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RESERVOIR ENVIRONMENT OF THE ONUMA GEOTHERMAL POWER PLANT, NORTHEAST JAPAN, ESTIMATED BY FORWARD ANALYSIS OF LONG-TERM ARTIFICIAL-TRACER CONCENTRATION CHANGE, USING SINGLE-BOX-MODEL SIMULATOR

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ABSTRACT

A single-box-model numerical simulator for personal computer analysis was developed in order to estimate macroscopic parameter values for exploited geothermal reservoirs and essential fluids coming from the depth. The simulator was designed to compute history data concerning total production and reinjection fluids at geothermal power plants from the assumed parameter values, based on conservation laws for water mass, heat energy and masses of conservative chemical constituents of geothermal fluids. Using two kinds of forward analysis techniques, i.e. the cast-net and pursuit methods, programs containing the simulator can semiautomatically select the optimum combination of the unknown parameter values by minimizing the differences between the simulated and measured history data for specific enthalpy and chemical compositions of the production fluids.

The forward analysis programs were applied to the history data from the Onuma geothermal power plant (production capacity, 10MWe) where waste hot water reinjection, chemical monitoring and artificial tracer tests have been conducted since 1970, almost the beginning of the geothermal exploitation. Using the history data, enthalpy and iodine concentrations of the total production fluids with the amounts of KI tracer injected as spikes, the macroscopic parameter values for the exploited reservoir and the essential hot water from the depth were uniquely determined as follows: mass of the hot water convecting in the exploited reservoir (M0), 3.23×10^9kg; recycling fraction of the reinjected waste hot water to the reservoir (R), 0.74; specific enthalpy of the essential water from the depth (H1), 385kcal/kg; iodine concentration of the water (I1), 0.086mg/kg with chlorine concentration (C1), 259mg/kg. These results support the conceptual model that the exploited Onuma reservoir mainly in the Tertiary volcanics is supplied with the neutral Na-Cl type hot water of abnormally high B/Cl mole ratio of around 1.0 by a large essential reservoir distributed at depth in the Paleozoic to Mesozoic detrital marine sedimentary rocks.

INTRODUCTION

Producing large amounts of geothermal fluids for power generation causes dynamic changes in reservoir, such as boiling, cold groundwater invasion and essential fluid inflow from the depth. Reinjection of the produced hot waters after steam separation to the reservoir, as at most geothermal power plants in Japan mainly for the purpose of environmental protection, has a large effect on the changes. Therefore, it is very important to optimize allocation of geothermal wells, and their production and reinjection rates, through understanding the nature of these changes and predicting their future, for the purpose of long-term stable operation of geothermal power plants.

In Japan, monitoring concentrations of major chemical constituents in production fluids has been conducted at almost all the geothermal power plants. Also, artificial tracer tests have been tried at many Japanese geothermal power plants. These chemical history data have been analyzed by many kinds of methods for various objectives (e.g. Shigeno, 1992a).

Among these, the studies for the hydrothermal system of the Onuma geothermal power plant by Ito et al. (1978), Matsubaya and Kubota (1987), Kubota and Matsubaya(1987), and Kubota et al. (1989) are very important concerning not only the optimization of geothermal reservoir exploitation but also resource assessments of hydrothermal systems. They tried to estimate macroscopic values for the exploited reservoir, i.e. total amount of the hot waters convecting in the reservoir and recycling fraction of the reinjected waste hot waters to the reservoir, based on a single box model using artificial tracer (iodine ion, I) test data and chemical (especially chlorine ion, Cl) monitoring data. Concerning a well at the Palinpinon geothermal power plant in the Philippines, Malate and O'Sullivan (1991) reported an application of the similar lumped-parameter model to the analysis of the production fluid chemistry changes.

