GDManager: A DEVELOPMENT IN THE MANAGEMENT, INTERPRETATION AND REPRESENTATION OF GEOTHERMAL FIELD DATA

P. R. Barnett, R. B. Farrell, A. R. Paterson, G. N. Ussher

Geothermal Energy New Zealand Limited GENZL

ABSTRACT

Geothermal exploration, development and production involves the collection and collation of large quantities of raw data. Interpretation of this data involves access to the data by scientists and engineers both within and outside their particular fields of expertise. This leads to the concept of a software environment which provides both management of data and the ability to execute standard interpretation and graphing routines. This papers describes the development of a PC based computer package for the management, interpretation and graphical representation of data collected during all phases of geothermal exploration, development and production programmes.

INTRODUCTION

GENZL, as a geothermal consultant, has been engaged in all aspects of geothermal development, from initial reconnaissance to final energy utilisation. This work has often involved review of existing data from a field to guide subsequent development. During these reviews it has become apparent that interpretation of the often massive amounts of data accumulated during geothermal exploration and development ideally requires a formalised system of data management, In particular, the ability to easily reinterpret data from its raw state using current interpretation methods and to compare data from several disciplines across the geothermal prospect is essential. This suggests that all data should be stored in a common database system and that this database should be established at an early stage of the development. To make the most efficient use of this database a wide range of interpretation routines should be simply interfaced with the database management system, enabling data retrieval, interpretation, presentation and then storage of the interpreted data.

Using these basic design requirements and a thorough knowledge of the data types used in geothermal development, a central database system for data management has been created. This system interacts with interpretation and analysis routines in the four major disciplines of Geology, Geochemistry, Geophysics and Reservoir Engineering. Development of further interpretation and analysis routines for these disciplines is continuing. The development of a Drilling database and interpretation system is planned.

The system is a very powerful data handling and analysis tool which provides the following main features:-

- Complete storage of raw field data.
- Provides data quality assurance checks.
- Encourages standardization of data formats.
- Fast interpretation of data.
- Multidisciplinary data access.
- Enables complete reinterpretation of data at any time using up-to-date methods.
- Encourages more complete and imaginative interpretation of data.

DISCUSSION

DATABASE MANAGEMENT SYSTEMS

A database may be defined as observed data stored for later use. In this sense a database may be used with or without the use of a computer. Computer databases are defined as observed data, stored in a computer, for later use. Further elaboration of this definition views a database as a generalised integrated collection of data which is managed in such a way so as to provide for the varying needs of it's users.

In order to be useful a database must be managed by an independent piece of software. A Database Management System (DBMS) is a system that generates, runs and maintains databases and includes all software required for this purpose.

A good DBMS should:-

1. Support a host programming language
2. Provide the ability for both database and programs to be altered independently of the other.
3. Enable the structure to be defined to provide for the various needs of users.
4. Provide the ability to execute interpretation programs written in other languages.
5. Adequately represent the relationships that may exist between data sets.
6. Permit access by more than one user.
7. Support high level query facilities.
8. Support the ability to build the database gradually.
9. Support the ability to export and import data to and from other application software.

Recognising the suitability of a DBMS to provide management of geothermal data, development was undertaken using PAL, the host programming language of PARADOX, itself a relational DBMS.

TABLES

Within a database data is stored in tables. A table is arranged so that each category of information is arranged in vertical columns while individual records of data am arranged in horizontal rows. An example of a table is shown in Figure 1. (Table 1.).

It is possible to store data in one large table. However, this approach leads to redundacy of data and does not provide the flexibility that is obtained when tables am normalised. That is, when tables are organised into discrete divisions of data or manageable units. A normalised table is small, discrete and contains a minimum of redundant data. Normalisation of tables enables data in one table to be related to data in another table, provided it is logical to do so, and provided they *share* a **common** field.

As an example the relationship between three tables is depicted in Figure 1. A description of the relationship between each of these tables follows.

Table 1 (of Fig 1) provides for the storage of information which describes the well. This information is accessible for reporting purposes. The table also provides a "lookup" so that valid field and well identifiers are used when temperature data is input.

Table 2 (of Fig 1.) provides for the storage of information which describes the temperature run. This information is accessible for reporting purposes.

