STUDY ON FEATURES OF WATER/ROCK EQUILIBRIUM DUE TO EXPLOITATION IN BEIJING URBAN GEOTHERMAL FIELD

Xiaoping Pan
Beijing Geothermal Engineering institute, 90 Bei Wa Road, Haidian District, Beijing 100037, China
e-mail: pxp81@sina.com

ABSTRACT

Geothermal monitoring including water level, well yield, temperature, chemistry etc. items has been carrying out in Beijing Urban Geothermal Field throughout whole reconnaissance, detailed survey and exploration periods. Water/rock equilibrium computation and study were carried out recently. It revealed that the changing of hydrodynamic condition brought corresponding geochemical behavior changing in deep geothermal reservoir along with the process of long term exploitation. The exploitation promoted and accelerated recharge from heat source. It induced also cold groundwater recharge. It means that if we do not drain the pond to get all the fish, e. g. keeping a proper drawdown of water level, artificial exploitation will bring benefit of increased recharge from both sources of heat and water. We have to pay attention to the reservoir engineering monitoring, in order to advise further scientific and reasonable development.

Keywords: Water/rock equilibrium, reservoir engineering, recharge, behavior, geothermal field, Beijing

1 INTRODUCTION

Beijing geothermal survey was started in 1970. Beijing Urban geothermal field was found in 1971. It has passed whole reconnaissance, detailed survey and exploration periods. The monitoring of reservoir engineering behavior has been carrying out in the whole periods. It gives significant research achievements around reservoir engineering. The initial behavior monitoring was for water level and well production only. Good relationship was found between them. We used this relationship for multi elements simulation to assess and predict the exploitable resources in the geothermal field. From 1984 geothermal water chemistry was added into the monitoring series. The relationship among hydrochemical main elements and its behavior change showed certain regularity. Along with the process of exploitation in the geothermal field, the components which representing heat source recharge increased progressively. And meanwhile the components which representing cold groundwater recharge increased progressively, too. This is a rather better matter. However, the water/rock equilibrium study has further demonstrated such behavior change from geochemistry in deep reservoir of view.

2 EXPLOITATION BEHAVIOR IN BEIJING URBAN GEOTHERMAL FIELD

Beijing urban geothermal field is located in Beijing graben geologically. The stratified reservoir is siliceous dolomite of mid-Proterozoic group. There are thicker cap rocks with about 500~3000m thickness. They are continental sedimentation of Neogene and Eogene systems mainly, but also including Quaternary and a part of Cretaceous and Jurassic systems. The cap rock has very low permeability except Quaternary sediments within 100-300 m thickness. Several faults extent in the graben made the fractured karst reservoir good permeability. The geothermal water is meteoric water origin. The highest temperature in the field is 88°C. The heat source is heat conductivity from deep earth crust mainly with a little heat convection along fault system. Single well yield is about 1,000 m^3 with maximum of 3,800 m^3.

Since the geothermal field was exploited the water level showed annual period of behavior with decline in winter and recovering in summer corresponding to the seasonal extraction mainly for space heating. But also a general trend of

progressive slow decline plays obviously throughout the whole period (Fig.1).