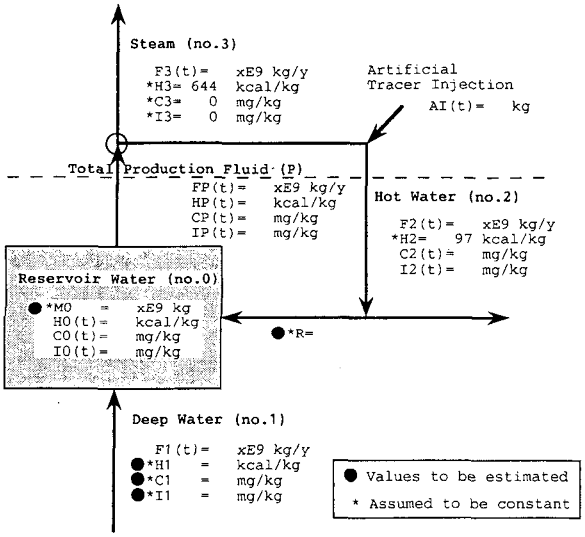
We developed semiautomatic forward analysis programs for personal computers in order to estimate macroscopic values for exploited geothermal reservoirs and essential geothermal fluids from the depth, through repetitions of single-box-model numerical simulations, using chemical monitoring data. These programs were applied to the monitoring data from the Onuma area, and the results were compared with those by the above papers, and with the previously proposed hydrothermal-system models for the Onuma area. In this paper, these methods and results were reported. For more details of this paper, refer to Shigeno et al. (1992b) and Shigeno (1992c).

ANALYTICAL METHOD

Single box model, and difference equations

Fig. 1 shows the very simple single box model of exploited hydrothermal systems used for the numerical simulations in this study. This model is based on Matsubaya and Kubota (1987). An exploited geothermal reservoir is represented by a single homogeneous box, in which only hot water circulates as the fluid phase (shown with suffix 0). Non-steady-state inflow to, and outflow from the reservoir box are as follows: an inflow of an essential hot water from the depth (1); outflows of total hot water (2), and total steam (3) through all the production wells; and an inflow of the waste production hot water which was reinjected through all the reinjection wells and partly recycled. The total production fluid, the sum of the separated total hot water and steam (1+2), is shown with suffix P. Neither conductive heating by high-temperature sources from the depth nor cold sweep process of the heat stored in rocks by the reinjected waters in and around the reservoir is included in this model.

In this model, the total hot water convecting in the reservoir box, the fluid flow rates, and the recycling fraction of the reinjected total hot water to the reservoir are shown with M0 ($\times 10^9$kg), F ($\times 10^9$kg/y), and R, respectively. Time-series data used in the analysis are specific enthalpies (H kcal/kg), Cl concentrations (C mg/kg), and I concentrations (I mg/kg) of the above geothermal fluids. Amounts of KI, which was injected into the reinjection wells as spikes during tracer tests, are also used as time-series data (AI kg).



F: Flow rate
H: Specific enthalpy
C: Cl concentration
I: I concentration
AI: KI tracer amount

*M0: Mass of convecting reservoir water
*R: Recycling fraction of reinjected water
*H1: Specific enthalpy of deep water
*C1: Cl concentration of deep water
*I1: I concentration of deep water

Fig. 1. Single box model of exploited hydrothermal system for numerical simulation forward analysis based on chemical history data.

Concerning the above single box model, the time difference equations {1} to {4} in Fig. 2 are assumed, based on the conservation laws of water mass, heat energy, and masses of Cl and I for the geothermal fluids. In addition to these, the equations {5} to {7}, and {8} to {11} are assumed for the relationships of the total production fluid and the hot water convecting in the reservoir, and for those of the total production fluid, and the hot water and the steam generated from the total fluid, respectively.

Algorithms of analysis, and programs

The objective of the present analytical method is to estimate systematically the unknown macroscopic parameter values for the exploited reservoir and the essential hot water from the depth, M0, R, H1, C1 and I1, when the history data of the production fluids, FP (or F2 and F3), HP (or H2 and H3), CP (or C2), and IP (or I2), as well as the history data of the artificial tracer injection (AI), are available.

