GEOSYS: AN X/MOTIF-BASED SYSTEM FOR ANALYSIS AND MANAGEMENT OF GEOTHERMAL DATA

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ABSTRACT

The Geothermal Data Management System (GEOSYS) has been developed to allow storage, retrieval, and analysis of the large volume of data associated with a geothermal reservoir, including well drilling data, well log data, production (chemical and flow) data, and geographical data. The system allows the user to display overlays of well locations, faults, and surface features on maps or topographic images. Subsurface cross-sections can be displayed by selecting any two points on the map. Cross sections show subsurface topography together with the projections of wells along the cross section. The structure of each individual well can also be displayed in detail. Downhole well logs can be selected, displayed, and expanded to arbitrary scale. Time histories of production data can be displayed for the field and for each well. Geothermometer temperatures can be calculated from a variety of chemical concentration measurements. Enthalpy can be calculated from pressure and flow measurements. Data from the Cerro Prieto, Oguni and Sumikawa geothermal fields have been used for development and testing of the system.

This type of system has been made possible by recent advances in hardware and software technology, and the dramatic reduction in cost of high speed workstations and disk storage. GEOSYS was developed using the X Window System and the OSF/Motif widget set. The X Window System was designed specifically to provide hardware independence for interactive systems based on bit-mapped graphics with a Graphical User Interface (GUI). Systems developed using X run on most modern workstations, and can run across a network with the application being resident on only one computer, but accessible to all others.
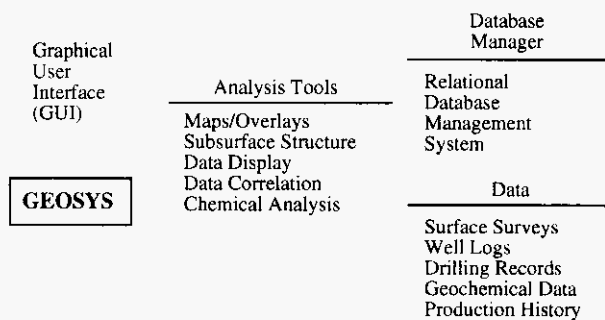
1. INTRODUCTION

The exploration, testing, development, and operation of geothermal reservoirs generates a great quantity and variety of data. Geothermal reservoir analysis and assessment require access to these data in ways that are often difficult to predict. The purpose of the Geothermal Data Management System described in this paper is to provide access to all of the data that are collected related to a particular geothermal reservoir, and to allow interactive extraction, manipulation, and display of these data in a wide variety of formats.

2. GEOTHERMAL DATA MANAGEMENT SYSTEM–CONCEPTUAL DESIGN

The Geothermal Data Management System is an example of a general class of systems built on four basic elements: data, analysis tools, a relational database, and a graphical user interface (Figure 1) In this case the data include well log data (e.g., pressure, temperature, and spinner); related well data such as well locations, deviation logs, and drilling logs; historical data such as production and well test histories, and physical data such as topography and fault locations. The analysis tools operate on this data and extract and/or display information. Examples of analysis tools are programs to display well logs and time histories, to overlay event and geographic information on maps and images and to calculate in-situ physical parameters from geochemical measurements. The data are maintained within a relational database system. The database structure is designed to allow virtually any type of data to be stored and accessed within the system. The relational database performs

GEOSYS (Geothermal Data Management and Analysis System)

Graphical User Interface (GUI)	Analysis Tools	Database Manager
		Relational Database Management System
GEOSYS	Maps/Overlays Subsurface Structure Data Display Data Correlation Chemical Analysis	Data
		Surface Surveys Well Logs Drilling Records Geochemical Data Production History

The **X** interface is **being** written using the X toolkit (Asente and Swick, 1990. Young, 1990).The Xtoolkitenforcesan object-orientedapproach to programming by combining the windows and the operations **an** the windows into "widgets". GEOSYS uses the Motif widget set (Version 1.2) developed by the Open Software Foundation (OSF, 1990) and some additional special purpose widgets.

