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GDMANAGER SOFTWARE: FOR THE STORAGE, MANIPULATION AND INTEGRATION OF DATA FROM GEOTHERMAL RESOURCES

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ABSTRACT

Experience by PB Power, GENZL Division in the exploration, prioritisation, assessment and management of geothermal resources in over 20 countries throughout the world has led to the development of the GDManager software for handling a wide range of scientific and engineering data.

The software has evolved through an ongoing program of development and refinement by an integrated team of software engineers, scientists and engineers. It currently operates in both DOS and Windows versions and is licensed by some 20 government agencies and private power producers for the management of more than 60 fields in over 15 countries.

GDManager ensures efficient storage and ready availability of field data, with functions which include maintenance of data integrity, data correlation between disciplines, integration of data from interdisciplinary studies, manipulation of data and its validation. The versatility and capabilities of the program will be demonstrated by a series of case studies.

1. INTRODUCTION

The evolution of GDManager has been described through several papers (Barnett et al, 1987; Anderson & Ussher, 1992; GENZL, 1994; Anderson, 1995; Anderson et al 1995). The DOS version has steadily developed from that described in Barnett et al (1987) to a comprehensive system that now stores virtually all the main geothermal data collected in the development of a geothermal field, from initial exploration through to, and including, production. Furthermore, data can be compared and contrasted, analysed, modelled, graphed and contoured, all within the one program.

The development of GDManager grew directly from GENZL's wide experience in the exploration, assessment and development of geothermal resources throughout the world. The primary aims of the program were:

- Orderly storage and retrieval of large amounts of geothermal data over a long time period.
- Tightly-integrated but flexible methods of graphical presentation, both within and between disciplines.
- Network operation to promote cross-discipline correlation and integration.
- Centralised "backbone" data management system to integrate data analysis and interpretation methods.

While achieving the first three aims, it was less successful with the fourth, partly because of DOS memory limitations and partly because of the move to the Windows operating system. GDManager for Windows will fulfil this "backbone" role, offering true integration between data management and sophisticated analysis and modelling programs.

2. COMPLETE DATA STORAGE

Data collection costs money, and it is very important that this information is stored safely and retrieved easily. In today's world, the best form of data storage for quick and easy retrieval, manipulation, and display is a central computer network.

Successful geothermal development requires integrated resource assessment, and this requires sophisticated data management. A central computer network provides safe and practical data control.

If properly entered, data can be retrieved and re-interpreted with subsequent data acquisitions for as long as the database is maintained/archived. If retained over the life of a field, this will be measured in decades. GDManager has many behind-the-scenes checks and systems in place to ensure that data is stored correctly and safely, even through program upgrades.

Data stored in a central registry minimises the cost of later data collection and collation. Previous data can be viewed to ensure that data-poor areas are infilled and overlaps are kept to a minimum whilst ensuring confidence between data sets.

3. MAINTAINING DATA INTEGRITY

The most important part of a database program is its attention to data integrity, i.e. its ability to protect the data from "operator error", such as entering the wrong data, accidentally deleting data, or overwriting previous data.

Data integrity in GDManager is achieved through various checks and validations that are brought into play when entering, importing, or editing data. Whenever attempts to transgress these rules are made, the user will be warned and prohibited from doing so.

These checks and validations include:

- data input ranges to minimise typing errors.
- unique naming requirements for all data sets, thus avoiding inadvertent duplication or overwriting.
- cascading updates to ensure that dependent data remains valid if parent data is changed
- rigorous control of deletion to prevent links between dependent data and parent data being broken.

3.1 Location Information

A geothermal resource under exploitation is a four-dimensional entity, and the various measured and calculated parameters may vary widely throughout. It is therefore extremely important that the physical location and time of each piece of data is accurately known. Without this information, the data may be useless as incorrectly placed data can lead to erroneous interpretations. When the geothermal development enters the production phase, time measurement become very important.

The structure of the GDManager database ensures that the location of all data is specified in both space and time. For some data sets, location fields are required fields and must be filled, while in other cases, the data is referred to a defined location by means of a common data name.

For example, data collected from a well can be entered in the database only if the well has already been defined. The well data set includes four required fields, the name of the well, and location information (depth, date and time).

Depth or subsurface elevation co-ordinates of data are particularly important for a database managing data from a subsurface resource. Surface based measurements of parameters at depth, such as geophysics must be converted to elevation, particularly in rough terrain. Measurements made downhole in wells need to have measurement depth converted to elevation and to take account of well deviation and elevation of the wellhead. GDManager does all of this, and for well measurements even allows the user to use RKB or wellhead referenced depth measurements. For example, correct 3D location information allows confident comparison between geophysical and well data sets.