The temporal changes of H0(t), C0(t) and I0(t) for the reservoir hot water, and of HP(t), CP(t) and IP(t) for the total production fluid can be simply numerically simulated using the history data of FP(t) and AI(t), based on the equations {1} to {11}, when the above five unknown parameter values are assumed, and the measured values of HP(1), CP(1) and IP(1) are used as the initial values, H0(0), C0(0) and I0(0). This is because the supplemental equations {5} to {11} are available, although the fundamental equations {1} to {4} are seemingly of implicit scheme. By the way, the measured values of HP(t), CP(t) and IP(t) are also available. Therefore, the optimum combination of the above parameter values can be obtained, using forward analysis methods, by minimizing the objective functions, σHP, σCP and σIP, which are defined by the equations {12} to {14} in Fig. 2.

In the present analytical method, the optimum combination of the unknown parameter values is semiautomatically determined by repeating the following two simple techniques, namely cast-net and pursuit methods. (1) Cast-net method (cover-all method): The parameter space, *in which the objective functions have low values,* is selected by systematic repetitions of the numerical

Fundamental equations:

M0 = M0 + F1(t)*Δt - (1-R)*F2(t)*Δt - F3(t)*Δt {1}
H0(t)*M0 = H0(t-1)*M0 + H1*F1(t)*Δt - (1-R)*H2(t)*F2(t)*Δt - H3(t)*F3(t)*Δt {2}
C0(t)*M0 = C0(t-1)*M0 + C1*F1(t)*Δt - (1-R)*C2(t)*F2(t)*Δt - C3(t)*F3(t)*Δt {3}
I0(t)*M0 = I0(t-1)*M0 + I1*F1(t)*Δt - (1-R)*I2(t)*F2(t)*Δt - I3(t)*F3(t)*Δt + R*AI(t)*0.76*E6 {4}

Supplemental equations:

HP(t) = H0(t-1) (Calculated) {5}
CP(t) = C0(t-1) (Calculated) {6}
IP(t) = I0(t-1) (Calculated) {7}

FP(t) = F2(t) + F3(t) {8}
HP(t)*FP(t) = H2(t)*F2(t) + H3(t)*F3(t) {9}
CP(t)*FP(t) = C2(t)*F2(t) + C3(t)*F3(t) {10}
IP(t)*FP(t) = I2(t)*F2(t) + I3(t)*F3(t) {11}

Parameters to be estimated:

M0 *E9 kg (Mass of convecting reservoir water)
R (Recycling fraction of reinjected water)
H1 kcal/kg (Specific enthalpy of deep water)
C1 mg/kg (Cl concentration of deep water)
I1 mg/kg (I concentration of deep water)

History data:

FP(t)	*E9 kg/y	
HP(t)	kcal/kg	(Measured)
CP(t)	mg/kg	(Measured)
IP(t)	mg/kg	(Measured)
AI(t)	kg	

Objectives: Estimate the M0, R, H1, C1 and I1 values (constants) that minimize σ_{HP}, σ_{CP} and σ_{IP}.

σ_{HP} = (Σ(HP(t)calc - HP(t)meas)^2/N)^0.5 {12}
σ_{CP} = (Σ(CP(t)calc - CP(t)meas)^2/N)^0.5 {13}
σ_{IP} = (Σ(IP(t)calc - IP(t)meas)^2/N)^0.5 {14}

Fig. 2. Equations, parameters to be estimated, history data and objective functions used for single-box-model numerical simulation forward analysis of exploited hydrothermal system.

simulations with the series of assumed parameter values, which are arranged to cover broad ranges with appropriate step sizes. (2) Pursuit method (gradient method): In the parameter space, values of the objective function(s) are calculated for a point of an initial combination of the parameter values, and for the adjacent points, at which one small step value is added to or subtracted from one of the parameter values, by a series of the numerical simulations. By this procedure, the point which has the lowest value(s) for the objective function(s) is selected. The same procedure is repeated around the newly selected point, until the point which has the optimum combination of the parameter values is settled. Two personal computer programs, which contain the single-box-model numerical simulator, were developed for the semiautomatic forward analysis of the chemical history data from exploited geothermal areas, based on the above two algorithms.

