JICA GEOTHERMAL EXPLORATION STUDY IN YANGBAJING, TIBET, CHINA

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ABSTRACT

By the official assistance program of Japanese Government it has conducted a geothermal resources exploration study at Yangbajing, Tibet, China. In this study project it has carried out some ground surface exploration, drilling a deep well, production test of an existing deep well and reservoir evaluation etc. A new deep exploration well has been drilled and has caught the deep reservoir but because of some well troubles it could not blow. Production characteristics of an existing deep well has evaluated by the production test. Reservoir simulation has carried out and geothermal resources capacity has evaluated. As a result, it has evaluated that Yangbajing reservoir, which includes the deep and the shallow reservoirs, can stably produce 200t/h steam more than 30 years.

Keywords: Yangbajing, geothermal exploration, reservoir evaluation, Japan aid

1. INTRODUCTION

From 2001 to 2006 Japan International Cooperation Agency (JICA) has conducted a geothermal resources exploration and development study project at Yangbajing, Tibet. JICA is one of the organizations which conducts overseas aids of the Japanese Government. This study is a cooperation project of JICA and Tibet Electric Power Company, the expense mainly fell on JICA but also partially on Tibet Electric Power Company. Exploration works were mainly conducted by Japan Metals & Chemicals Co., Ltd. (JMC) which was entrusted the operation of this study by JICA, and partially conducted by Geothermal Development Company of Tibet and Tibet Geothermal Geological Term.

At Yangbajing geothermal power generation was started in 1977 by Chinese technology. But since the firstly developed geothermal reservoir distributed from 200m to 400m depths and reservoir capacity was not enough, the power output has been only about 13MW in average though the power plant capacity was 25.18MW. Chinese exploration during 1990's, with additional research conducted with UN assistance, revealed that a high temperature deep geothermal reservoir exists in the Yangbajing north field at depths of 1000m to 2000m. Electric Power Company of Tibet hoped to develop this deep reservoir, but they have neither the technology nor funding required to explore and develop such a deep high temperature reservoir. Therefore, the Chinese Government requested assistance from Japan, through the Japanese Official Assistance Program.

This JICA's study project started in 2001 and ended in 2006. During this period it carried out some ground surface explorations, drilling of a deep exploration well, production test of an existing deep well, reservoir monitoring, evaluation of reservoir potential and making a basic development plan.

2. OUTLINE OF YANGBAJING FIELD

Yangbajing geothermal field is situated about 90km northwest from Lahsa city. It is situated at southeast side of Nianqingtanggula mountains and is inside of a basin which elongates NE-SW direction. It is at 4300m from sea level. Through the Yangbajing field the China-Nepal national road passes in NE-SW direction. The development area in southeast side of this road is called the south field and northwest side is called the north field. The south field is a flat plane and there existed a lot of hot springs, fumaroles and hot water pond, and there are many shallow production wells. The north field is at the foot of mountains and deep reservoir was found at depth of the north field. (fig.1)

3. THE GROUND SURFACE EXPLORATION

3.1 Exploration Plan

As at the Yangbajing field, there exists a lot of exploration data mainly conducted by Tibet Geothermal Geological Term, so the JICA team planed to conduct complementary survey based on these existing data. That is geological survey, fluid geochemical study and magnetotelluric (MT) survey.

3.2 Geological Survey

In the north field, there are many NE-SW directed faults, and in the same direction also there exists some strong rock alteration zones. Tibet Geothermal Geological Term reported that at the same zone there exists a high temperature zone at the shallow depth. So it is thought that under this zone there exists an up flow zone and the deep high temperature reservoir. (fig. 2)

