RESERVOIR SIMULATION OF THE YANGBAJIAN GEOTHERMAL FIELD IN TIBET, CHINA

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ABSTRACT

The report describes distributed parameter models of the Yangbajian geothermal field in Tibet, China. The field is a liquid-dominated reservoir with a two-phase zone on the top. Despite insufficient time-dependent prodoction data and lack of continuous water level measurement in observation wells, the obtained reservoir parameters could be used to predict the response of the reservoir in the future. When production is increased from 200 *kg/s* to *550 kg/s,* the future water level drawdown is predicted to increase quickly. Therefore, the influence of two different reinjection schemes in the fllowing twenty years has ***also*** been taken into account in this paper, including the subsequent temperature decline due to reinjection.

Key words: ***reservoir simulation, Tibet, reinjection, Water level***

1. *Introduction*

In recent years, the use of geothermal reservoir modelling has been much developed. Numerous quantitative models for different geothermal fields are available. The main scope of this work is the calibration of reservoir parameters and the prediction of the future response of the reservoir to different production rates and reinjection. The calibration and prediction processes were carried out by using the AQUA programme package developed by Vatnaskil Consulting Engineers, Iceland.

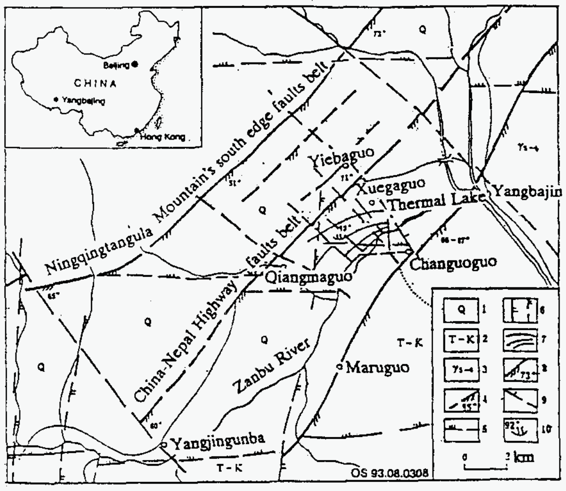

Figure 1: Structural map of the Yangbajian Basin, 1. Quaternary system; 2. Triassic to Cretaceous system; 3. Granite from late Yanshan to Ximalaya; 4. Compress-shear principal faults; 5. E-W regional compress faults; 6. N-S faults; 7. Brush structure; 8. Occurrences of faults; 9. N-W tensile or tense-shear faults; 10. Hot spring and its temperature (°C) (Kang et al., 1985)

2. **Survey of *the field***

Every time we mention Tibet, it reminds us of beautiful snow-covered mountains and warm springs. Among the springs, Yangbajian is the most famous. It is located 90 km north-west to the Lasha City, the capital of the Tibet Autonomous Region. The Yangbajian geothermal field is controlled by a crisscross of fault systems (Figure 1). The system consists of three N-E compress-shear faults and three perpendicularly N-W tense-shear faults to form the boundaries of the field. There is dense and hard granite in the basement of Yangbajian. The tense-shear faults formed by stress action are good flow paths for hot water. The faults are very steep to control the vertical upflow of hot water in the basement and partly horizontal migration where the palingenetic fractures or pore systems exist. This has been confirmed by the work to reveal the distribution of tritium (T) isotope in the field. The hot water flows up along the faults in the basement to the Quaternary grit layer to form a shallow reservoir. The faults extend deep in the reservoir according to the exploration and there are also basement faults passing through the reservoir. The hot water not only migrates horizontally in the field, but also extends to far away from the field boundary. The hot water flows to the boundary of the basin along the bottom of the Quaternary and the temperature and pressure all decline gradually.

The area of Yangbajian geothermal field is about 15 km^2 delineated by the 30 R-m contour of resistivity which coincides with the 40°C temperature contour's delineation. The resistivity in the centre of the field is 4-5 R-m, 20-30 R-m at the boundary faults where it suddenly increases to several hundred R-m. This means the boundaries of the field are very clear. This may relate to the variation of lithofacies, controlling faults, temperature gradient, pressure and permeability with depth of the field.

