logs were taken by means of recording probes. These recorded temperature and pressure at time intervals as they were lowered down the hole. The observations were then transferred to a computer and the record of depth with time was combined to give a log of temperature against depth. Since these logs could be noisy, they have usually been reduced to average temperatures at intervals of one metre.

Measurements were usually made after the temperature had had time to recover from the disturbance of drilling and circulation. Oil and gas exploration wells, particularly in the Arctic, have a recovery time of many years, as shown by the sequences of logs. Logs taken shortly after drilling, when temperature of the fluid in the hole is not in equilibrium with its surroundings and possibly changing rapidly, are indicated by date and time wherever possible.

Conductivity File

Most conductivities have been measured by means of a divided bar. The sample may have been a disc, water-saturated or dry, or rock fragments in a cell. Where the sample was a disc the conductivity was the measured quantity, either dry or saturated as specified. Where the sample was crushed and measured in a cell the result was the conductivity of the solid granular material. To arrive at a rock conductivity from this requires an estimate of the original porosity and a correction for the fraction of water or ice originally present.

In the first few years after 1962 samples were cut into four or more discs of different thickness. Conductivity was then calculated from the slope of the line of thermal resistance against thickness, thus eliminating the contact resistance between the disc and the divided bar. This method was found to be unreliable, since small differences in the conductivity of neighbouring discs could obscure the contact resistance. Furthermore, more samples could be measured with no loss of accuracy by using one disc from each sample with a standard value for the contact resistance. Results from both methods of calculation have been given in the data files.

Diffusivity observations are associated with conductivity observations, but they were not necessarily measured at the same time. They have been measured by an Angstrom apparatus

(Drury, et al, 1982)

Density observations for a disc refer to the dry rock. To derive a true density requires an estimate of porosity and a correction for the water or ice present. Where the fluid filling the pores is water one may simply add the figure for porosity to the dry density to obtain the saturated density.

Porosity has been measured only when the sample was a saturated disc. Since it depends on subtraction of the saturated weight from the dry weight, the possible error is high and has been assessed at 10%. Where porosity is low the penetration of water into the pores was probably not complete. Where the sample was crushed and measured in a cell the original porosity was unobtainable, and any estimate given is derived from some other source.

Heat Generation

Heat generation observations have four columns for depth. Many samples were made up of small pieces of core from a depth interval, in order to collect enough rock for a 330 gm sample. These samples thus have minimum and maximum depths, both along the hole and vertical.

Some samples have no known depth, and these are numbered sequentially, starting with 1, in the minimum depth column.

Rock Petrology

Petrology or lithology of the rocks has been derived in various ways. Some crystalline rocks have been assessed by point-count methods, but most have been assessed by visual inspection.

Inclination

Inclination observations have been obtained from the drillers or from company records. Several methods have been used, as indicated in the log file. Many holes have one value only, the starting inclination at the surface, and in these holes the change in inclination of the hole during drilling is not known. Where no inclination observations are recorded it may be assumed that the hole was vertical at the surface, but that any subsequent deviation is unknown.

Site Topography

Generally the log files contain no observational data that are part of the log. The topographic logs are an exception to this.

Site topography logs contain spot heights on a polar grid with the collar of the well or borehole at the centre. These data are unlike the rest of the data in that there are quantities recorded in the log file that are essential for their use. These are the magnitude of the measurement increments of radius and elevation, the elevation of the collar, and the number of radial increments included. Azimuth and the position of the first radial increment of the line are given in each data line. Steps of azimuth are uniform, and it is unnecessary to give the increment of azimuth.

Heights are expressed in fractions of an increment above a chosen datum, at radial distances expressed in terms of a radius increment. All increments have been expressed in metres, whatever the scale of the map from which the data were read. The elevation of the collar is given in metres above the datum. Geothermal gradient and collar temperature must be derived by the user from temperature logs. Atmospheric temperature gradient, or "lapse rate" must be estimated by the user. Where the height entry is -99.9 the grid point is located in a body of water. Water temperature and the age of the water body must estimated by the user. At some sites the only significant topographic feature is the water. In these logs the other spot heights are all zero, and a line containing nothing but zeros is omitted.

Supplementary files

Bibliography

A list of all Canadian contributions to geothermics and the applications mentioned above has been included. Items that deal with measurement or interpretation of any site are indicated in the site file.

