Proceedings World Geothermal Congress 2000
Kyushu - Tohoku, Japan, May 28 - June 10, 2000

DEVELOPMENT OF GEOTHERMAL DATABASE SYSTEM-THE GEOCHEMISTRY OPTION

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Key Words: geochemistry, geothermal database system, post-processor, geochemistry thermometer, Yanaizu-Nishiyama geothermal field

ABSTRACT

Geothermal reservoir analysis and the prediction of geothermal production behavior are important considerations for reservoir management. It is necessary to combine surface exploration results and well data obtained from various surveys in order to form an integrated three-dimensional model of a geothermal reservoir. Exploration data has been collected by many researchers in the fields of geology, geophysics, chemistry, drilling, logging, reservoir engineering, etc. over a long period of time. Specialists in geology and reservoir engineering must make a great effort to find essential information for geothermal reservoir modeling from the tremendous amount of data presented in various formats.

The geothermal database system GEOBASE (Sato et al., 1995) was developed to assist in reservoir management. GEOBASE includes well data (drilling, logging etc.), and geological, geophysical, topographic, production/injection, and image data etc. GEOBASE works on many platforms including PC's (Windows95/98/NT), UNIX (HP, SUN workstation) and client server systems. Based on ORACLE7.3, client server systems are easily constructed using LAN/WAN networks on PC and UNIX machines. The system also has a functional post-processor for numerical reservoir simulations. This system operates by clicking on a data keyword and then immediately drawing the selected data by using X-Y line graph options or two / three-dimensional mapping options.

Although geochemistry is one of the important factors in understanding a reservoir, GEOBASE previously did not have functions to access geochemical data. Recently, such function as the geochemistry table and display functions were added to GEOBASE. This paper describes a summary of GEOBASE, the addition of the geochemical functionality, and the application of GEOBASE to the Yanaizu-Nishiyama geothermal field in northern Japan.

The efficiency of handling geochemical data was improved by upgrading the software. Newly developed graphic routines include 1) Ternary diagrams, 2) Hexadiagrams, 3) X-Y plots, 4) Time series displays, and 5) Shoeller plots. Furthermore, a geochemical thermometer computing facility was added to estimate reservoir temperatures.

The database functions were applied to the Yanaizu-Nishiyama geothermal field. Comparison and correlation of chemical elements from different wells was accomplished by using the graphing functions. These indicated the distribution of the chemical elements in each well. The reservoir temperature was calculated by appropriate use of a silica geochemistry thermometer .

1. INTRODUCTION

Geochemical techniques using chemical and isotope data have a remarkable impact on the evaluation of hydrothermal systems. The techniques are expected to substantially contribute to the development of geothermal systems. Geothermal investigations using geochemical techniques have been discussed in the U.S.A., New Zealand and Italy from the earliest stages of modern geothermal development. Recently, geochemical monitoring has been recognized as an effective technique in evaluating the origin and flow of geothermal fluids. This is primarily due to improvements in chemical analysis technology.

Geochemical monitoring is an important factor in maintaining the geothermal reservoir, the power generating facility, the environment, etc. after the start of commercial operations at a power plant. For example, with regards to for the power generating facility, the pH, salt, and H_2S concentrations must be monitored for erosion and corrosion problems, and SiO_2, $CaCO_3$, SO_4 concentrations must be watched to prevent plugging of the production and injection wells. These problems may be effectively dealt with chemical monitoring. Regarding environmental management, As and H_2S concentrations must be monitored as well as CO_2 from a global warming viewpoint. Thus, monitoring the geochemistry is a factor as important as temperature and pressure monitoring.

Recently, White (1995) developed a geochemical reservoir simulator (CHEM/TOUGH2) which can handle the interactions between fluid and rock masses. An accurate geothermal reservoir model can be made by using the simulator. Detailed geochemistry and altered mineral database will be an important input to the reservoir modeling.

In this paper, the development and addition of chemical functions to the geothermal database system GEOBASE is presented. And we showed the application of these new functions to the Yanaizu-Nishiyama geothermal field in northern Japan.

2. SYSTEM BACKGROUND

The Yanaizu-Nishiyama geothermal power station is located in Yanaizu-cho in the Fukushima Prefecture in the northern part of the Japan Main Island. It is a single-unit geothermal power station with the largest single-flush type steam turbine in Japan with an approved production capacity of 65MW. Tohoku Electric Power Company is responsible for the power generation section of the station and Okuaizu Geothermal Company is responsible for the steam supply section. The station began operation in May, 1995.