Table 3 (of Fig 1.) provides for the storage of temperature data.

It should be noted that Tables 1 and 2 are examples only and are not as they appear in GDManager (when more extensive representation of well and temperature run information is held).

Table Name — Categories of data (Fields)

Wellhead	Field ID	Well No	Northing	Easting	Elevation
1	VNU	402A	53220	221080	375
2	VNU	403A	54580	220230	2550
3	VNU	404A	54330	221820	525
4	TLK	302A	45095	204566	218

Individual Records

(Table 1)

Weltemh	Field ID	Well No	Run No	Run Date	Well Status
1	VNU	402A	1	05.01.87	24 Hr Shut In
2	VNU	402A	2	10.01.87	Pumping for 16 hrs
3	VNU	402A	3	12.01.87	Heating for 21 days
4	VNU	403A	1	23.02.87	Flowing Survey
5	VNU	404A	1	03.03.87	6 Hr Shut In

(Table 2)

Weltemd	Field ID	Well No	Run No	Depth	Temperature
'1	VNU	402A	1	500	66
2	VNU	402A	1	600	142
3	VNU	402A	1	700	163
4	VNU	402A	1	800	142
5	VNU	402A	1	900	132
6	VNU	402A	1	1000	117
7	VNU	402A	1	1100	118
8	VNU	402A	1	1200	121
9	VNU	402A	1	1300	135
10	VNU	402A	1	1400	161
11	VNU	402A	1	1500	198
12	VNU	402A	2	500	17
13	VNU	402A	2	600	19
14	VNU	402A	2	700	21
15	VNU	402A	2	800	22
16	VNU	402A	2	900	23
17	VNU	402A	2	1000	25
18	VNU	402A	2	1100	35
19	VNU	402A	2	1200	50
20	VNU	402A	2	1300	74
21	VNU	402A	2	1400	116
22	VNU	402A	2	1500	148

(Table 3)

FIG 1 -An example of table normalisation and table relationships.

This example demonstrates the normalisation of tables and relationships that exist between tables. Each table contributes additional data. Although there is duplication of field and well identifiers (which is essential to maintain the relationship between tables) there is otherwise no redundant data. Data is observed to be stored in discrete manageable units. These units are able to be combined to provide adequate representation of the data in the form of reports and graphs.

GDManager OVERVIEW

GDManager, which stands for Geothermal Data Manager, is modular in form. A schematic representation of the relationship between the various modules is shown in Figure 2.

The Base Module is a database and like all databases requires management. This module has been designed using table normalisation methods and provides management of the quantities of data likely to be encountered for several large geothermal projects. The only real limitation is the disk storage capacity of the computer.

The Base Module is menu driven and provides data capture for Geochemistry, Geology, Geophysics, and Reservoir Engineering. Data integrity was a high design priority feature - checks for duplicity of data and range checking is made upon input of data. Immediate graphing of data further ensures that the quality of input is maintained. Once captured, data is accessible by all disciplines.

A facility for the backup of data for transportation purposes is provided within the Base Module.