Figure 1a shows the GDManager interface, viewing the well temperature data and illustrates the relationship between the location referenced through the well name (AT-601), and the measured depth of the temperature measurement. The well deviation data, which enables the conversion from measured depth to elevation and X, Y location is held in a linked table.

3.2 Selection and Filtering

With a small data set, selection of the data to perform the required function is usually straightforward. With time, a database swells in size as data is added, and will require specialised tools to allow data to be easily selected.

Ideally, if care is taken over the naming of the input data, data selection at a later stage will be reasonably straightforward - even for large data sets. However, despite all good intentions, data selection is not always easy, and especially so if data sets have been named in a chaotic or random manner.

Within GDManager, complex data selection is accomplished by a series of filters that can be applied to the data. By the use of successive filters to pare the data, the required data can then be easily selected for processing. Furthermore, the selected data set can be saved as, or added to, a "group". Thus a complex selection can be built up from successive simple selections. The use of named groups is very valuable for repeated selections of a complex data set.

Figure 1a gives an example of data selection, showing data filtering by groups and ranges to reduce the quantity of data viewed. Any number of data sets (a data set being an individual downhole log, for example) can be manually selected for graphing, reporting etc.

A graphical selection of spatial data is enabled through the use of a map view of the data locations - wells in the example shown in Figure 1b.

3.3 Units

Problems with units, especially the mix between SI and Imperial, has proved problematical throughout the world, indeed, even out in space where in 1999 a Mars probe missed the target because of a conflict in units! In a scientific database, it is very important that the issue of units is effectively addressed.

In GDManager, all data is stored in SI units, regardless of the unit used for data collection and entry. The advantage of this is that data within the database are integrated with a common basis and can be compared or merged easily. The system has the flexibility to cope with data entry from different sources, and be flexible when the data is used, i.e. drawing a graph, or exporting to another program. Data can be presented or exported in any measurement units while leaving the core data in the database unchanged.

Changing units is made by a simple drop down menu triggered by a right click on the data, as shown in Figure 1a.

4. FROM DOS TO WINDOWS

Generally specifications for Windows versions of any DOS program are quite simple and specific - “It must do everything the DOS version does, but better”. From the experience gained in developing DOS software, and bearing in mind the multidisciplinary nature of the geothermal industry, our Windows software has to be better geared to multidisciplinary work.

Writing Windows software is an expensive undertaking, especially in a limited market such as geothermal. So to minimise the impact of a new system on the geothermal community we made the two versions, DOS and Windows, compatible throughout development until the full Windows version is finalised. Furthermore, constant improvements to the DOS program are therefore immediately seen in the Windows version.

The determined attention to data integrity in the DOS version allows the database contents to be confidently handled and manipulated. This is maintained in the Windows version, which further provides easy to produce, and striking graphical displays that aid geothermalists in their interpretation.

5. DATA MANIPULATION AND CORRELATION

The inherent flexibility afforded by computer programs routinely allows the presentation and comparison of data in a wide variety of ways, giving the geothermal resource scientist the tools to think “outside-the-square”. For instance, powerful cross-discipline comparison and correlation of data facilitates a more complete approach to reservoir interpretation. Furthermore, the ability to group and present data by different parameters can highlight trends or patterns that are otherwise hidden.

5.1 Example 1 – Magnetotelluric (MT) delineation of a geothermal resource.

The electrically conductive clay alteration layer that overlies a high-temperature geothermal system has traditionally been the target of resistivity surveys.

In steep terrain, regional hydrology, and the delicate interplay of buoyancy and gravitational forces, means that the apparent low resistivity anomaly is rarely directly above the hottest "upflow" zone, and therefore does not delineate the geothermal target.

In recent years there has been a move to 2D modelling to model and visualise the sub-surface resistivity structure. A simpler approach is to perform discrete 1D modelling and collate the information from individual layers (Anderson et al, 2000). This technique relies on the database structure for data storage and the ability to assemble diverse data sets into a coherent group for subsequent processing.

Using 1D-resistivity models from each MT sounding, the interpreter can group together layers representing the conductive cap. This group of layers can then be treated as a single body with certain physical properties, such as depth to the upper and lower surfaces, elevation of these surfaces, thickness, resistivity and conductance. Individual sounding models are iteratively adjusted to ensure that the variations in any of these properties are not greater than is physically reasonable.