The relational database tables **used** in GEOSYS are independent of the particular relational database management system used for accessing the tables. GEOSYS **can** use either a proprietary local database manager or interface with an **Oracle** relational database management system either locally or over a network. All database tables are documented in a standard format before being created or used within the system. All files required **for** defining the database structure in SQL. **as** well as internal data structures used within the GEOSYS system are generated directly from this documentation. This way typographic errors are avoided and any changes in the **database** structure can be made throughout the system by changing only the documentation and regenerating dependent files.

GEOSYS takes advantage of the color capabilities of modern workstations to display maps. images, overlays, and graphic displays. The **256** color colormap can he redefined to the optimum set of colors foreach graphical image. Both grayscale and color images can therefore be displayed with maximum dynamic range. Because this paper **is** limited to black and white figures, the extensive use of color within GEOSYS cannot **be** shown here. but representative displays will he presented at the meeting.

4. SYSTEM COMPONENTS

GEOSYS **is** an evolving system of analysis tools that has matured and expanded in functionality through several years of use at S-Cubed for internal research projects. In particular, expon capabilities to other programs and tools for geochemical analysis have been added to the system. **The** Geothermal Data Management System currently consists of 7 modules:

GEOSYS

This is the master program to select data and execute other modules. This and all **of** the other modules contain on-line help to aid the **user** in understanding the options available for each module.

MAP

The Map module allows display of a background image which may he an aerial or satellite photograph, a color or grayscale representation of topography, **an** image displaying a subsurface parameter (e.g. temperature at a given depth). or any other geographic image. Other information may be overlaid on top of this image. Some types of overlays include well locations, hot spring locations. faults, topographic contours, roads. towns, and other surface or subsurface features. Wells can **be** selected hy pointing at any well on the Map. **Any** of the other GEOSYS modules can then **be** started using the selected well. The Cross Section module can he started by selecting any two points with the mouse.

CROSS SECTION

The Cross Section module displays the topography, subsurface geology, and the projection of each well along the selected cross section. This module is normally started from the Map module, although it can be started directly from GEOSYS to display a cross section through **a** selected well.

WELL

The Well module shows the structure of each well in detail, including well deviatinnn along North-South, Est-West, **and** vertical projections, hole/casing structure. cemented and slotted regions, circulation loss points, surface elevation. and stratigraphic layers along the well. Additional information about the well can be displayed in tabular form.

WELL LOG

The Well Log module **is** used to display subsurface profiles of temperature. pressure. spinner, and other downhole measurements (Figure **2).** The displays can be expanded to show fine details of the profiles by simply drawing a rectangle with the mouse around the region to he expanded. Well logs can he displayed as a function of measured depth, true depth, or elevation. The well structure. hole/casing size and locations of circulation **loss** paints can be displayed together with the profiles, and automatically rescale when a region is expanded.
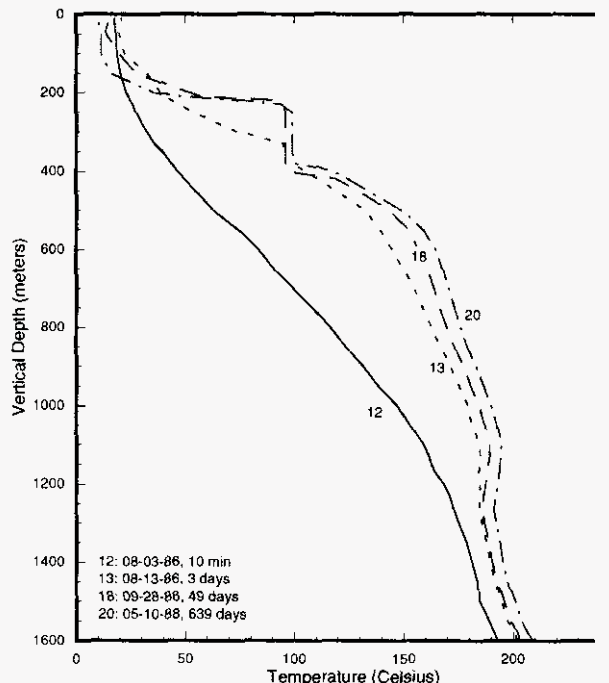

Figure **2.** Temperature log exported from the Well Log module of **GEOSYS.** This figure was exported to Delta Graph on **an** Apple Macintosh for publication.