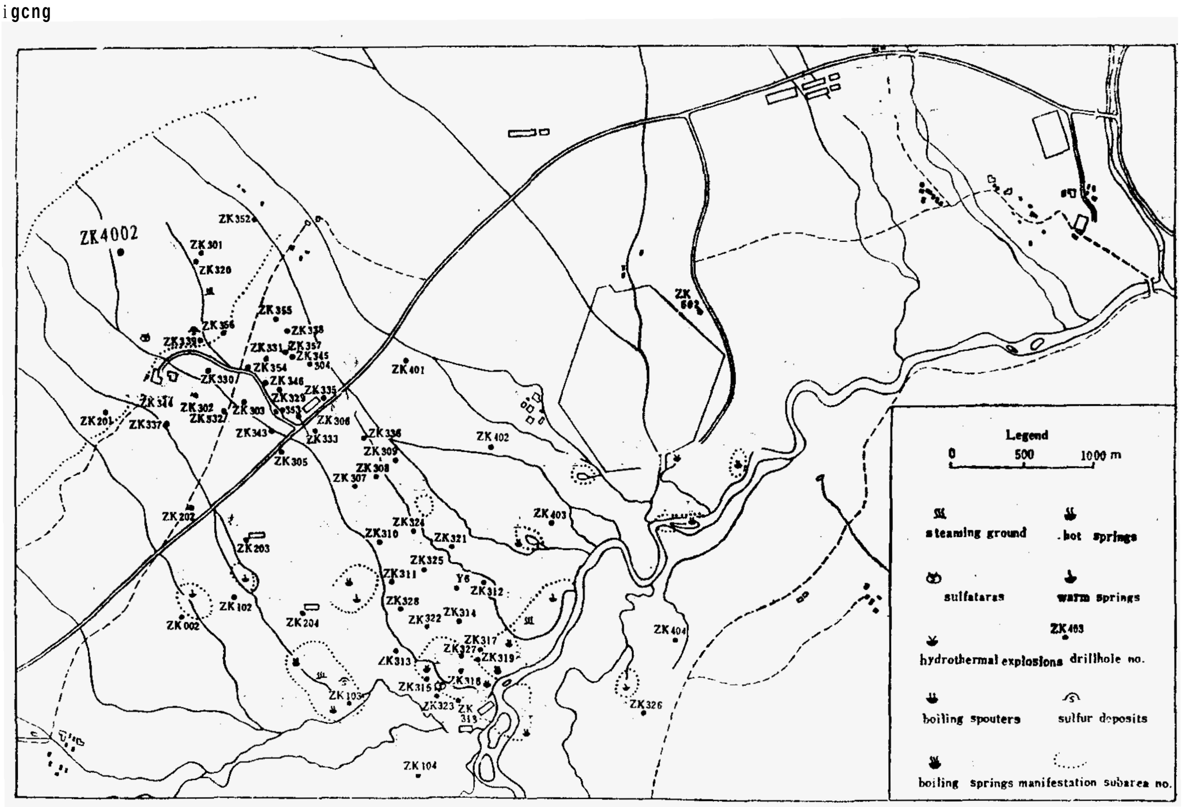

Figure 2: The well distribution in the field (Liu Shibing et al., 1992)

The borehole temperature gradient, especially in wells ZK-318, ZK-203, ZK-403, ZK-319 and ZK-313 (see figure 2 for locations) show that there is a lateral horizontal migration in the shallow reservoir (Figure 3). Generally, convection occurs at above 800 m depth while conduction happens in the underlying basement. The reservoir is liquid-dominated, however, boiling was observed on the top of flowing wells in the field.

3. Production and utilization history

Much of the exploration work in the field has been carried out during the last two decades and the field has been under exploitation since 1976. In the past eighteen years, work on geology, well drilling, physical and chemical exploration has been carried out while collecting data from more than fifty exploration and production wells. The first 100 kW pilot geothermal plant was built on the world famous Tibet Plateau in 1977. It not only changed the energy composition in Tibet, but also opened a new page of the research work of new energy in China. In 1992, the Yangbajian field produced $25MW_e$ from its geothermal resources. This was equivalent to about 85% of the geothermal generated electricity in China and was 25% in Tibet's energy composition. Table I shows the parameters of producing wells and their potential power capacity. ENEL-AQUATER has done a lot of work in this field (1985).