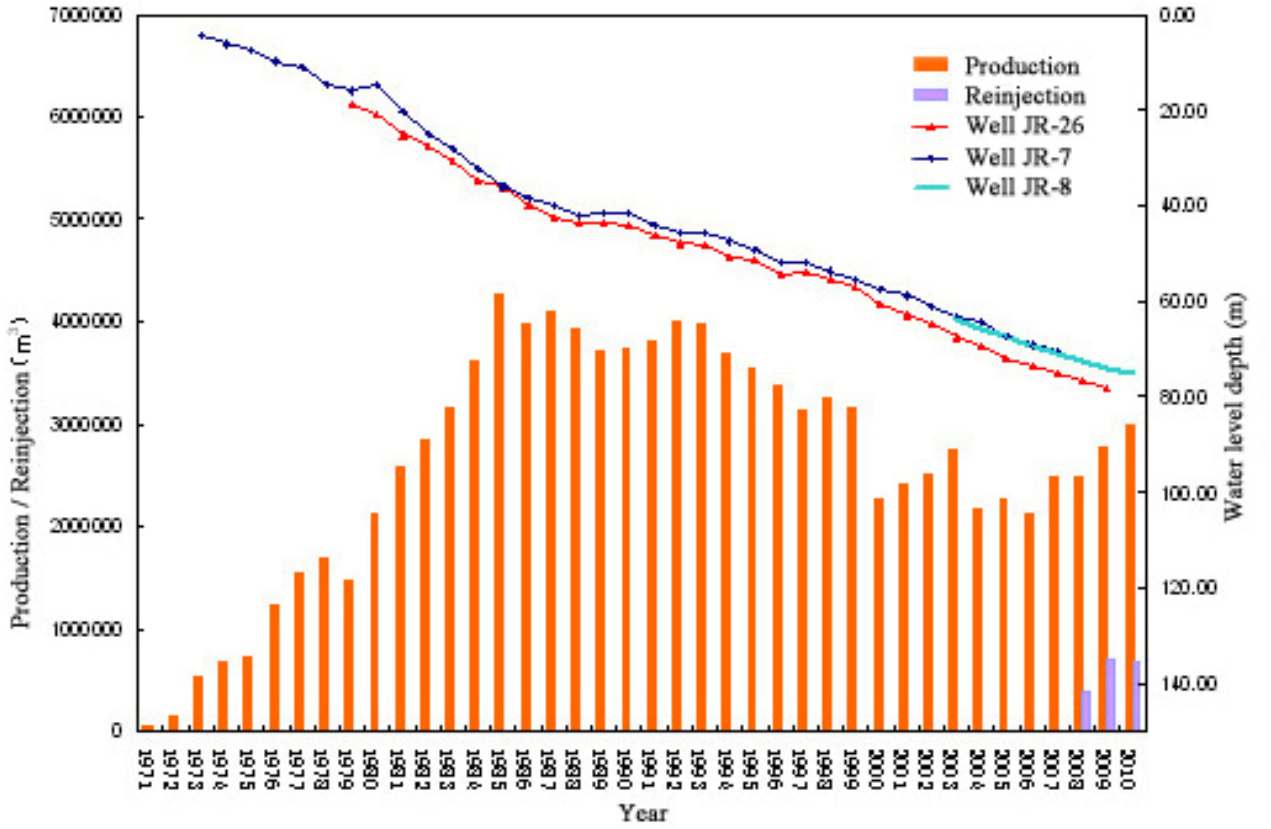

Fig.1 Production, reinjection and water level behavior in Jxw reservoir in Beijing Urban geothermal field (after Xu)

3 WATER CHEMICAL MONITORING AND WATER/ROCK EQUILIBRIUM STUDY

Geothermal water chemical monitoring was started in 1984 along with the strengthening of geothermal resources management in Beijing. It has been lasting for 28 years. Well JR-42 was selected as monitoring well of water chemistry. Water sample was collected twice per year in spring (finish of space heating) and winter (starting of space heating) respectively. Total 35 chemical items, including main anion, cation, silica, fluoride and pH so on were detected for each sample. There is a pity the monitoring well had to be changed into Well JR-45, because of the previous well was buried by reforming of the city. Several wells were continued as the monitoring but Well JR-4 is better for matching prior behavior. Within the long series monitoring for 28 years, the geothermal water chemical behavior was shown in Fig.2.

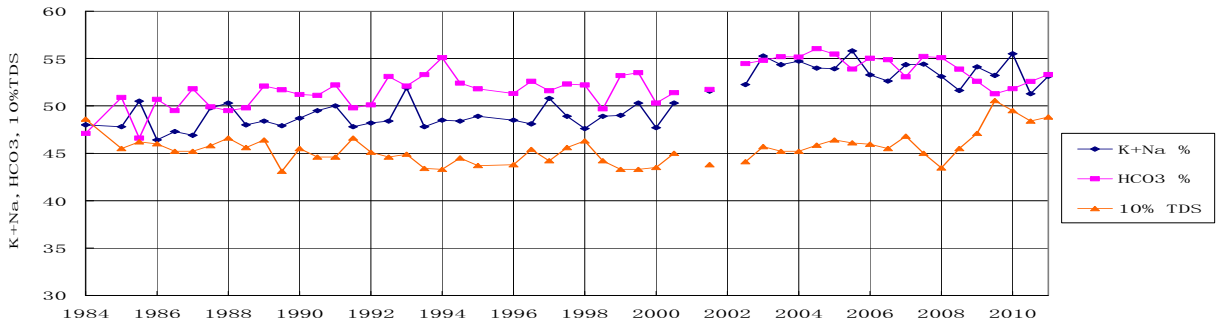

Fig.2 Water chemical behavior of Beijing Urban Geothermal Field

The sodium and potassium percentage of cations shows a trend of weak increase with fluctuating. It reflects a trend of weak increase of heat source recharge. The bicarbonate percentage of anions shows also a trend of weak increase with fluctuating. It reflects a trend of weak increase of cold groundwater recharge. The TDS (total dissolved solids) in the monitoring series shows a trend of weak decrease at the early half of period, but a trend of weak increase at the later half of period. Generally to say, it keeps roughly flat balance except recent two year's little rising.