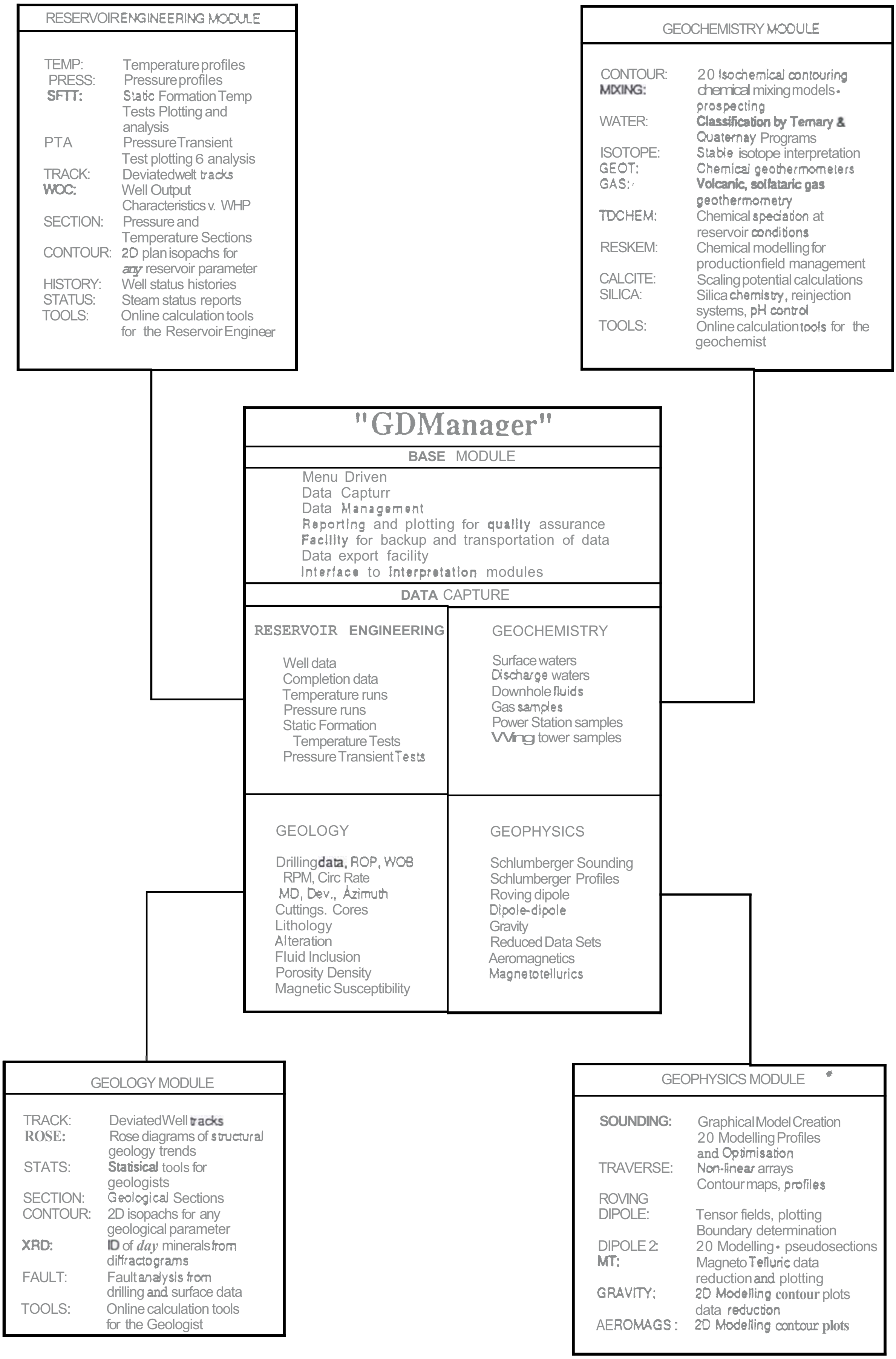

FIG 2 - A schematic representation of the modules contained within **GDManager.**

The Base Module provides the ability to execute interpretation, graphics, profiling and contouring routines. That is, the Base Module provides the interface to the Geochemistry, Geology, Geophysics and Reservoir Engineering Modules. These modules are programs Written in PASCAL, QUICKBASIC and FORTRAN. Data contained within GDManager is accessible via the interactive mode of PARADOX, the relational DBMS. Ad hoc queries of the entire database may be made using the query facility of PARADOX. Once data has been retrieved in this manner the data may be then worked on in PARADOX or exported to other application software such as graphics packages.

Further to this the user may develop applications in PAL (or some other language) and interface these programs with GDManager.

GEOCHEMISTRY

The Base Module provides capture of chemical data for the following geochemical sample types:-

1. surface waters (hot and cold spring and meteoric waters)
2. hot water and steam samples from geothermal well discharges
3. downhole water and gas samples
4. gas samples from fumaroles and solfataras
5. turbine supply steam quality samples
6. cooling tower chemical samples

Input data is then sent to screen for verification or to printer in the form of formatted output reports, or to application modules which generate a wide range of geochemical parameters for interpretation and field monitoring purposes. Any of these parameters can be plotted against each other or against time using a resident graphics program.

The following applications modules are currently under development.