4. Basic assumptions and parameters for the model

Drilling and geological exploration have shown that the Quaternary morainal grail layer in the Yangbajian field has very good permeability, however, it is anisotropic in both the vertical and horizontal directions. The low permeability caprock of the reservoir is mostly clay in the

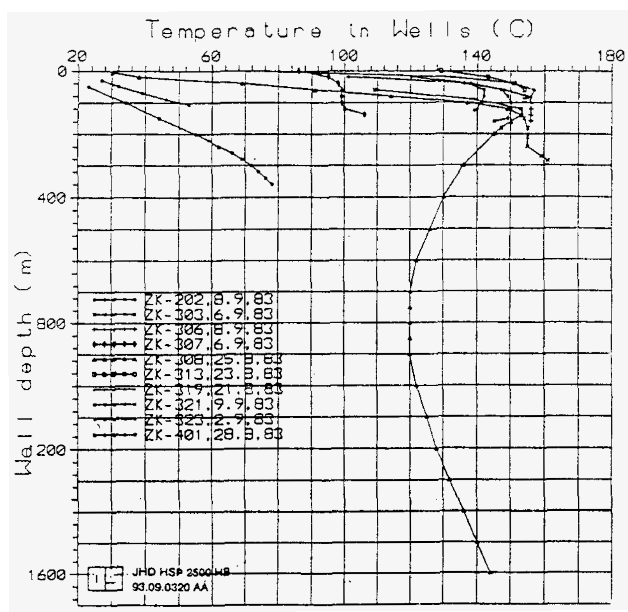

Figure 3: Temperature profiles of the wells in the Yangbajian field

TABLE 1: Parameters of wells in the Yangbajian **field**

Well No.	Max.T in well (°C)	Work T at WH (°C)	Work P at WH (bar)	Lip P (bar)	Total M.flow (kg/s)	Steam M.flow (kg/s)	Steam ratio (%)	Power (KW)
ZK203	141	125	2.3	0.766	23.8	2.5	10.73	818.5
ZK204	147	122	2.3	0.716	21.2	2.5	11.95	767.3
ZK302	172	137	3.6	1.066	25.7	4.4	17.23	1124.2
ZK303	167	134	3.2	1.066	26.9	4.3	15.70	1109.9
ZK304	172	133	3.8	1.066	25.7	4.5	12.24	1109.9
ZK309	160	146	4.6	1.916	49.0	7.2	14.63	1948.8
ZK310	160	125	2.9	0.836	22.4	3.3	14.63	890.2
ZK311	157	147	4.7	1.716	45.6	6.4	14.00	1775.6
ZK312	149	138	3.7	1.116	32.0	4.0	12.36	1174.8
ZK313	161	131	3.3	0.966	25.2	3.7	14.85	1009.8
ZK314	160	131	3.5	1.106	28.9	4.4	15.09	1164.7
ZK315	152	127	3.1	1.856	20.1	2.7	13.17	761.2
ZK319	161	130	3.3	1.116	29.3	4.4	14.84	1174.8
ZK321	155	120	2.1	0.716	20.0	2.7	13.61	767.3
ZK324	160	147	4.3	1.816	47.1	6.9	14.66	1874.8
ZK325	155	143	4.1	1.666	45.0	5.6	13.60	1725.9
ZK327	152	116	2.6	0.916	25.9	3.4	12.98	971.9
ZK328	152	138	3.5	1.370	38.1	4.8	12.98	1430.4

The reference temperature for the calculation **is** 85°C.

southern part. The dense and hard granite in the bedrock also has very low permeability because of poor porosity and fracture development. Therefore, the high permeable zone in the bed rock must be connected with the main hot water transportation paths.

The total surface area covered by the calculation mesh is about 118 km^2. The model was created with 521 nodes and 764 elements. The northern boundary for the distributed model is established as fixed flowrate boundaries because of the recharge from the northern mountains. The other boundaries are all set at no-flow. The dividing elements for calculation are showed in figure 4. As to the initial state prior to production, it was assumed that the reservoir water head was constant so that there was no hydraulic gradient in the area at the beginning.