As a deepen research for water geochemical behavior, water/rock equilibrium computation and study were carried out for the rare 28 year's monitoring series recently. The WATCH3 program which compiled by Icelandic scientists was used to carry our computation for whole series of monitoring data of water chemistry. The purpose is to deduce the geochemical environment in deep reservoir along with the long term exploitation.

WATCH3 computation requires to imput water chemical data. It calculates ion strength and ionic balance to get each component's concentration in deep water, and each ion's activity coefficient in deep water. Then the ion strength and ionic balance in deep water were gained. So we know the chemical compositions in deep water. Then the geothermometers and the oxidation/reduction potential were calculated for deep reservoir. Finally the logistic solubility products of minerals in deep water were shown. When the calculated value was higher than theoretical value it means this mineral has occurred in deep reservoir. The 26 soluble alteration minerals have their own implication for deep reservoir environment. They represent temperature, permeability, oxidation/reduction features, granite occurrence and so on environment conditions respectively. The total sum of occurred minerals represents general strength of geothermal activity. By this way we could recover many geochemical features of the geothermal water in deep reservoir.

4 FEATURES OF THE BEHAVIOR OF WATER/ROCK EQUILIBRIUM

Total 51 samples representing 28 year's monitoring series showed regularity rather obviously. The only shortcoming is that the monitoring series was not so matching between early and later periods. The two monitoring wells showed roughly like repeated process.

4.1 Indication of Temperature of Origin

There are several temperature indication minerals. Montmorillonites (K-, Na-, Ca- and Mg-montmorillonite) represent their origin temperature of 140-150°C. Laumontite represents its origin temperature of 110-230°C. While wairakite represents its origin temperature of 230-300°C. The occurrence of such minerals was displayed in Fig.3. It showed two like similar serieses for early Well JR-42 and later Well JR-45. They showed lack in beginning period. Then they were rare occurrence in middle time. And they were dense occurrence in later period.

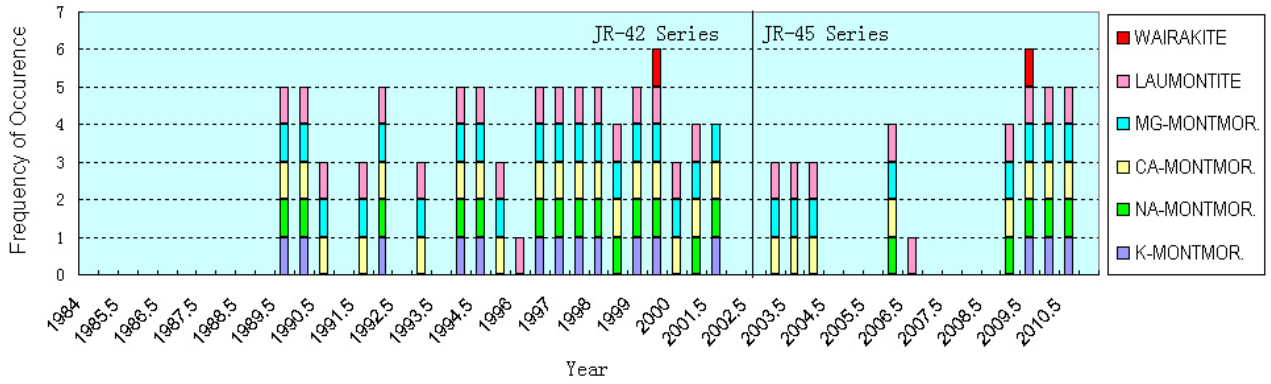

Fig.3 Occurrence frequency of minerals showing temperature index

4.2 Features of Temperature in Reservoir

Some minerals represent certain temperature environment. Calcite represents in lower temperature environment.