While all patterns and trends of the conductive layer provide information about the underlying geothermal system, the most useful anomaly is the elevation of the lower surface of this layer. This broadly corresponds to a temperature of about 180°C, where conductive smectite alteration is substantially replaced by more resistive illite. The zone of highest elevation has been shown to be at or near the "upflow" zone and a favourable drilling target. Figure 2, taken from Anderson et al. (2000) shows wells (dots) located on the flanks of an anomaly defined by the elevation of the base of the conductive layer. Wells are progressively more successful towards the centre of the anomaly.

5.2 Example 2 – Summary graphs

For well data, it is particularly important that data from many different data sets, from a single well or from a number wells can be compared. Computer programs are powerful tools for allowing this type of comparison. Different data sets can be assigned to a standard graphical format, or graph formats can be customised to suit a specific set of data. Graphs can be plotted against measured depth or against elevation, particularly useful for comparison between different wells.

Figure 3 shows what can be achieved without having to collate data from different files, or cut and paste graphs from different programs. Well data (casing, geology, and reservoir) from one well are shown side by side against depth. A more powerful use of this type of graph is to plot data from different wells, in which case it is more appropriate for the Y-axis to be elevation.

5.3 Example 3 – Profile graphics and contour plots

After exploration wells are drilled, integrated geothermal resource assessment demands that data from each well can be accurately compared and correlated, with other data from the same well, with adjacent wells, and with data from other survey techniques, particularly geophysics. Summary graphics (Example 2 above) provide same well comparisons, while profile graphics and contour plots are ideal tools for cross-well and cross-discipline studies.

Figure 4 shows a profile comparing temperature, the interpreted reservoir limits, and resistivity data, while Figure 5 compares well lithology with downhole resistivity log data. All these data correlation's, and many more, are readily available, and provide the opportunity for a true multi-disciplinary integrated resource assessment.

Because of the often sparse and imperfect data available for geothermal interpretation, different techniques for comparison and correlation are recommended. For instance, a profile demonstrates vertical detail and variation along the profile, but ignores changes out of the profile plane, while contour maps display the variation of a single parameter, while others are fixed.

Fence diagrams, complementary contour plots (e.g. temperature at a selected elevation, elevation of a selected temperature) and stacked plots are all necessary to depict the complex three-dimensional reservoir, and 3D visualisation is one of the goals of sophisticated data management packages.

5.4 Example 4 – Integration with reservoir simulators

The aim of collecting geothermal data is to build up a conceptual model of the resource in order to focus subsequent work, be it more exploration, drilling, development, or production. A reservoir simulator could be described as the ultimate conceptual model, as it models the very workings of the resource. The success of a simulation is dependent on the successful interpretation of all the data collected thus far into the field's life. If data is missing, the simulation quality can suffer as a result.

Two different reservoir simulation programs are in common use within the geothermal industry, namely the TETRAD/ASTRO and the MULKOM/TOUGH families. GDManager provides tools to select and process production and injection data for history matching, and to export it in the appropriate format for each simulation program. Simple simulation grids can also be entered and stored, and used to assign feed zones in the wells to the correct grid layers and blocks. This is especially useful if wells are highly deviated, as manual methods are tedious and prone to error.

6. CONCLUSION

The geothermal industry relies on effective multidisciplinary project teams to deal to the wide base of data collected over periods of several years, if not decades. This mountain of data has to be effectively, carefully and consistently stored. At a later date, the amassed data set can be recalled at the touch of a button. Continued manipulation and interpretation helps provide an increasingly more accurate conceptual model of the resource. This model is used to base your drilling program, and to keep track of your data requirements during the development and production of the field.

With over 25 years experience of geothermal resource work, we find that using a holistic data management system is invaluable. As data input is strictly controlled by the program, we are confident of our stored data, thus securing peace of mind. The ready accessibility of this data on a computer network means that interpretative work is quick, and the closely integrated presentation packages further enhance the final product.