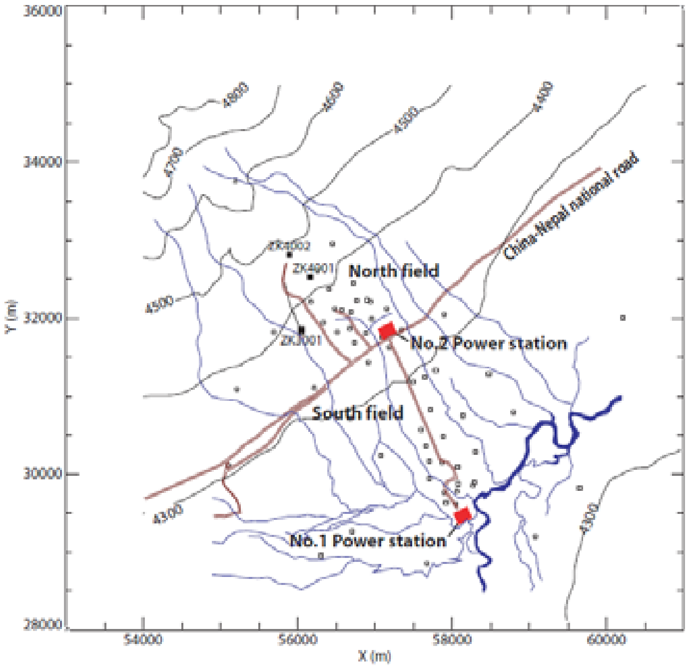

Fig.1 Outline of Yangbajing field

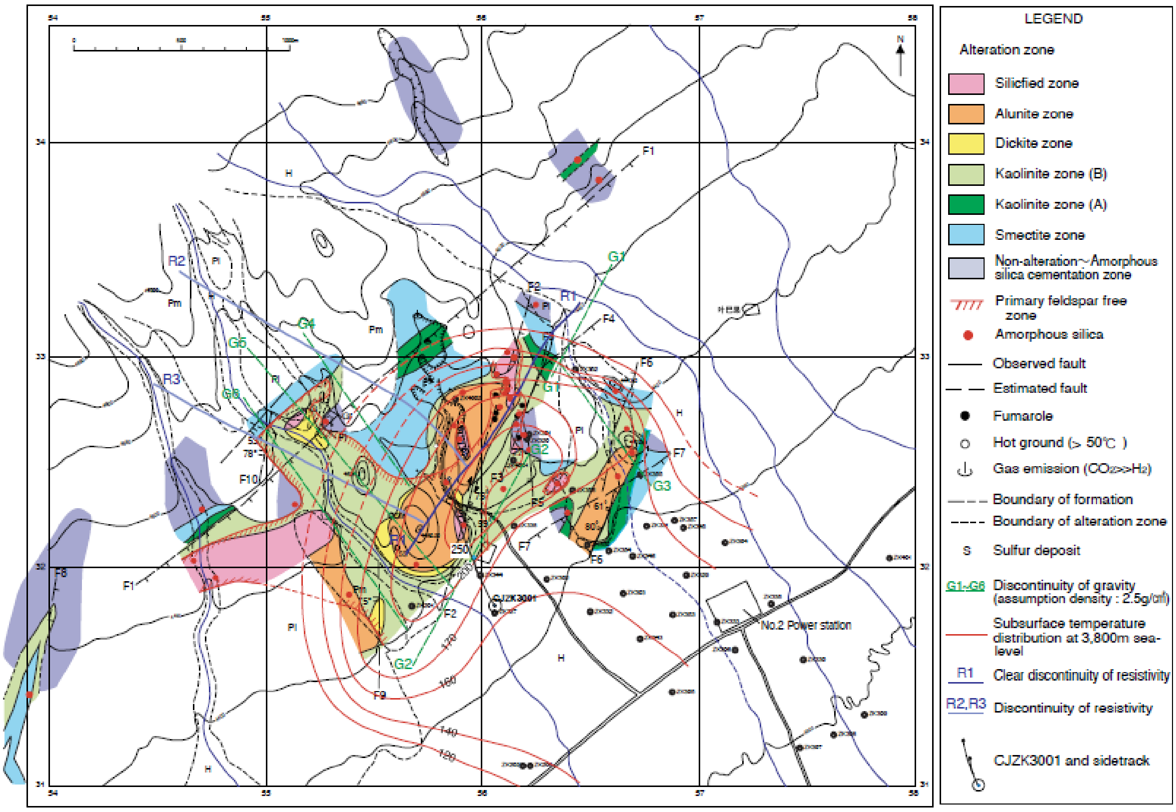

Fig.2 Exploration results

3.3 Fluid Geochemical Study

Produced fluids from geothermal wells, hot springs and ground waters are chemically analyzed. Geothermal fluid in the shallow reservoir is mixture of ground water and deep geothermal fluid flown up from the deep reservoir in the north field. This shallow reservoir fluid is flowing from the north field to the south field in the shallow reservoir. At now the production rate of geothermal fluid from the shallow reservoir is possibly the same or a little bit more compare to the supplying rate into the shallow reservoir.

3.4 Magnetotelluric Survey

In the north field a magnetotelluric survey using a remote-reference method and 1-, 2-, 3-dimensional analyses were conducted. As a result, a resistivity discontinuity line which coincides with the high temperature zone in the north field was found.