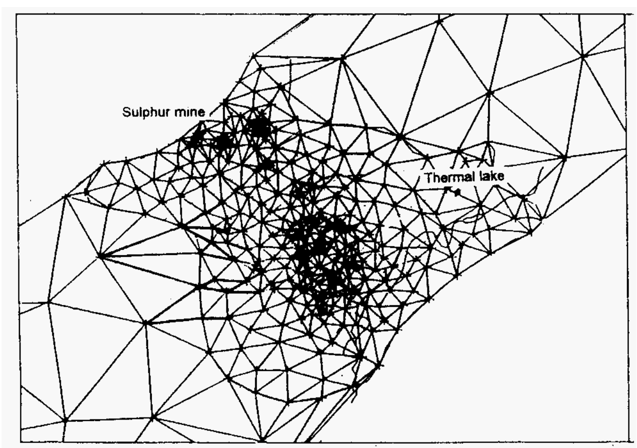

Figure 4: The dividing elements for caculation

5. Results from the calibration

By simulating the production history on the basis of the observed water level drawdown in the Yangbajian field, the transmissivity and the storage coefficient were obtained. The transmissivity in the area covered by the model varies from 5.00E-04 to 7.5E-2 m^2/s (Figure 5). The low value covers the outside of the production zone in the Yangbajian Basin while the transmissivity in the reservoir is very high. Simultaneously, the storage coefficient distribution for this model varies from 8.00E-04 to 0.17 (as shown in figure 6). The highest value is assumed to the two-phase zone in the northern part of the field. This obtained value is very high if it is compared with the values calculated by well testing. It is possible to explain with two different mechanics which appear during the exploitation of the field because the dry steam storativity is much greater than the compressible storativity of a liquiddominated reservoir. During utilization of the reservoir, the increase of the storativity is

