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Determining the Yield of Carbonate Thermal Reservoir by Logging Data

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ABSTRACT

Presented is a method of determining the yield of carbonate thermal reservoirs by logging data and well test data. The method is used in other geothermal wells. Taking Xiongxian geothermal field as an example, the calculation method of thermal reservoir yield is introduced. The calculated thermal reservoir yield is basically consistent with that determined by water test data, which provides a new feasible method for determining geothermal well ~~Yield~~ yield in geothermal fields.

1. INTRODUCTION

Geothermal energy is a rich, stable and reliable zero-carbon, clean energy. The vigorous development and utilization of geothermal energy is of great significance for promoting the reduction of greenhouse gas emissions such as CO_2, achieving climate goals and sustainable economic development (Lin Wenjing et al., 2013; Zhang Wei et al., 2019). At present, geothermal resources have become a hot spot for global new energy utilization.

The production capacity of geothermal wells is crucial for the development and utilization of geothermal energy. It is reported that between 2015 and 2019, about 2647 geothermal wells were drilled in 42 countries for geothermal power generation and direct use(Ma Bing et al.,2021).~~.~~ Among these geothermal wells, hydrothermal geothermal wells account for the majority. For hydrothermal geothermal wells, after drilling a well, the capacity of geothermal wells is the most concerned. If there is no capacity, it means that the drilling ~~is failing~~has failed, causing, ~~avoiding~~ unnecessary investment. Therefore, the ability to know the capacity data as soon as possible after drilling and completion~~, which~~ is of great significance for the later investment and development and utilization. At present, the capacity data of geothermal wells is mainly derived from the water test data, but the water test data is lagging behind. If the logging data can be used to predict the production capacity of geothermal wells, it will have important guiding significance for the completion plan and development and utilization of geothermal wells. Some results have been achieved in the study of predicting the capacity of geothermal wells using logging data. Discussion on influencing factors and productivity evaluation methods of Carbonate rock reservoirs (Fan Jinlu, 2012); Using the stress sensitive model of Carbonate rock reservoir and the high-speed non Darcy percolation coefficient model, the gas productivity equation was established (Gao Shusheng et al., 2015); The productivity prediction model of Carbonate rock reservoir was established based on the electric imaging logging data (Li Xiaohui et al., 2015); Research on parameters of high productivity geothermal wells in Carbonate rock (Wu Aimin et al., 2018); The steady-state productivity equation of fractured porous Carbonate rock gas reservoir is established by using fracture permeability and other parameters (Liu Ronghe et al., 2022). Most of these results are based on theoretical equations, and finally explanatory models are established, and some of these model parameters will use logging results, ~~[1-6].~~ A new method for evaluating carbonate capacity using logging data is proposed. The method discovers the regularity of its existence based on the pumping test data, and then uses its regularity to establish a relationship with the logging data. This method realizes the purpose of directly using logging data to evaluate the capacity of geothermal wells, and can provide capacity results after logging, which is of great significance for the completion of geothermal wells and the development and utilization of geothermal energy. However, first of all, it is necessary to collect some capacity data for wells, suitable for newly developed geothermal fields and already developed geothermal fields.

2. ESTABLISHMENT OF WATER YIELD EVALUATION MODEL

Xiongxian geothermal field is mainly based on hydrothermal geothermal resources, mainly developing carbonate thermal reservoirs. ~~, l~~Lithology is mainly dolomite, argillaceous dolomite, etc., with karst fracture development and~~,~~ good connectivity(Wang Guiling et al., 2020)~~[7].~~

According to the design and procedure requirements, Each well needs to undergo a pumping test~~these 5 wells have three landing paths, each of which corresponds to different depth and water production~~, and the specific pumping test data is shown in Table 1. In Table 1, DY1, DY2, XNG1, ZM1, and ZM2 are the names of wells, S is drawdown and Q is the corresponding water yield of S.