OUTLINE OF THE ONUMA AREA

The Onuma area is located in the Sengan regional geothermal field, Northeast Japan. Mitsubishi Metal Co. (presently Mitsubishi Materials Co.) has been conducting geothermal exploration and well drilling in and around this area since 1965, and began the operation of the Onuma geothermal power plant (capacity, 10MWe) in 1973.

The Onuma area is locate in an extension of the Hanawa graben of N-S trend. The Quaternary andesite composite volcanoes, Hachimantai and Akita-Yakeyama, are distributed to the east and west of the Onuma area, respectively. At the Onuma area, a hot-water system of around 215°C is developed at the exploited level, mainly along fractures, in the Neogene formations composed mainly of volcanic and pyroclastic rocks. The hot waters are basically of the neutral Na-Cl type with low Cl concentrations of about 400 mg/kg but abnormally high B/Cl mole ratio of around 1.0.

At the Onuma area, all the produced hot waters have been reinjected underground since the beginning of the geothermal exploitation (see Fig. 3). Ito et al. (1977, 1978) systematically conducted artificial tracer tests during 1975-76, by injecting KI tracer (total amount, 1500kg) into four reinjection wells (depth, 600-1200m), and measuring the changes of I ion concentrations at five production wells (depth, 1400-1800m). The fifth tracer test (KI, 300kg) was tried in 1983, using the temporarily-used reinjection well O-8R, when the production from the well O-10R began (Kubota et al., 1989).

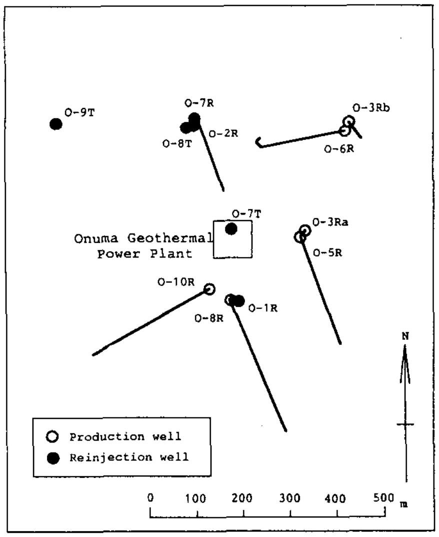


Fig. 3. Distributions of production and reinjection wells at the Onuma geothermal area (modified from Kubota et al. (1989)).

Concentrations of major dissolved components in the hot waters from the production wells have been periodically measured at the Onuma area since the beginning of the geothermal exploitation. Kubota et al. (1989) reported the annual averages of the total production fluids, from 1970 to 1987, for the wellhead pressure, flow rate, specific enthalpy, Cl and I concentrations, Cl/B mole ratios, and the reservoir temperatures estimated by the SiO_2 and Na-K-Ca geothermometers.

The Sumikawa area, which is located about 1.5 km west to the Onuma area, has been under intensive geothermal exploration since 1981. Mitsubishi Materials Co. and Tohoku Electric Power Co., Inc. have been conducting well drilling and production tests with a schedule of opening a geothermal power plant (capacity, 50MWe) in 1995 (Sakai et al., 1986; Ueda et al., 1991).

FORWARD ANALYSIS OF THE ONUMA HISTORY DATA

Data and methods

Concerning this forward simulation analysis of the Onuma hydrothermal system, history data used were basically the annual average values of the total production fluids: flow rate (FP), specific enthalpy (HP) and I concentration (IP) during 1970-1987, and the injected KI tracer amount (AI) (Ito et al., 1978; Kubota et al, 1989). The changes of the allocation and the use of the wells during the period (Kubota et al., 1989), were not regarded in this study. The KI tracer injection into the O-8R well, which was temporarily used as a reinjection well in 1983 (Kubota et al., 1989), was not included in this analysis, because the KI tracer was seemingly not mixed with the hot waters convecting in the exploited reservoir.