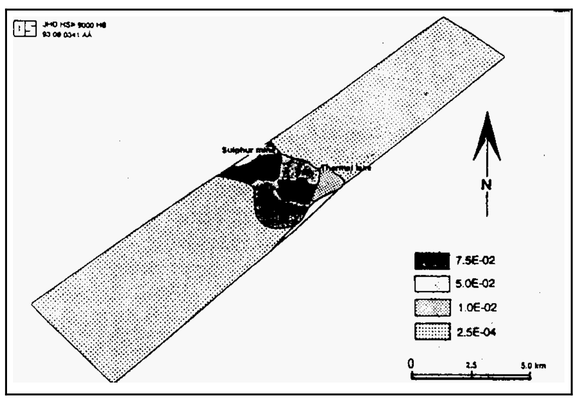

Figure 5: Transmissivity distribution in the field

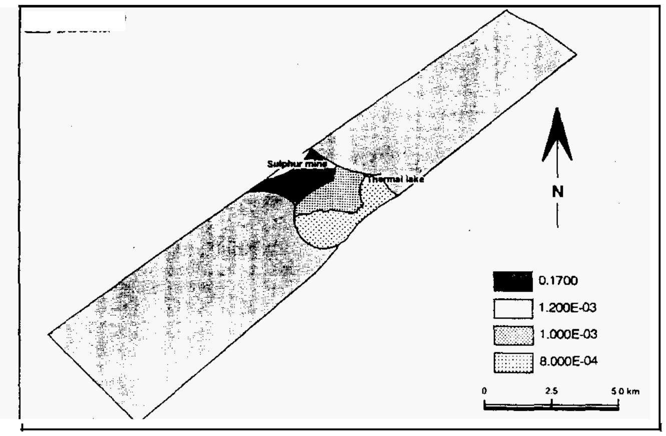

Figure 6: Storage coefficient distribution in the field

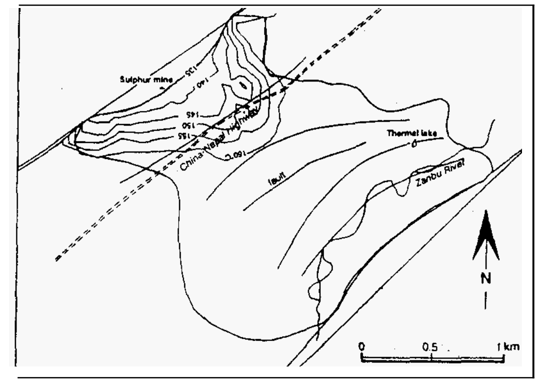

Figure 8: Temperature decline with reinjection in the northern field

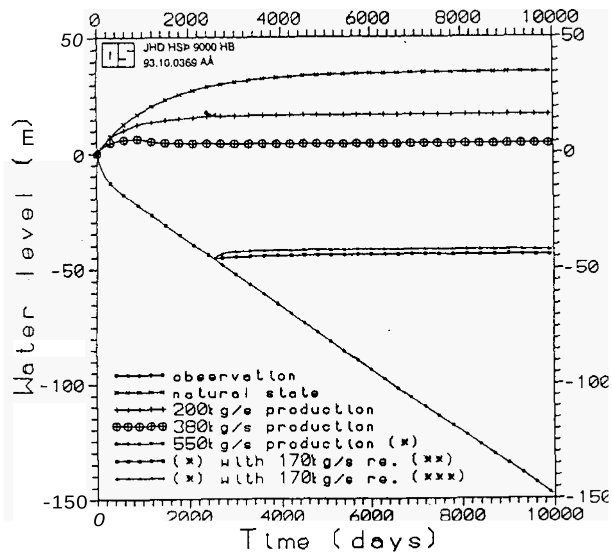

Figure 7: Water level under different production rates and reinjection

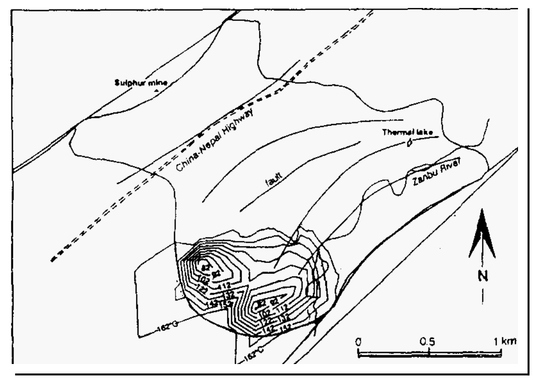

Figure 9: Temperature decline with reinjection in the southern field

mainly caused by delayed yield and double porosity effects when the reservoir turns from liquid-dominated into steam-dominated.

The longitudinal transmissivity (T_{xx}) and transverse transmissivity (T_{yy}) ratio $(sqrt(T_{yy}/T_{xx}))$ are set 0.477 in *the southern* part, 0.316 in the northern part of the producing area and 0.8 outside. The values show the anisotropic transmissivity distributions in the field.

The calculated water level for well ZK-306 under different production rates is shown in Figure 7. When the production is increased from 200 kg/s to 550 kgls, water level drawdown increases rapidly in the reservoir Therefore, the reinjection rate of 170 kg/s is taken into account in the future prediction in the Yangbajian field. The reinjection is supposed to be carried out in two ways. The first scheme is to put the reinjection wells in the northern part to mix with the recharge water in the vertical convection before the water enters the reservoir at 140°C. The other strategy is to put the reinjection wells in the southern part close to the power plant and to use 80°C cold waste water from the plant. The temperature decline after twenty years due to cold water reinjection is shown in Figures 8 and 9. The parameters used for the heat transport problem are as follows:

Longitudinal dispersity: 50 m;
The ratio of $sqrt(\alpha_T/\alpha_L)$: 0.316;
Porosity *of the reservoir 0.17;*
Heat retardation constant: 0.238;
Aquifer thickness: 200 m;
Initial temperature: 165℃;
Reinjection temperature: 80℃;
Reinjection flowate: 170 Kg/s

6. Conclusions and Discussion

The study of the Yangbajian geothermal field shows that if the production rate is greater than the recharge of the field, the water level in the field would have a very fast drawdown. Reinjecting water at 80°C, either in the north or south, would not drastically cool down the reservoir but be effective to maintain the water level in the field. Although the distributed parameter model **is** already capable of predicting the future responses of the field, its accuracy can further be enhanced by a re-evaluation using more time-dependent production and observation data.

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