Chalcedony represents a medium temperature environment. While Quartz represents in higher temperature environment. We can see from Fig.4 that calcite and quartz occurred in whole period. So the occurrence of chalcedony showed the reservoir environment temperature change of increase. For the Well JR-42 series it showed lack in beginning period. Then it was rare occurrence in middle time. And it was dense occurrence in later period. For the Well JR-45 series it plays not so completed in later period.

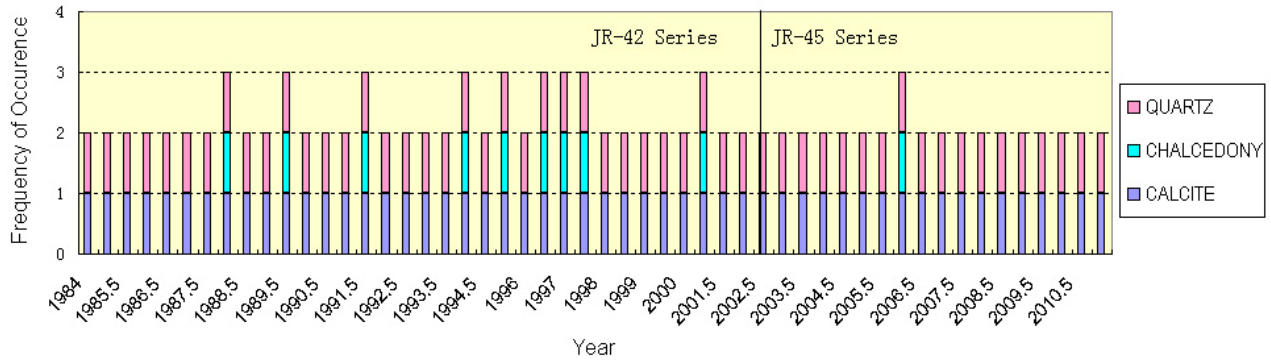

Fig.4 Occurrence frequency of minerals showing reservoir temperature environment

4.3 Permeability Features

Some minerals represent permeability condition. Pyrrhotite represents bad permeability. Low-albite represents medium permeability. While adularia represents good permeability condition. We can see from Fig.5 that pyrrhotite occurred in almost all samples. So the occurrence of low-albite means improvement of permeability. And the occurrence of adularia means great improvement of permeability. We can see the same regulation for Well JR-42 series and Well Jr-45 series as the temperature condition. The minerals showing permeability improvement were lack in beginning period. Then they were rare occurrence in middle time. And they were denser occurrence in later period. Such behavior changing reflected that the permeability had been improved progressively along with long term exploitation.

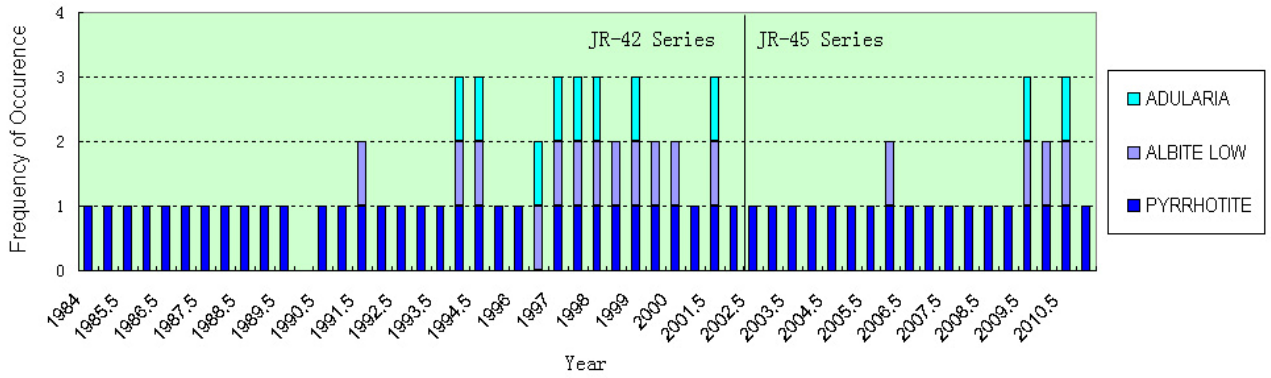

Fig.5 Occurrence frequency of minerals showing permeability

4.4 Oxidation/Reduction Features

Pyrite and marcasite occurred in whole monitoring period. It represents a reduction condition in deep reservoir. It is actual. The reservoir was buried in such depth of 1,000-3,000 m with thicker impermeable cap rock. So there is no oxygen in the deep reservoir.