4. DRILLING OF THE EXPLORATION WELL (CJZK3001)

4.1 Drilling Plan

Based on the exploration results described above, we made a drilling plan of a deep exploration well. The aim of this deep exploration well was to confirm the deep geothermal reservoir. This well was named CJZK3001. The drilling target of this well was settled at 2000m depth of the NE-SW directed fracture zone described above. It was also targeted to drill through the fracture zone by NNW direction from southeast side of the fracture zone by controlled directional drilling. There had been no experience of a controlled directional drilling at Yangbajing, so this drilling technology was an important technology transfer item. Drilling site was selected where assumed less possibility of lost circulation at shallow depth.

4.2 Drilling Process and Result

From 200m to 500m there encountered a lot of large lost circulation zones, and there happened some stacking accidents of drill strings, so drilling work was very difficult. From about 1000m to 1250m, because there are the deep reservoir, there occurred a lot of lost circulation, but in order to drill to deeper area, we sealed these lost circulation zone and insetted casing pipes and continued drilling. After 1600m there was no lost circulation and rock alteration became weak, so we judged that there was no additional deep reservoir, thus we stopped drilling at 2254m depth. After that we decided to do production test using the deep reservoir in 1000m to 1250m depth. The 9 5/8" casing pipe was cut and sidetrack drilling has started from 877m. At 1051m and 1095m there encountered large lost circulations accompanying drilling brakes, and at 1195m it became very difficult to continue drilling, then stopped drilling.

4.3 Exploration of Well

At CJZK3001 we conducted rock geological survey, fluid inclusion survey and well logging. It revealed that strongly altered zones distribute 60-375m, 850-1155m and 1220-1300m. These depths correspond to shallow reservoir and deep reservoir respectively. Well temperature at the shallow reservoir is about 150℃ and that of the deep reservoir is about 270℃, and underground temperature shows a two layered structure. (fig. 3)

4.4 Production Test

At CJZK3001 we tried to initiate the production by air lift, but it did not. The reasons are as follows.

1) At 135m-205m, the casing pipe was broken and relatively low temperature shallow water flows into the well, and prevented the blowout.

2) Deep reservoir fractures at 1051m and 1095m are sealed by some well troubles.

Though the well did not blowout, there are large fractures and temperature is very high, so we believe there is a deep reservoir.

5. PRODUCTION TEST OF THE EXISTING DEEP WELL (ZK4001)

5.1 Production Test Plan

In order to evaluate deep reservoir adequately, we had planed simultaneous production test with the existing deep well ZK4001 and the new deep well CJZK3001. But since CJZK3001 did not blow, thus only ZK4001 could be used for production test. ZK4001 is one of the deep wells that was drilled by Chinese team in 1996, total depth is 1495m and at 1225m the highest temperature of 251℃ was measured. ZK4001 produced steam and hot water 302t/h in total. But at that time, duration of the production test was only 15 days. Flow rate was measured by lip pressure method that steam and hot water was not separated. Thus detailed well evaluation was not conducted. So in this JICA study we planed to do 3 month production test.

5.2 Result of Production Test

Procedures of the production test were as follows. Steam and hot water were separated at well site, and after that temperature, pressure and flow rate were measured. Then, fluid samples for chemical analysis were taken. We conducted 3 month production test 2 times. At the first test a lot of rock dusts blew out from the well, so measurement of data was not complete. At the second test stable blow out condition was continued. In this period we conducted back pressure test to get well production characteristics. Steam and hot water flow rate were about 50t/h and 300t/h respectively at well head pressure 1MPa.