Okuaizu Geothermal Company, which is also in charge of development of the station, started computer control of production injection data immediately after the start of operation. They have been selecting data required for future reservoir control using the GEOBASE program. GEOBASE has been developing since 1995 using Yanaizu-Nishiyama data. The production/injection histories of the field are reviewed by using TOUGH2. The numerical model for TOUGH2 is produced by using a GeoCAD pre-processor program.

3. SYSTEM OUTLINE

The system consists of :

(1) GEOBASE2.4 : Exploration and Production database used for entering, querying, and displaying all types of data in a comprehensive manner (see Figure 1).

(2) GEOCAD3.0 : Pre-processor GeoCAD3.0 used for constructing a 3-dimensional numerical model based on a conceptual model developed by an integrated data analysis using the database.

(3) TOUGH2 : Reservoir simulator TOUGH2 (Pruess, 1991).

(4) GEOSURF : WWW (World Wide Web) system Geo-Surf.

GEOBASE2.4 runs on PC (Windows9X/NT) and UNIX (HP9000/700, SUN) systems. GeoCAD3.0 runs on PC's (Windows9X/NT) and UNIX (HP9000/700) and Geo-Surf runs under Windows NT.

GEOBASE was developed using Oracle (the current version is

Oracle 7.3 or Personal Oracle 7.3). This is a decentralized relational database and is widely used all over the world. The database is a simple structure. It is easy to redefine and enter all types of data. With Oracle 7.3 it is also possible to form a decentralized system (client-server system) using a LAN or WAN that can easily join many PCs and UNIX machines. The data retrieval and mapping functions of the database allow 2- and 3-dimensional representation of the data obtained by using single data sets or superimposing several data sets, e.g., geological column diagrams, logging data, surface survey data, production/injection data, or the results of a reservoir simulation. Recent developments including faster data retrieval and display functions for geochemical data makes GEOBASE even more efficient for reservoir management than before. Figure 1 shows an example display of GEOBASE2.4. Figure 2 presents the data structure of GEOBASE2.4.

In the following sections, the functions and features of the newly developed geochemistry data table are illustrated using Yanaizu-Nishiyama geothermal field data.

4. GEOBASE GEOCHEMISTRY FUNCTIONS AND THEIR APPLICATION TO THE YANAIZU – NISHIYAMA GEOTHERMAL FIELD

4.1 Function and Features of the Geochemistry Table

Since geochemical data have been registered (the keyword is the chemical composition) as time series in GEOBASE, the data are displayed in time series plots. The following features have been added to the newly developed geochemistry data table: 1) Improvement in searchability, 2) Easy registration, 3) Simplified comparisons with retrieval data, 4) Data sharing. Components that may be registered are shown in Table 1.

It is possible to register most chemical compositions and isotopic ratios, pH and electric conductivities with brine, steam and vapor condensation. It is also possible to register optional components by adding a keyword to the chemical database.

The following graphs can be easily produced with the geochemical data table. These are 1) Ternary diagrams, 2) Hexadiagrams, 3) X-Y diagrams, 4) Time series displays, and 5) Shoeller plots.

Reservoir temperatures can be calculated using the geochemistry thermometer computing facility. Ten types of geochemistry thermometers (e.g. silica and Na/K) are available with the system. Registered equations are shown in Table 2. Graphically calculated geochemistry thermal data can be displayed as time series.

4.2 The Application of GEOBASE to Yanaizu-Nishiyama Geochemistry Data.

We applied the geochemical function to the Yanaizu-Nishiyama field. Firstly we made the geochemistry database of the Yanaizu-Nishiyama field.

The data retrieving procedure is to choose an appropriate type of graph from the tool bar. We need to choose necessary data for the graph such as "name of well", "element", "sampling period". The units and scale (linear or logarithm) of the graph are changed easily.

We made the ternary diagram (Figure 3). This diagram shows that Na-K-Ca-Mg concentration from 3 wells are similar in Yanaizu-Nishiyama geothermal field.

Deuterium isotope values are plotted relative to Oxygen-18 isotope (^{18}O) values for brine samples (Fig. 4). The meteoric water line is indicated. There is a positive ^{18}O shift relative to meteoric water. This indicates that the rock/water ratio is fairly high and/or the system is relatively mature.

Figure 5 is the time series diagram, which can easily manage history data. Especially, A vertical axis shows the Na concentration divided by Cl concentration, which can watch the influence of other source. It is an important feature that we can use the recalculated concentration like this.

Figure 6 is the shoeller plot, which can be used to compare the tendency of the chemical concentration.