The two kinds of the newly developed programs were used for the data analysis. The major unknown parameters determined were M0, R, H1 and I1, and the objective functions were σIP and σHP. The time-step numbers a year used for the numerical simulations were basically 4 times, but 12 times during 1974-1978 when the IP values rapidly changed due to the KI tracer injections. The assumed

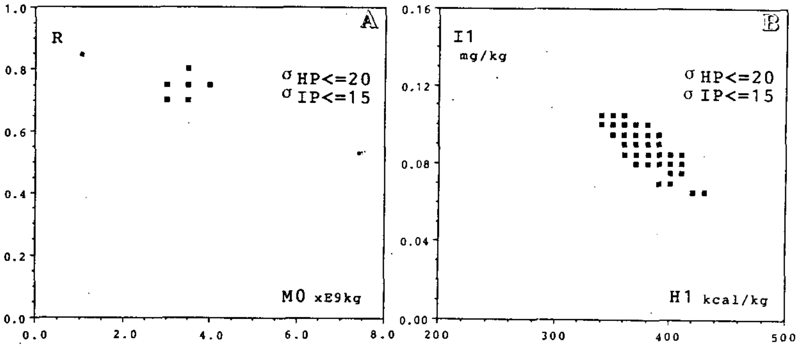


Fig. 4. Forward analysis results of Onuma history data by the cast-net method program using σIP and σHP as objective functions: Cases with suitable combinations of parameter values were projected on M0-R plane (A) and on H1-I1 plane (B).

parameter value, I1, was used as the initial I0 value for each case of the numerical simulations, because the IP values before 1974 were not available (Kubota et al., 1989). The objective function, σIP, was accordingly calculated for 1974-1987.

Results by the cast-net method

Table 1 shows an example of the data analysis by the cast-net method for the Onuma hydrothermal system. Fig. 4 (A) and (B) show the results of this example, plotting the points of suitable parameter-value combinations on M0-R and H1-I1 parameter planes, respectively. Fig. 4 indicates that the points gather in one place in the four-dimensional space, suggesting that the unique solution exists in the limited space. However, the correlations between σIP and σHP indicate that σIP and σHP do not take their minimum values at the same time. Hence, the point, at which the modified optimum condition that the lowest σIP value is obtained with the σHP value close to the minimum value is satisfied, was searched for. Based on these results for the large parameter space, the cast-net method was applied, several times, to the gradually limited space with smaller step sizes of the parameter values. As the result, the optimum combination of the parameter values, M0, R, H1 and I1, obtained were 3.23 x10^9kg, 0.74, 385 kcal/kg and 0.086 mg/kg, respectively.

Results by the pursuit method

Fig. 5 (A) and (B) show analytical results of one case by the pursuit method, in which σIP and σHP were used as the main and associate objective functions, respectively, plotting the pursuit trail on the M0-R and H1-I1 parameter planes. Fig. 6 shows the changes of the σIP and σHP values with increasing pursuit step numbers. The decrease of the σIP value by this pursuit was associated with the increase of the σHP value after passing the minimum point of the σHP value (no. 237). Hence, this point was selected to be appropriate as the solution point. All the parameter values of the above point were consistent with those obtained by the cast-net method. These results were certified by several times of applications of the pursuit method analysis with different initial parameter values.

Summary of the results

Using the optimum-value combination of the parameters, M0, R and H1, the optimum C1 concentration of 259 mg/kg was obtained by the cast-net method with the objective function, σCP. Fig. 7 shows the monthly changes of HP, CP and IP, which were calculated by the numerical simulation method with the above optimum parameter values and 12 time-steps a year, in comparison with the measured values. The temperature of the essential hot water from the depth was calculated to be 342°C from the above optimum H1 value. Fig. 8 conceptually shows the reserves and the flows of water mass, heat energy and aqueous ions of Cl and I in and around the exploited geothermal reservoir of the Onuma area in 1976.

Table 1. An example of the cast-net method forward analysis using single-box-model numerical simulator for the history data (IP and HP) from the Onuma geothermal power plant (see Fig. 4).