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Table 1: pumping test data for five5 wells

well name	DY1		DY2		XNG1		ZM1		ZM2	
	S (m)	Q ($10^{-3}m^3/s$)	S (m)	Q ($10^{-3}m^3/s$)	S (m)	Q ($10^{-3}m^3/s$)	S (m)	Q ($10^{-3}m^3/s$)	S (m)	Q ($10^{-3}m^3/s$)
	8.95	33.36	6.65	33.67	5.66	28.36	5.66	33.3	4.97	33.35
	3.1	29.39	2.63	25.04	4.11	19.24	3.65	25.04	3.1	25.21
	2.35	25.04	1.53	16.68	2.96	11.21	1.92	16.68	1.45	16.88

DY1		DY2		XNG1		ZM1		ZM2	
S	Q	S	Q	S	Q	S	Q	S	Q
8.95	33.36	6.65	33.67	5.66	28.36	5.66	33.3	4.97	33.35
3.1	29.39	2.63	25.04	4.11	19.24	3.65	25.04	3.1	25.21
2.35	25.04	1.53	16.68	2.96	11.21	1.92	16.68	1.45	16.88

In order to find the relationship between depth reduction and water production, multiple transformations were carried out on three sets of depth reduction and water yield data for each well, and rendezvous and relationship fitting were carried out.

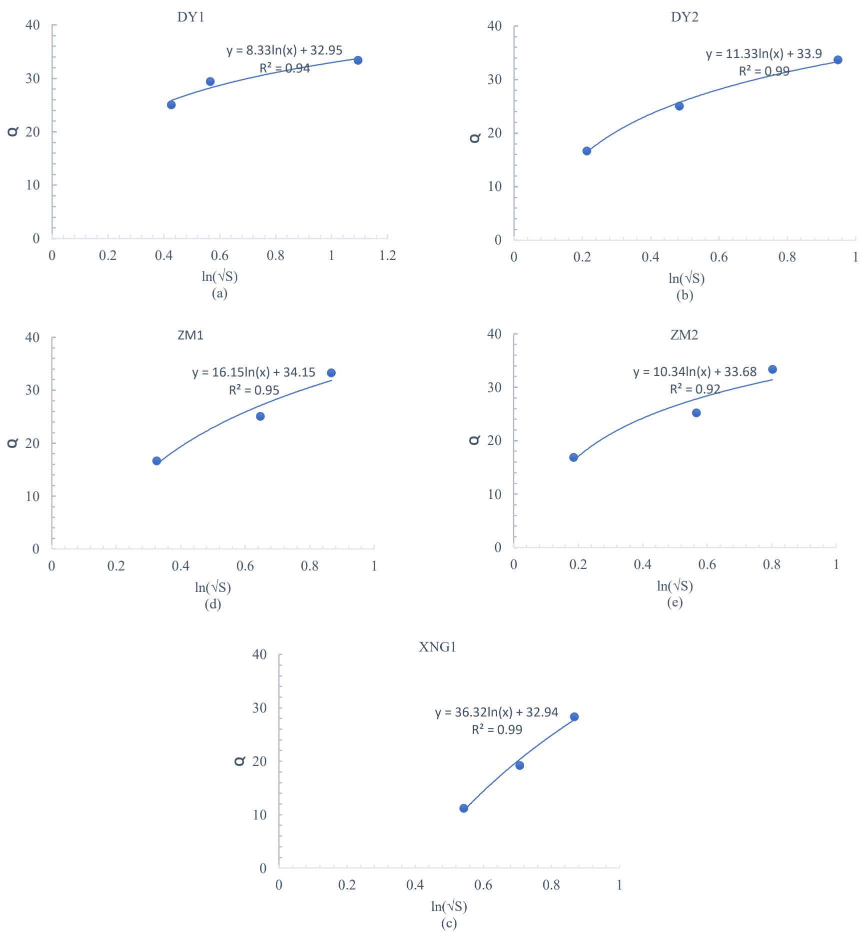

Figure 2: Relationship between drawdown and yield in five wells

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When the relationship between Q and ln (√s) is analyzed, it can be observed that the constant term in the relationship between 5 wells is approximately 33. The discovery of this law establishes a relationship between the amount of water produced by different geothermal wells. For the five geothermal wells, the relationship between water production can be expressed as:

$$Q = \alpha \ln(\ln \sqrt{S}) + 33 \tag{1}$$

Where *Q*, *α*, *S* are yield, coefficient and drawdown, respectively. Although the mechanism of this law is not very clear, it can be believed that this law should not be a coincidence and does not affect its application. This rule is an important finding for evaluating capacity using logging data.

Continuing to observe this relationship, it can be found that the water production of a well *Q* is directly related to α and *S*. If the depth *S* is known, then *Q* is directly related to *α*. At the same time, it can be seen that for the water production of a well, if the depth of the drop is known, then the water production *Q* will only be related to *h* and *k*, where *h* and *k* are the reservoir thickness and permeability. Therefore, *α* must be directly related to *h* and *k*, and *h* and *k* can be obtained from logging data..