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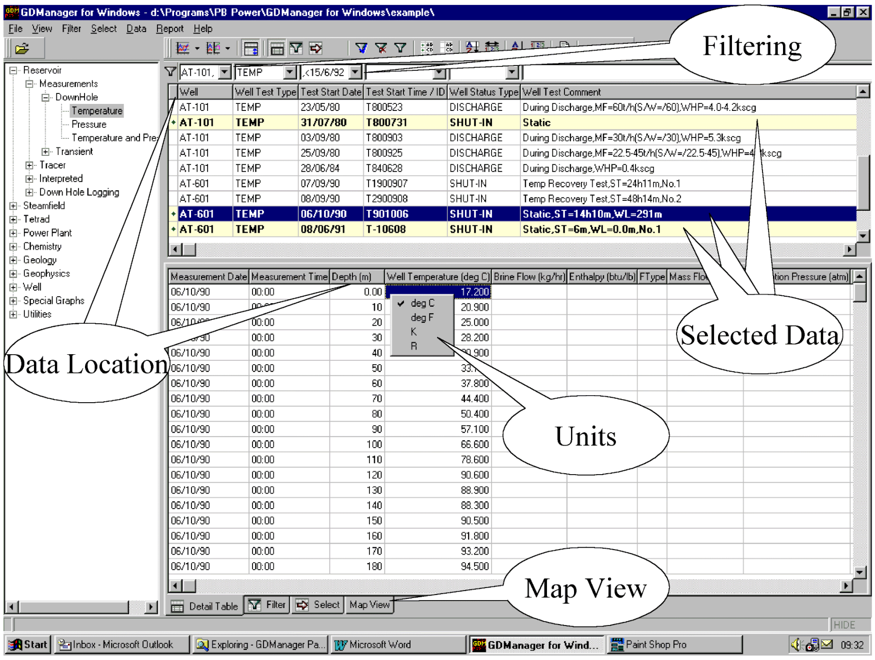

Figure 1a: GDManager Screenshot emphasising location information, filtering, selection abilities, and units conversion.

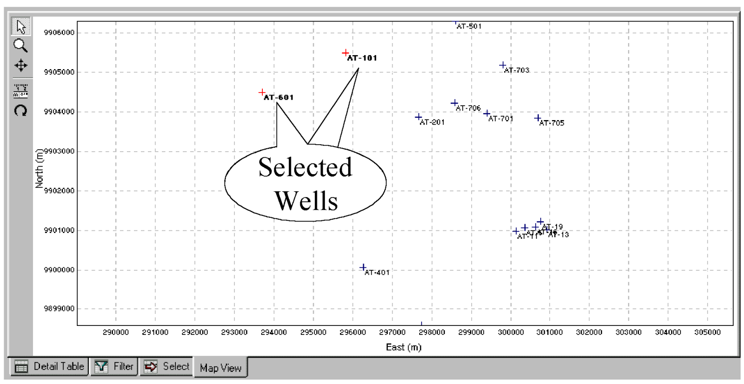

Figure 1b: Map View Screenshot expanded from figure 1a.