Chemical geothermometer temperatures are calculated using the standard chemical geothermometer equations. This is illustrated graphically in Figure 7. This was calculated using the equation for "Quartz-no steam loss". The tendency of the reservoir temperature is indicated. Of course, it is possible to compare results using the other chemical geothermometer equations too. Estimates of reservoir temperatures are more accurate using GEOBASE's ternary diagrams (ex. Na-K-Mg).

Combining these newly developed geochemistry functions, information and reservoir management become more effective.

5. CONCLUSIONS

GEOBASE now includes a geochemistry database. We can analyze the geochemical data using newly developed graphs and functions.

These functions make it possible to compare different elements in many ways. In particular, it is an important feature that we can recalculate a component concentration using another component.

Thus, reservoir management will be more effective by integrating newly developed geochemical functions to the present GEOBASE.

6. REFERENCES

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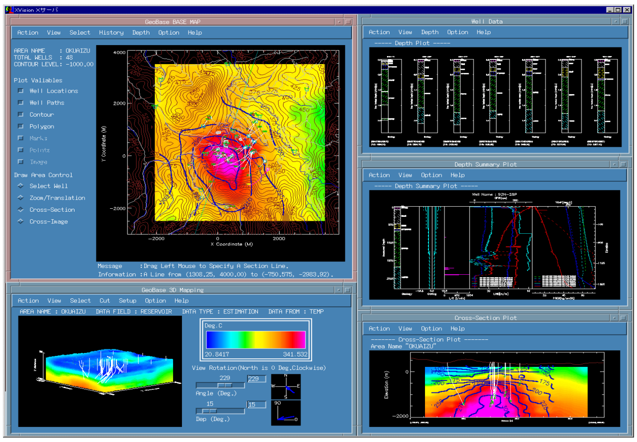

Figure 1. Overview of GEOBASE2.4

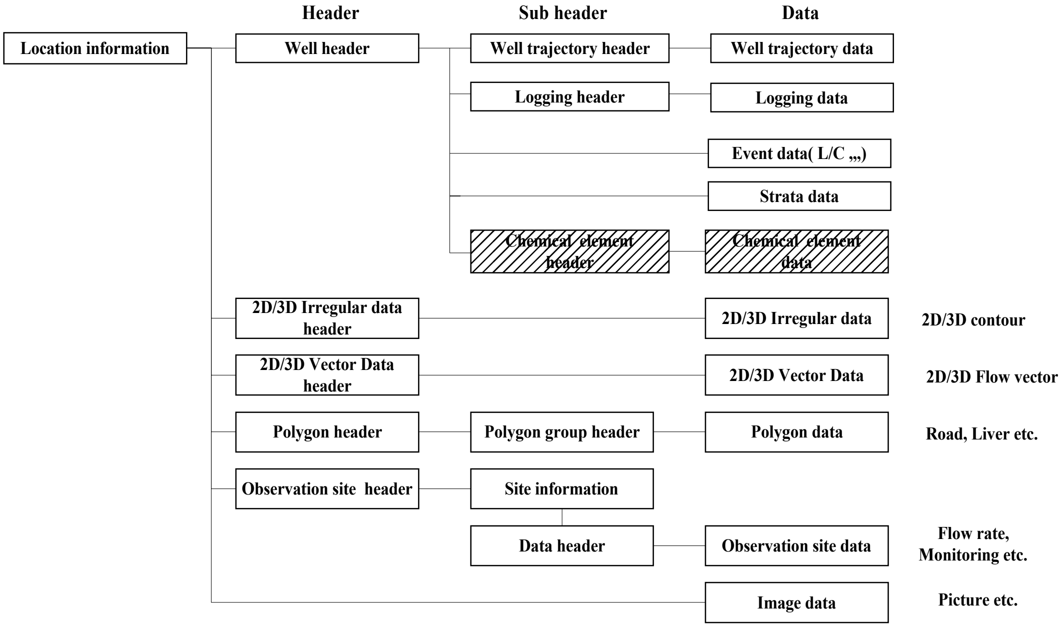

Figure 2. Data structure of GEOBASE2.4

Table 1 Geochemical component registration data

Brine	pH, EC, Chemical components, Isotope components etc.
Steam	Chemical components, Isotope components etc.
Condensate	Chemical components, Isotope components etc.