4.5 Granite Occurrence Environment

Fluorite occurred almost in whole monitoring period. It represents such an environment with occurrence of fluorite in the geothermal system. The granite might intruded in geological history at the location.

4.6 General Strength of Geothermal Activity

The total sum of occurred minerals in water/rock equilibrium calculation represents the general strength of geothermal activity. We can see the behavior changing in Fig.6. For the Well JR-42 series of monitoring, it was flat at early period. Then it was a sudden rising in 1989. Then it varied in weak increase trend with large amplitude. For the Well JR-45 series of monitoring, it had similar changing. Generally to say, the general strength of geothermal activity showed an obvious trend of enhance progressively.

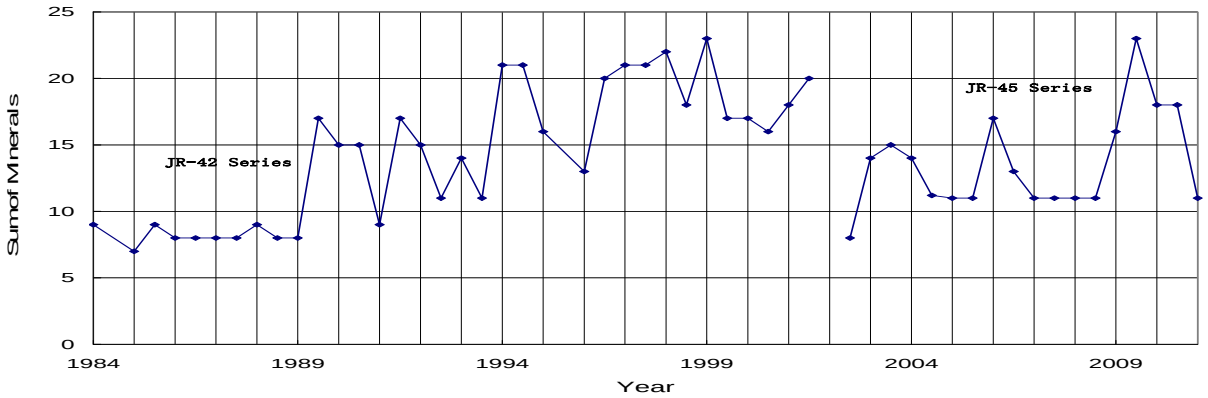

Fig.6 Behavior for sum of minerals showing general strength of geothermal activity

5 PROSPECTS PREDICTION FOR DEVELOPMENT IN BEIJING URBAN GEOTHERMAL FIELD

Why the behavior of water/rock equilibrium showed some bends in the monitoring period? They have the reason in changing of hydrodynamic condition and in driving of physical features.

There was maximum exploitation in Beijing Urban geothermal field in 1985. When geothermal resources management was started implementation in Beijing, the total production reduced. It showed a lower valley of production. So we can see a bend of water level appeared in 1988 as showing in Fig.1. Geothermal water extraction from 1971 to 1989 has reached 40.22 milliom m^3 with a water level drawdown of near 40 m. It made obvious difference of hydrodynamic condition at that time. So the heat recharge rose with inertia from had linked deep reservoir to reach the exploitation section of shallow reservoir. So such information of increased heat source recharge was pumped from well JR-42.

Another important event is large scale reinjection carried out in Beijing Urban geothermal field. It was injected 400,000 m^3 in 2008 and 700,000 m^3 in 2009 respectively. They made big difference of hydrodynamic condition at that time. Our water/rock equilibrium behavior changing was matching such changing of hydrodynamic condition.

We have seen many simultaneous changing within the long term process of exploitation. They showed temperature and permeability increased progressively along with geothermal production.

However, continuous exploitation brings certain water level drawdown in the production reservoir. It is inevitable. But it seems to be not an unlimited decline as tragedy. It just likes the real results of water/rock equilibrium behavior, the hydrodynamic mechanism in geothermal reservoir has been demonstrated. It means that if we do not drain the pond to get all the fish, e. g. keeping a proper drawdown of water level, artificial exploitation will bring benefit of increased recharge from both heat sources and water source. We have to pay attention to the reservoir engineering monitoring, in order to advise further scientific and reasonable development.

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