(1) Run number: N-124

(2) Assumed parameter values:

		Minimum value	Maximum value	Step value	Number of cases
M0	*10^9kg	0.5	7.5	0.5	15
R		0.05	0.95	0.05	19
H1	kcal/kg	250	450	10	21
I1	mg/kg	0.050	0.150	0.005	21

(3) Objective functions: σ_{HP}<=20 and σ_{IP}<=15

(4) Total numbers of simulated cases: 125,685
Suitable cases for the objective functions: 70
Suitable case ratio: 0.000557

DISCUSSIONS FOR THE ONUMA HYDROTHERMAL SYSTEM

Comparisons of results obtained with single box models

Table 2 shows the macroscopic parameter values for the exploited reservoir at the Onuma area estimated by the previously reported studies and by this study, based on single box models using the artificial tracer test and chemical monitoring data. Matsubaya and Kubota (1987), Kubota and Matsubaya (1987), and Kubota et al. (1989) used the history data stabilized or changed in one year, assuming that the Cl and I concentrations of the essential hot water from the depth were equal to those of the total production fluids obtained at the initial stage of the geothermal exploitation.

The M0 value, which is about 30% smaller than the present result, by Matsubaya and Kubota (1987) using the changes of the Cl concentrations and the $\delta^{18}O(H_2O)$ values

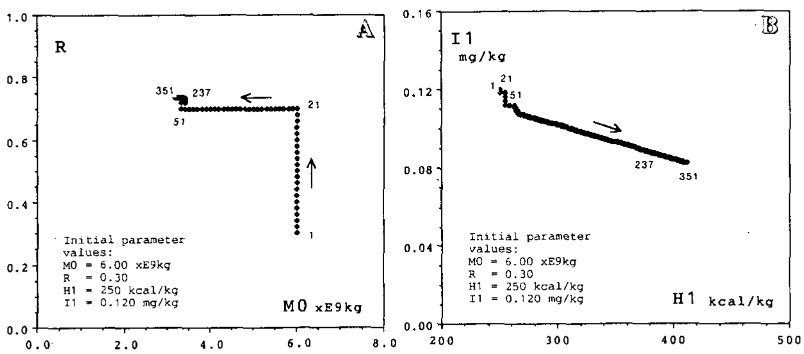


Fig. 5. Forward analysis results of Onuma history data by the pursuit method program using σIP with σHP as objective functions: Pursuit trail for more suitable combinations of parameter values was projected on M0-R plane (A) and on H1-I1 plane (B) (step numbers are shown in the figure; refer to Fig. 6).

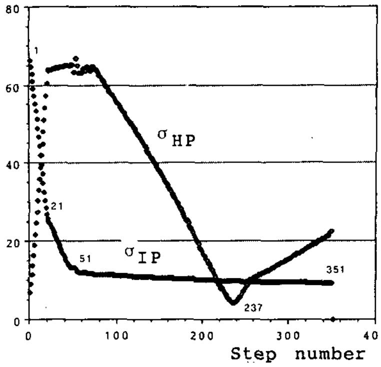


Fig. 6. Forward analysis results of Onuma history data by the pursuit method program using σIP with σHP as objective functions: Changes of σIP and σHP values along the pursuit trail for more suitable combinations of parameter values (refer to Fig. 5).

for the production fluids may indicate that the convection cell size of the exploited reservoir before 1976 was smaller than after 1976 due to the allocation of the wells. However, the smaller M0 value might be obtained by the less reliable calculation: the Cl concentrations and the $\delta^{18}O$ values showing relatively small temporal changes were used, and the Cl concentration and the $\delta^{18}O$ value of the essential hot water from the depth were assumed as mentioned above.

In contrast, the results by Kubota and Matsubaya (1987), and Kubota et al. (1989), using the changes of the I concentrations during 1976-1983, coincide with the present results, within 10% differences except the I1 value, when the assumed cold sweep effect of the reinjected hot water was imposed on the specific enthalpy of the essential hot water from the depth, H1. The high I1 values by Kubota and Matsubaya (1987), and Kubota et al. (1989) were probably caused by the procedure that the I1 value was assumed with the I concentration measured for the total production fluids in 1974, 0.11 mg/kg, which had already been concentrated by the geothermal exploitation. The other macroscopic parameter values estimated by Kubota and Matsubaya (1987), and Kubota et al. (1989) might change, to some extent, if the I1 value estimated by the present study had been used.