Table 2 Present geochemistry thermometers available in GEOBASE

Quartz-no steam loss	Amorphous Silica
Quartz-maximum steam loss	Na/K (Fournier)
Chalcedony	Na/K (Truesdell)
α -Cristobalite	Na-K-Ca
β -Cristobalite	$\Delta\, ^{18}O(SO_4^{2-}-H_2O)$

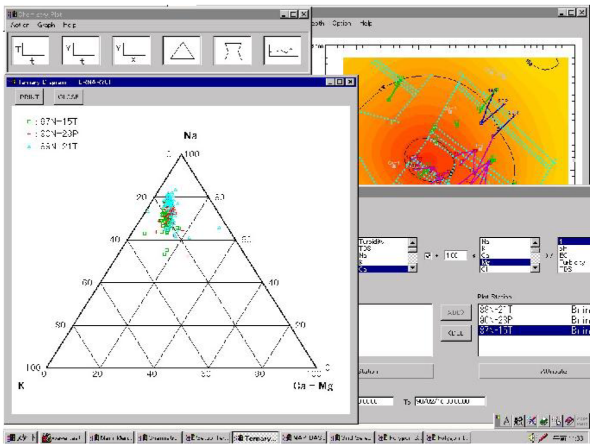

Figure 3. Ternary diagram

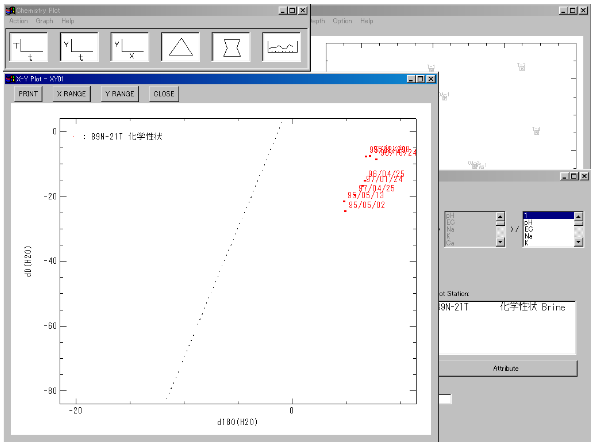

Figure 4. X-Y plot

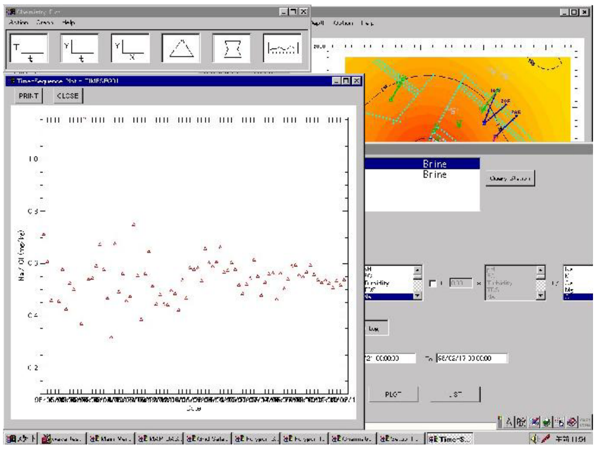

Figure 5. Time series diagram

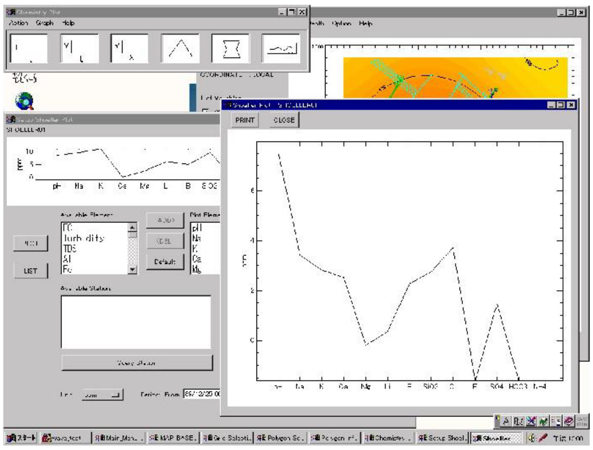

Figure 6. Shoeller plot

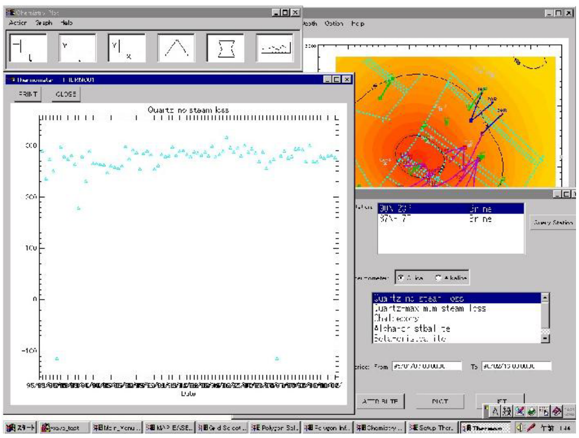

Figure 7. Geochemistry thermometer diagram