Solution and Gas Geothermometry:

These two applications compute geothermometry estimates of subsurface fluid temperatures for all commonly used solution and gas geothermometers, both empirical and thermodynamic.

Total Discharge Chemistry:

From the composition of water and gas samples collected at surface from a well with discharge enthalpy H, a total fluid composition is computed at reservoir conditions. Up to three total discharge composition can be calculated depending on whether the value of H with respect to chemical geothermometry indicates no excess enthalpy, or excess enthalpy due to either dominantly flashing flow or the addition of "global" (i.e. free) steam.

Speciation:

Calculates chemical speciation and equilibrium constants at reservoir conditions from computed total discharge or measured downhole compositions.

Calcite:

Calcium carbonate equilibria and potential for scaling are computed during flashing of geothermal fluid up the well bore and through surface plant.

Silica:

Similar to Calcite this module produces calculations which track the dissociation of silicic acid resulting from increasing pH during flashing and allows the user to model the effects of pH control on silica saturation through chemical dosing.

Exploration Geochemistry:

Application modules of interest to the exploration geochemist include CONTOUR which allows for 2-D vertical and plan isochemical contouring; MIX which computes chemical mixing models; and TYPE which classifies a water chemical type through ternary graphical procedures.

GEOLOGY

The Base Module is structured to allow geologic and drilling data to be continually entered as geothermal well drilling progresses so that at any time the rig geologist can produce an up to date well log.

Input consists of keyboard entry at any well depth of lithology, hydrothermal alteration mineralogy, fluid inclusion geothermometry, coring points, casing program and various drilling parameters such as bit weight, rpm, rate of penetration. These data are then output as a plot of each parameter versus depth in a format suitable for direct use in a well geological report.

The following application modules are currently under development to extend the capabilities of the Geology Module:

Section:

Constructs geological sections along user defined section lines to allow for correlation of rock units and alteration assemblages.

Track:

Plots deviated well tracks in vertical and plan section.

Contour:

Generates 2D vertical or plan isopachs for any geological parameter.

Fault:

Provides analysis of fault attitudes from well track intersections and surface traces.

Statistics:

Provides geological statistical analysis including standard deviation calculation, correlations and analysis of variance.

Rose Diagrams:

Constructs rose diagrams for analysis of structural geology trends.

XRD:

Provides auto-identification of hydrothermal clay minerals from X-ray diffractograms.

GEOPHYSICS

The Geophysics Module will provide interpretation routines for the major geophysical methods used in geothermal exploration; DC resistivity traversing (profiling) and soundings, gravity surveying and aeromagnetic and MT surveys. Graphical interpretation methods are used wherever possible which encourages interpretation by the scientist. The calculation speed of these routines has also been optimised which further encourages the interpreter to try a wider range of model structures or variables than would normally be practical.

Schlumberger Soundings

The Base Module can accept raw field data or calculated apparent resistivities as raw data sets. Data processing and interpretation routines are provided to create "workfile" data from sounding raw data to subsequently allow for modelling of the workfile data.

The raw data, workfiles and models are all stored in the database and are registered as relating to their original sounding. The raw data for any sounding can have several related workfiles and each workfile can have several related models. The models are available for selection and plotting on profile cross-sections through a geothermal field.

Workfile Creation

The routine reduces raw sounding data contained in the database to workfiles which contain no overlaps (i.e. have no duplicate AB/2 values). The workfiles are then stored in the database and used in later modelling routines.

The routine has a facility for graphing the raw data to determine data quality and to assess the effect of MN elimination. The raw data can be edited graphically to adjust or delete erroneous datapoints before workfile creation (this will not however affect the raw data in the database). Several methods for removing MN overlaps are provided. The created workfiles are coded in a way which indicates the process(es) used in their creation.

Layered (1D) Model Creation

This routine enables graphical creation of initial 1D resistivity models and provides the ability to graphically adjust these models or a model sent from the database. Provision is made for calculation and display of the calculated apparent resistivity response curve for the models. This curve can be compared with the sounding workfile and the models adjusted until a satisfactory match is obtained. All model creation and adjustment can be done without leaving the graphical environment. Several models can be created and saved for any workfile.

An automatic routine is available for optimising the fit of any models in the database. Any of the model parameters can be selected to be unmodified during this optimisation.