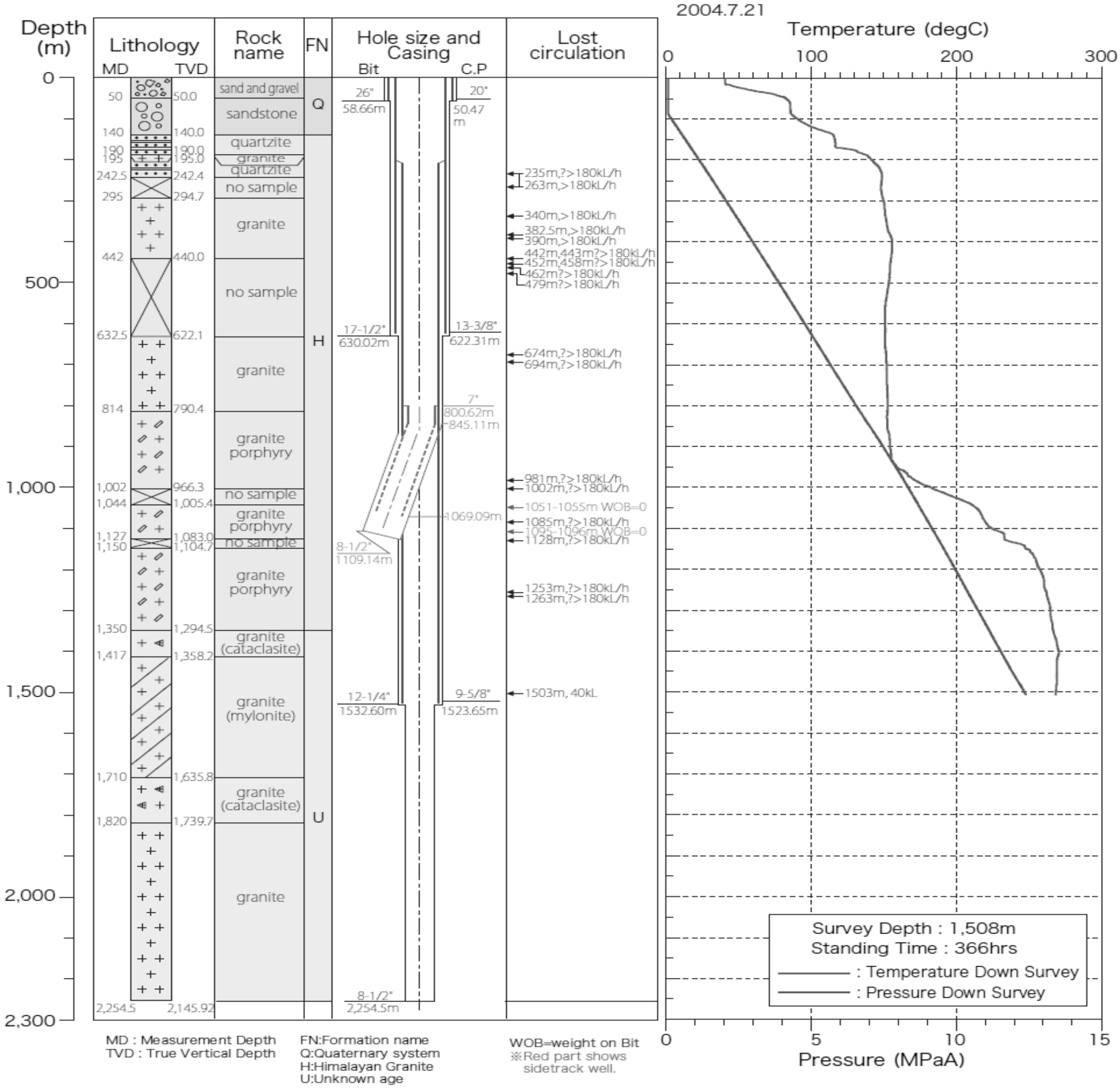

Fig.3 CJZK3001 drilling & exploration result

6. RESERVOIR EVALUATION

6.1 Evaluation Method

We conducted reservoir evaluation by numerical simulation. The simulation code is FIGS3C. At Yangbajing field, there are relatively a little data of production, reinjection, well temperature and pressure history etc. So in the JICA study, we monitored water level of wells and chemical transition of produced fluid of wells, and used them for history matching in the simulation. Number of grids for simulation was about 11,000.

6.2 Reservoir Model

We analyzed many data comprehensively and constructed a conceptual model of the geothermal reservoir. (Fig. 4) At Yangbajing field, low dipped Nianqingtanggula shear zone and steeply dipped normal faults are main fault structures. NE-SW directed normal faults are main path of ascending flow of the geothermal fluid from deep region. Along the Nianqingtanggula shear zone it forms the deep reservoir. From the deep reservoir, a part of geothermal fluid flows up to shallow depth, then mixed with ground water and flows from northwest to southeast direction and forms the shallow reservoir.