PRODUCTION

The Production module allows production data taken over thr history of the field and individually for each well to be accessed, displayed. and correlated. Any type of production data including mass flow rate. enthalpy, temperature, and chemical measurements can he stored and accessed by this module. The Cerro Prieto production database used to test the system contains over **120.000** measurements taken from **200** wells over a period of **25** years. The Production module can also perform a variety of calculations using geochemical data, and can display the results of these calculations together with any of the geochemical measurements. Eight **types** of geothermometer relations can **he** used to make temperature estimates. Enthalpy estimates using steam tables together w
Figure **3** shows chloride concentration together with temperature estimates based on silica concentration.

DATABASE

The Database module is the link to the relational database that allows data to be entered. changed, and removed from GEOSYS. Forms are provided for data entry and review for **each** of the **24** database tables. however data may also be added by reading from a **file** in a format that mimics interactive entry. This can be a very significant convenience when a large amount of data is to be added to the system. Data added by file can then he reviewed, edited, and corrected interactively.

5. CURRENT PROJECTS

GEOSYS is currently being used **in** a case study of the **Sumikawa** geothermal field, a high temperature volcanic field located in Japan.
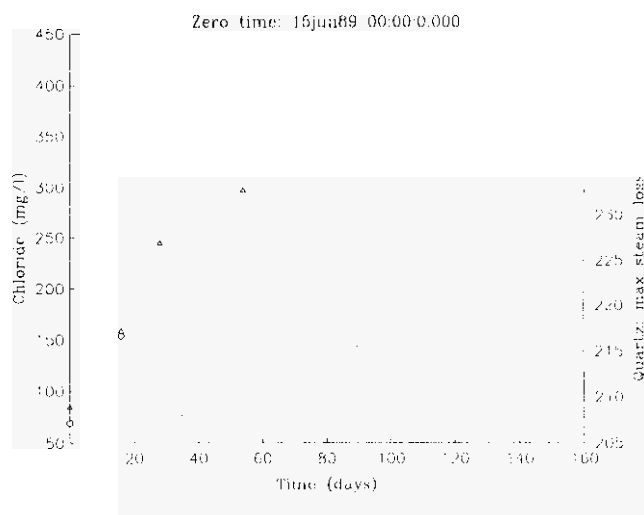
Figure 3. Geochemical data from the Production module of GEOSYS. Chloride concentrations (triangles) **is** compared with geothermometer temperatures (circles) **based on** silica concentration.

This study is being sponsored by the U. S. Department of Energy (DOE) with cooperation from Mitsubishi Metal Corporation (MMC) of Japan. GEOSYS maintains surface maps including well **locations,** topography and tectonic features, **well** histones, drilling data, downhole temperature/ pressure/spinner logs. and geochemical and production data. Upon completion of this project and approval by DOE and MMC, the data will he distributed to qualified users to aid researchers in interpreting **and** analyzing this data **set**

6. CONCLUSIONS

The development of **systems** such as GEOSYS has been made both **necessary and** feasible for three reasons:

1. The volume of data associated with **a** geothermal field and **used** in reservoir assessment has **been** rapidly increasing. This volume of data has great benefits in the ability to analyze a field, but is difficult to analyze by traditional means.

2. Over the last few years, the cost of high speed workstations and disk **storage** has decreased dramatically. while the computational speed and storage capacity have simultaneously increased dramatically. The capabilities of these systems make it possible to develop interactive systems that access and analyze large volumes of data.

3. The development of the X Window system has **made** it possible to develop sophisticated systems with a transportable Graphical **User Interface** capable **of** operating on machines from a wide variety of vendors and on different types of machines **across a** network. Because of this, the software no longer **is** restricted to a particular brand of hardware. and can be easily transported to different machines **as** hardware technology improves.

As a **result.** it is **now** possible to maintain nearly all of the data associated with a geothermal field on a workstation, and to provide the capability to access and analyze thin data.

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