Deep hydrothermal environment at the Onuma area

At the Onuma area, the optimum total amount of the hot waters convecting in the exploited reservoir, M0, was estimated to be about 3.2×10^9kg, as shown in Fig. 8. For the Onuma power plant, the total amount of the geothermal fluids produced in a year, about 4.0×10^9kg, is fairly close to the value, and the total amount of the production fluids during 1970-1987, about 6.8×10^{10}kg (refer to Fig. 7), is more than 20 times the value. For this fluid mass outflow, only about 58% of the mass has been recharged by the waste hot-water reinjection, because neither the steam, about 22% of the total production fluids nor about 26% of the reinjected hot waters has returned to the exploited reservoir. Concerning the heat energy outflow associated with the large mass outflow, neither cold sweep process of the reinjected hot waters in and around the reservoir nor thermal conduction from the depth was probably sufficient to keep the enthalpy of the reservoir hot waters very constant through the 18 year operation history (see Fig. 7), especially if cold groundwater invasion to the reservoir occurred. These results indicate that the deep environment of the exploited Onuma reservoir is prosperous enough to supply the reservoir with large amounts of the high-temperature waters that have been able to compensate

Table 2. Comparisons of the macroscopic parameter values estimated by single-box-model calculations using the chemical history data for the Onuma hydrothermal system.

Study report		Ito et al. (1978)	Matsubaya & Kubota (1987)	Kubota & Matsubaya (1987)	Kubota et al. (1989)	Shigeno et al. (1992)
Applied data		IP 1975-1977	CP, HP 1970-1983?	IP, HP 1976-1983	IP, HP 1976-1983	IP, HP 1970-1987
M0	$*10^9$kg	5-8	2.0	3.0	3.1	3.23 *
R		-	0.71 (0.75)*1	0.70	0.70	0.74
H1	kcal/kg	-	-*2	-*2	230 *2 (359) *3	385
C1	mg/kg	-	-*2	-	275 *2	259
I1	mg/kg	-	-	-*2	0.110 *2	0.086

*1 $\delta^{18}O(H_2O)$ values of production fluids were used instead of CP.

*2 Assumed with the data obtained at the reservoir development initial stage.

*3 Corrected value by simply imposing heat energy derived by cold sweep effect estimated for recycling reinjected hot-water on deep essential water inflow.

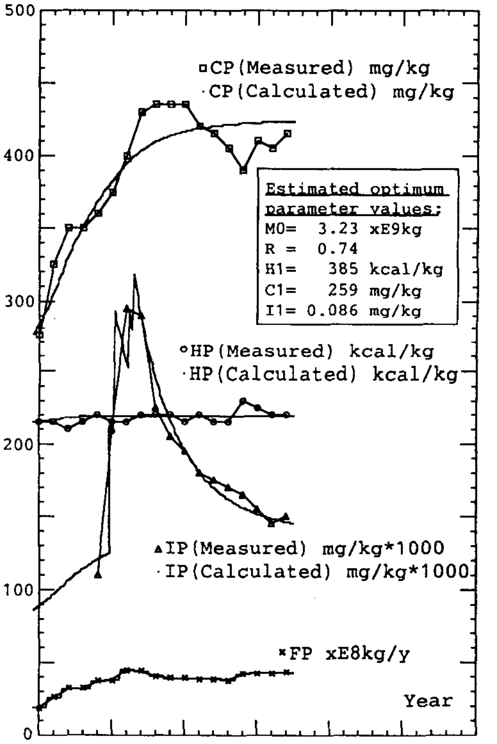
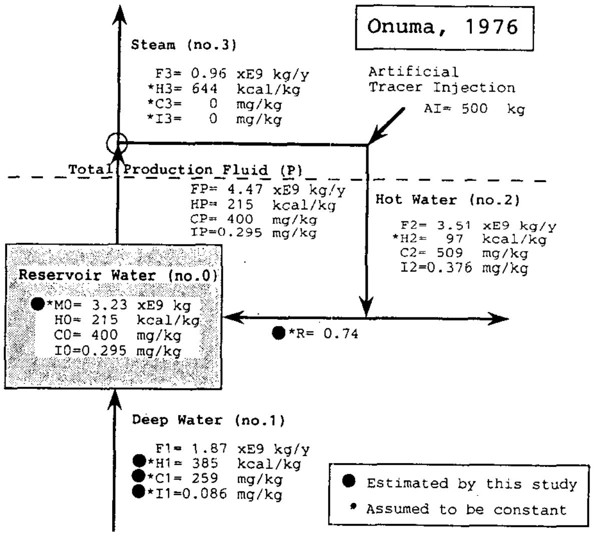