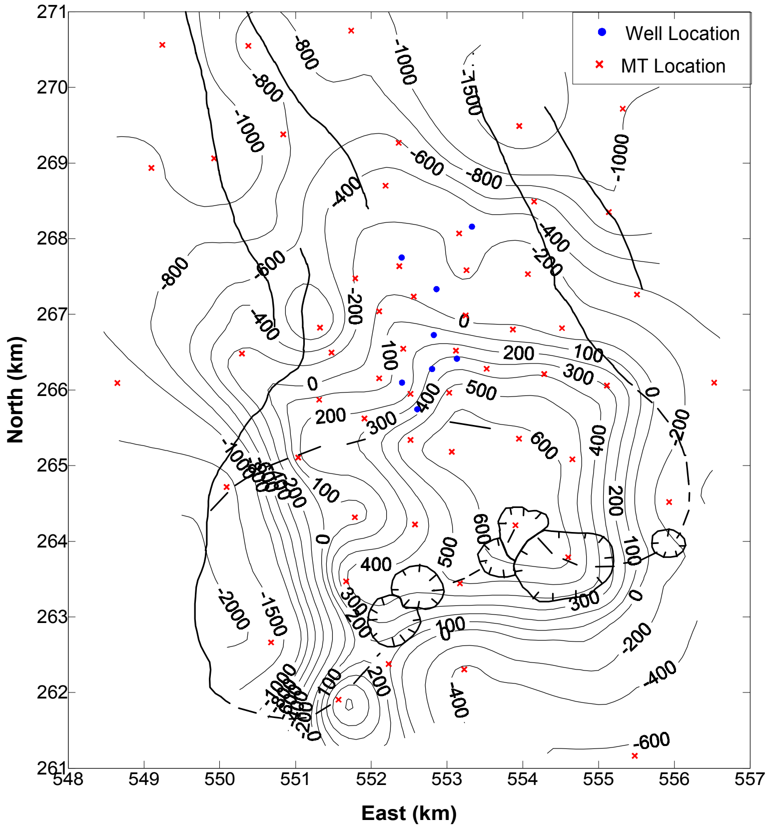

Figure 2: Elevation of the base of the conductive layer

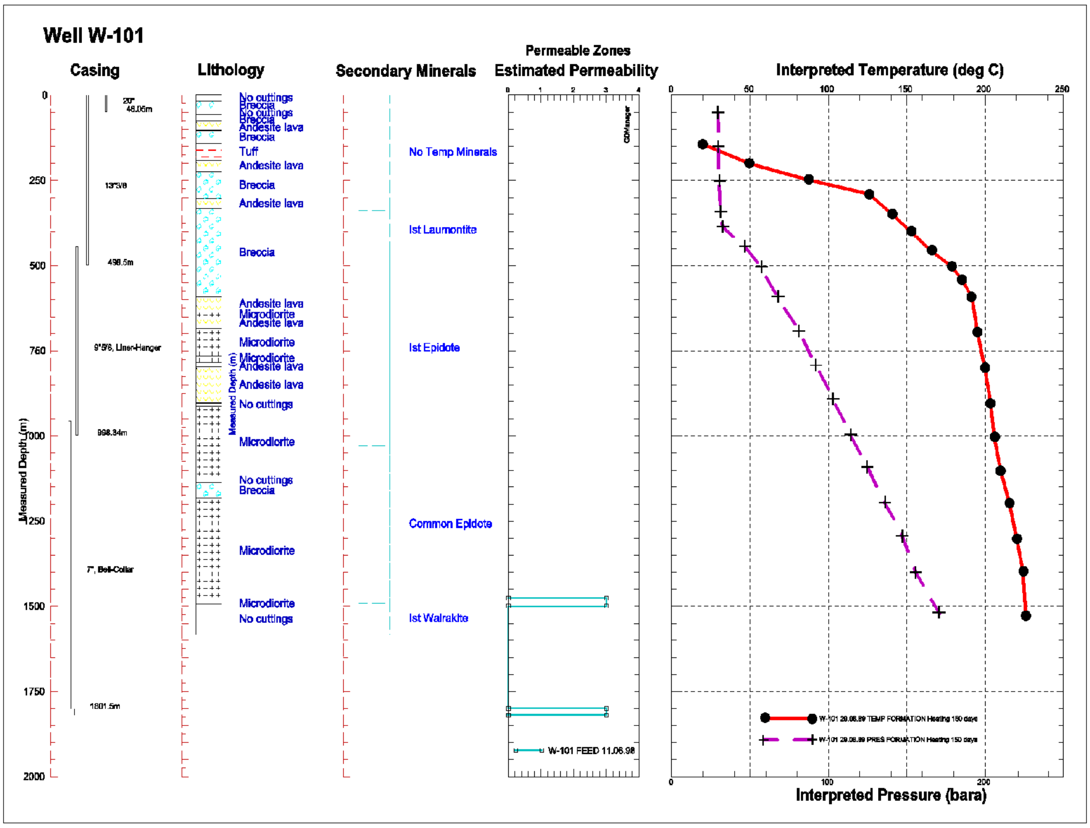

Figure 3: Downhole logging – casing details, well lithology, temperature, and pressure data.