6.3 Result of Reservoir Evaluation

Based on the conceptual model, we conducted natural state simulation and history matching simulation and got an

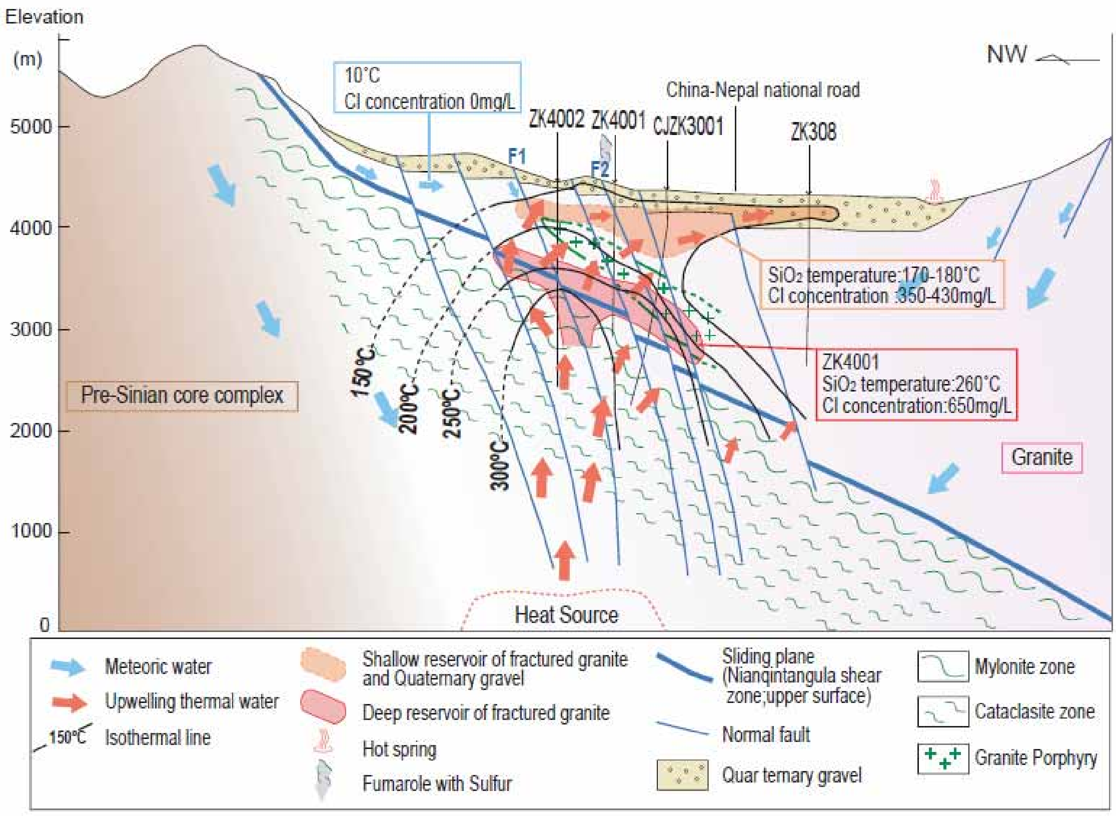

Fig.4 Conceptual cross section of Yangbajing reservoir

appropriate numerical reservoir model. Using this numerical model, we simulated prediction runs of many production and reinjection schemes, and calculated reservoir pressure and temperature change. Among these cases, we chose some cases that resulted in continuous and stable production and reinjection. We evaluated these cases to be the reservoir capacity. As a result, we evaluated the Yangbajing reservoir, which includes the deep and the shallow reservoirs, can stably produce 200t/h steam more than 30 years.

7. CONCEPTUAL DEVELOPMENT PLAN

Based on the results of the reservoir evaluation, we discussed a conceptual development plan. It was considered that, in the future it is appropriate to use the deep high temperature reservoir for production, and existing power plants will be decrepit gradually so it is better to replace them with new power plants. Specifically, in 2010 existing 9000kW No.1 power plant shall retire and construct a new 6000kW No.3 power plant. Then in 2020 existing 15000kW No.2 power plant shall retire and construct a new 12000kW No.4 power plant. In this plan, power plant capacity will decrease but utilization factor will go up to about 100% so net power output will increase.

8. CONCLUSION

This report is based on the JICA study project. Based on the result of this study, the geothermal resources at Yangbajing has enough capacity to continue power generation in the future. Moreover in Tibet there are so many geothermal resources, so we hope that development of these geothermal resources will proceed by the cooperation of many countries and organizations.

ACKNOWLEDGMENT

We would like to thank Japan International Cooperation Agency (JICA) and Electric Power Company of Tibet for their permission to publish this paper.

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Japan International Cooperation Agency (2006) Geothermal resources development study at Yangbajing, Tibet, China. *A report of the development study of JICA* (in Chinese and Japanese)