Fig. 7. Forward analysis results of Onuma history data using σIP and σHP as objective functions: Simulated temporal changes of IP, HP and CP with the optimum parameter values (calculated with 12 time steps/year).



F: Flow rate
H: Specific enthalpy
C: Cl concentration
I: I concentration
AI: KI tracer amount

*M0: Mass of convecting reservoir water
*R: Recycling fraction of reinjected water
*H1: Specific enthalpy of deep water
*C1: Cl concentration of deep water
*I1: I concentration of deep water

Fig. 8. Optimum combinations of macroscopic parameter values for the Onuma hydrothermal system estimated by single-box-model numerical simulation forward analyses based on chemical history data.

the above large losses of the water mass and the heat energy caused by the geothermal exploitation.

Shigeno and Abe (1983, 1987) suggested that a high-temperature hot-water convection system of meteoric water origin is developed in the basement rocks under the exploited reservoir at the Onuma area, based on the very high B/Cl mole ratios of about 1.0 for the neutral Na-Cl type hot waters of low salinity from hot springs and the geothermal wells, as well as on the geologic structures and the volcano distributions in and around this area. Namely, the essential geothermal reservoir is developed in the Paleozoic to Mesozoic detrital marine sedimentary rocks, which probably have relatively high porosity and permeability with abundant fractures, at the Onuma area, which is located in the extension of the Hanawa graben of N-S trend. And, the deep reservoir is probably heated mainly by the thermal conduction from the magma chambers of the two Quaternary composite volcanoes located to the east and west of the area. The results of the present study: the high recharge ratio of the deep essential fluid flow to the fluid production from the exploited reservoir, 0.42, and the low Cl concentration of the essential fluid, 259mg/kg, clearly support the above conceptual hydrothermal-system model. Also, the stable neutral pH and the slightly increasing high B/Cl ratios of the total production fluids observed by the long-term monitoring (Kubota et al., 1989) support the model.

The Na-Cl type reservoir hot waters from the Sumikawa area, which is also located in the extension of the Hanawa graben, show almost the same abnormally high B/Cl mole ratios of about 1.0 as those from the Onuma area with high temperatures (higher than 300°C at maximum) (Sakai et al., 1986; Ueda et al., 1991). These data suggest that the essential reservoir at the Sumikawa area is also developed at the depth in the Paleozoic to Mesozoic detrital marine sedimentary rocks. At the eastern part of the Sumikawa area, SN-7D well, which was drilled by the New Energy and Industrial Technology Development Organization, reached to the Neogene granitic rocks at about 2500m deep level, and discharged the neutral Na-Cl type hot water with the very high B/Cl mole ratio close to 1.0 (Ueda et al., 1991). By the pressure transient test of this well, the distribution of a large-scale reservoir of more than 3km^3 was estimated at depth (e.g. Ishido, 1990). These results suggest that the shallow and deep geothermal reservoirs at the Onuma and Sumikawa areas are three-dimensionally connected, and have such a large-scale as of the whole width of the graben structure (Shigeno et al., 1992b; Shigeno, 1992c).

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