Schlumberger Profiling (Traverses)

Either reduced data with calculated apparent resistivities or raw field data can be entered directly into the database. Provision is made for calculation of apparent resistivities for the raw data and correction is made for a non-linear electrode array. The Geophysics Module provides the capability to sort data for passing to contouring or profile pseudo-section presentation routines.

MT (Magneto-Tellurics)

Provision is being made for storage of MT data at the cross and auto power level. This enables calculation and plotting of apparent resistivity and phase data at various rotations as well as the plotting of resistivity polar diagrams. 1D sounding interpretation and profile presentation routines are available.

Gravity

External data reduction routines are used to reduce field gravity measurements to a format suitable for inclusion in the database. These routines provide for automatic terrain corrections using a digitised image of the topography up to 60km radius and subsequent calculation of Bouguer anomalies at densities ranging from 1.8 to 3.2 x 10^3 kg/m^3 in steps of 0.1 x 10^3kg/m^3.

The gravity data is stored in the database as observed gravity data, free-air anomaly, station (X,Y, height), terrain correction values at 2.67 x 10^3 kg/m^3 (for both land and water covered terrain) and calculated Bouguer anomalies at terrain densities as described above. The wide range of Bouguer anomalies is stored to enable very fast display and plotting of the data at various densities for visual investigation of the influence of terrain on the data. Sufficient data is stored for calculation of Bouguer anomalies at arbitrary densities if necessary.

Gravity data can be selected on any user-defined profile line and passed to a 2D interactive modelling routine.

Aeromagnetics

Aeromagnetic data will be stored in a gridded format which is suitable for passing to contouring routines. The Geophysics Module provides procedures for selecting data on profiles and passing this data to a 2D graphical modelling routine.

Other Data Types

Procedures for entering data from Roving-Dipole and Dipole-Dipole (or any other) surveys could be included in the Base Module and the related data presentation routines would be added to the Geophysics Module. Any such addition would be dependent on establishment of a demand for the particular data type.

RESERVOIR ENGINEERING

The Base Module provides for the capture of the following well measurements data:-

- Temperature survey
- Pressure survey
- Pressure transient survey
- Static formation test temperature surveys
- Deviation survey data
- Well output data

An environment is provided where individual data sets may be combined to generate more complex models, such as contouring of isobars and isotherms from individual well survey data.

There are some interpretation problems in Reservoir Engineering that lend themselves to computer solutions, in particular those problems which depend on many repetitive graphical presentations to provide the interpretive information i.e. profiles and contours.

Graphical information to be provided includes:-

1. Temperature Well Profiles with Multi Survey and BPvD curve.
2. Pressure Well Profiles with Multi Survey and BPvD curve.
3. Pressure Transient Data
   - MDH Semilog plots
   - Horner/Semilog plots
   - Russell 2-Rate Cartesian plots with straight-line slope analysis
   - Log-log Plots for Type-Curve matching to same scale as published curves.
4. Static Formation Temperature Tests
   - Roux et al. Semilog Plot
   - Brennand Semilog Plot
   - both with Straight line extrapolation to Formation Temperature
5. Well Output Characteristics
   - Parameters Plotted v WHP
   - H, Q, MW(e), H_v, Q_v
6. Profiles across a field
   - Isotherms
   - Isobars including the conditioning of the well survey data to be used for the profile such as MD to TVD and selection of survey.
7. Contours across a field.
   - Isotherms
   - Isobars
   - including the conditioning of the well survey data to be used for the contour such as MD to TVD and selection of survev.

There are many smaller programs that are of regular use to reservoir engineers. Several of these programs are executable menu choice, TOOLS.

Routines included in TOOLS are:-

- Steam Tables
- Boiling Point and Depth
- Well Output Calculations
- Weir Flow
- Resource Calculations
- Pressure Transient Analysis Calcs

CONCLUSION

The flexibility of PC based database management systems lends their usage for the capture and management of geothermal data. Interpretation and representation of captured data may be carried out via programs executable from the DBMS. A DBMS provides query facilities enabling retrieval of combinations of data that may then be worked upon or exported to other application software. A DBMS allows for an upgrade path to match availability of resources.