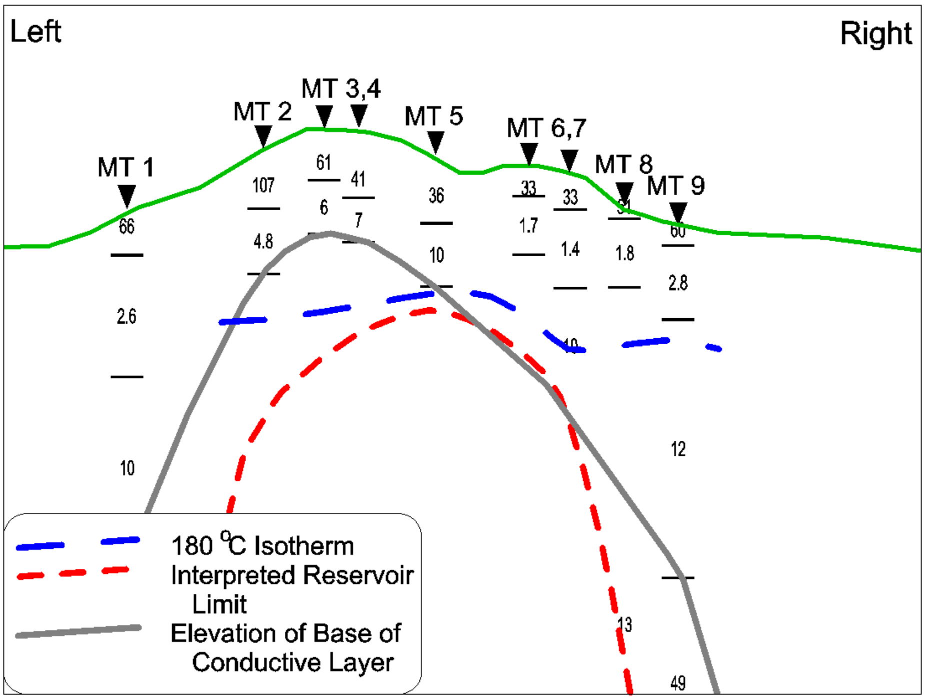

Figure 4: Sketch profile comparing temperature, interpreted reservoir limit, and resistivity data.

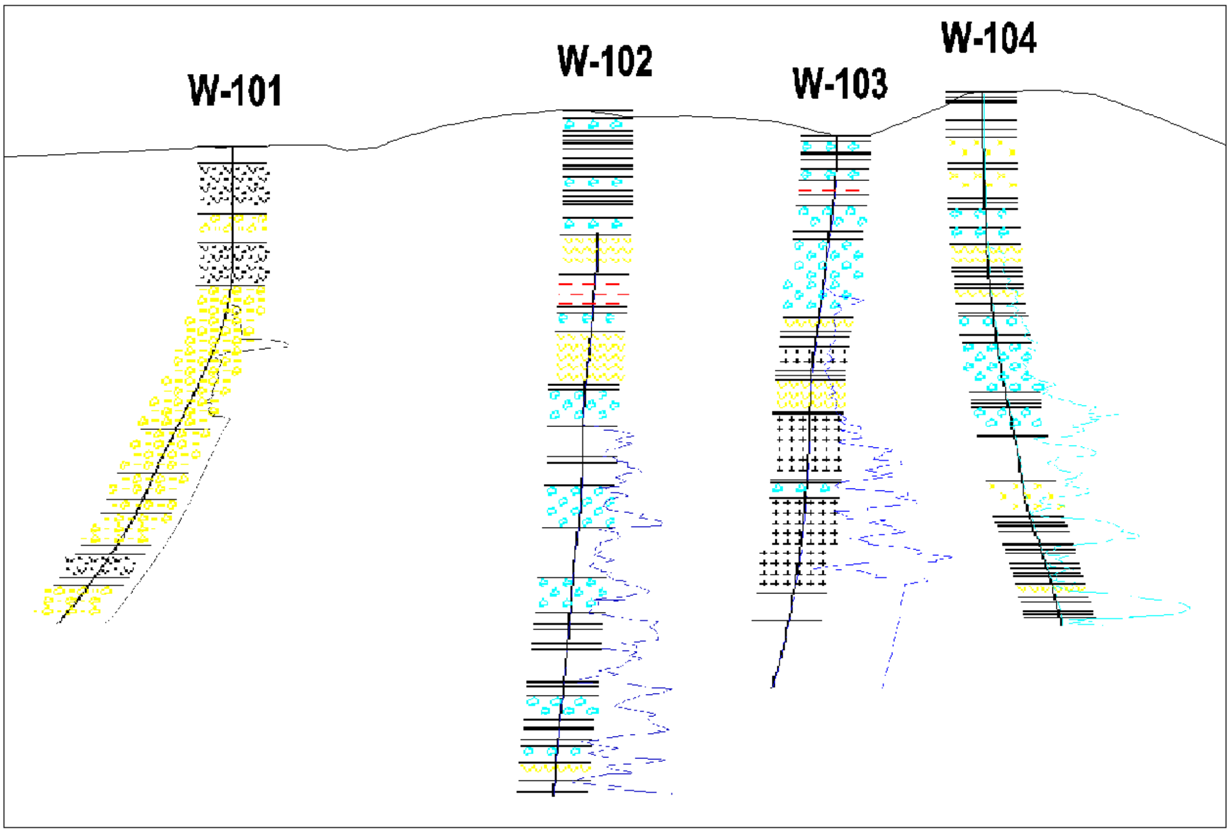

Figure 5: Downhole logging - well lithology, and resistivity data.