In this bibliography a "Canadian contribution" is any publications where one or more author is Canadian, regardless of the location of the study, or any study of part of Canada, regardless of the authorship.

Bibliography is in a file named BIBLIOG.TXT

Data Finder

A Fortran program is included, to enable the user to find sites by name or by geographical area and to find what logs are available for each site. The program is given in both FOR and EXE forms, so that the user can modify or recompile if necessary.

Readme files

The introductory text is included as a README file, in a portable document file named README.PDF and a text file named README.TXT

Site Description

Site descriptions are intended to give the user information about the nature and history of the terrain, vegetation cover, proximity of buildings or other human disturbance, access to the site, and any other relevant factor.

Site descriptions are in a portable document file named SITEDESCR.PDF and a text file named SITEDESCR.TXT

Errors and Omissions

These data files are as complete and accurate as it has been possible to make them up to

November 2004. They are capable of being corrected and updated. The authors would appreciate notification of errors, problems in using the data, data that have not been included, or new data that contributors are willing to include. Comments or data should be sent to the first author, either at the address given on the title page or at the Geological Survey of Canada, 3303 33rd Street NW, Calgary, Alberta, T2L 2A7.

Related data collections

There are several other data collections that may overlap this collection in part, or that are related in nature.

Radioactive heat generation of rocks in Canada has been compiled by Trevor Lewis and Wanda Bentkowski, and has been published as Open File 1744 of the Geological Survey of Canada.

Thermal data related to permafrost has been assembled by Alan Taylor and included in a compact disc entitled "CAPS: Circumpolar Active-Layer Permafrost System, Version 1.0, June 1998", published by the National Snow and Ice Data Centre, Cooperative Institute for Research in the Environmental Sciences (CIRES), Campus Box 449, University of Colorado, Boulder, CO 80309-0449, USA.

A collection of temperature data from log headings of wells in all parts of Canada is in preparation. These data will not be complete or up to date, but will include data from Manitoba, most of Saskatchewan, some areas of Alberta and British Columbia, the Northwest Territories, and some early wells on the Atlantic Continental Shelf.

The Alberta Research Council keeps a similar compilation of temperature from log headings for the northern part of Alberta.

A study of heat flow in Lake Superior has been carried out by US institutions (Hart et al, 1993). Some of these measurements were in the Canadian part of Lake Superior, but the site detials and data are not included in this compilation.

Acknowledgements

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Appendix One

List of Files

Site files:

SITENAME.TXT,
SITESUHN.TXT

Log Files:

LOGTMP.TXT
LOGCND.TXT
LOGHGN.TXT
LOGPTR.TXT
LOGINC.TXT
LOGTPG.TXT

Temperature files:

TMP00001.TXT
TMP00011.TXT
TMP00015.TXT
TMP00051.TXT
TMP00061.TXT
TMP00071.TXT
TMP00081.TXT
TMP00101.TXT
TMP00121.TXT
TMP00131.TXT
TMP00141.TXT
TMP00151.TXT
TMP00161.TXT
TMP00201.TXT
TMP00221.TXT
TMP00251.TXT
TMP00271.TXT
TMP00281.TXT
TMP00291.TXT
TMP00301.TXT
TMP00311.TXT
TMP00341.TXT
TMP00351.TXT
TMP00361.TXT
TMP00381.TXT
TMP00401.TXT
TMP00451.TXT
TMP00501.TXT
TMP00651.TXT
TMP00701.TXT
TMP00751.TXT
TMP10001.TXT
TMP10181.TXT
TMP10221.TXT

Conductivity files

CND00001.TXT
CND00011.TXT
CND00051.TXT
CND00061.TXT
CND00081.TXT
CND00101.TXT
CND00111.TXT
CND00151.TXT
CND00201.TXT
CND00301.TXT
CND00351.TXT
CND00401.TXT
CND00701.TXT
CND10001.TXT

Heat generation files

HGN00001.TXT
HGN10001.TXT

Petrologic files

PTR00001.TXT
PTR00051.TXT
PTR00101.TXT
PTR10001.TXT

Inclination data

INC00001.TXT
INC00301.TXT
INC10001.TXT

Topographic files

TPG00001.TXT
TPG00101.TXT

Supplementary files

BIBLIOG.TXT
SITEDESCR.TXT
SITEDESCR.WPD