In order to study the relationship between *α* and *h* and *k*, the *α*, *h*, and *k* values of the five wells were multi-converted and fitted, respectively. It was found that α had a good correlation with ln(*hk*)., and Table 2 listsed the α and ln(*hk*) of the 5 wells.

Table 2: *α* and ln(*hk*) data

well name	α	ln(hk)
		h(m) k($10^{-9}m^2$)
DY1	8.33	11.5
DY2	11.33	9.54
ZM1	16.15	8.92
ZM2	10.34	9.95
XNG1	36.32	5.01

well name	α	ln(hk)
DY1	8.33	11.5
DY2	11.33	9.54
ZM1	16.15	8.92
ZM2	10.34	9.95
XNG1	36.32	5.01

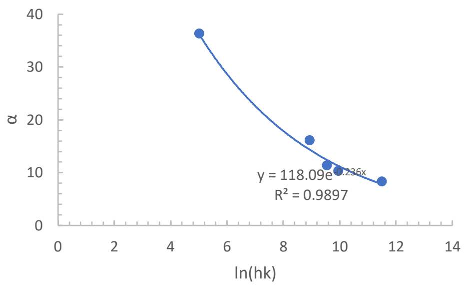

Figure 3 :Diagram of *α* and ln(*hk*)

Through data fitting, it can be found that the relationship between *α* and ln (*hk*) exists as follows.

$$\alpha = 118.09e^{-0.24\ln(hk)} \tag{2}$$

Where *α*, *e*, *h*, *k* are coefficient in the formula(1), natural constant, reservoir thickness and permeability, respectively. From the formulas (1) and (2) can get the expression of the amount of water produced *Q*.

$$Q = 118.09e^{-0.24\ln(hk)} \ln(\ln \sqrt{S}) + 33 \tag{3}$$

The formula is the evaluation model of the industrial quantity *Q*, and the *h*, *k* in the equation can be obtained from the logging data. Using this model, it is possible to evaluate the amount of water produced at different depths.

The selection of the five wells is random, so it can be assumed that this model was not produced by accident in the geothermal field of Xiongxian County, but has its regularity. The model can be generalized to other wells. This model achieves the purpose of directly using logging data to evaluate production capacity, which is easy to operate and practical. The disadvantage is that there is less sample data.

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3. APPLY THE EFFECT

In order to verify the applicability of the model, the model was used to calculate the yield of three wells located in the same block, YPN1, YPN3 and XM1, and the calculation results of the model were compared with the results of the on-site pumping test. In the table3figure, *S* is the depth reduction, Q_m is the model calculation result, and Q_s is the pumping test result.

Table 3: Model results are compared with pumping test data

well name	YPN1			YPN3			XM1		
	S (m)	Qm ($10^{-3}m^3/s$)	Qt ($10^{-3}m^3/s$)	S (m)	Qm ($10^{-3}m^3/s$)	Qs ($10^{-3}m^3/s$)	S (m)	Qm ($10^{-3}m^3/s$)	Qs ($10^{-3}m^3/s$)
	3.32	38.12	39.06	3.21	42.06	41.52	3.22	38.58	39.28
	2.51	38.07	37.32	2.59	40.49	39.96	2.58	37.63	38.50
	1.21	34.22	33.8	1.81	37.71	37.30	1.79	35.95	36.46

YPN1			YPN3			XM1		
S	Qm	Qt	S	Qm	Qt	S	Qm	Qt
3.32	38.12	39.06	3.21	42.06	41.52	3.22	38.58	39.28
2.51	38.07	37.32	2.59	40.49	39.96	2.58	37.63	38.50
1.21	34.22	33.8	1.81	37.71	37.30	1.79	35.95	36.46

Through the comparison of the data, it can be found that the model results of the three wells are basically consistent with the results of the pumping test, indicating that the explanatory model is applicable to the block.

4. CONCLUSIONS

The production capacity of geothermal wells in the same block has regularity, and the model of calculating geothermal well capacity using logging data is established by using its regularity. Through field practice, it is proved that the established model is applicable.

The model is only valid for geothermal fields in Xiongxian. Thermal reservoirs are different in each region, so different geothermal fields have different models.

The mechanism by which some of the data in the model is generated is not clear. In future research, it will be used as a key research project to tackle key problems

NOMENCLATURE

S drawdown, m;
h reservoir thickness, m;
k reservoir permeability, $10^{-9}m^2$;
Q yield, $10^{-3}m^3/s$;
Q_m yield, 10-3m3/s;
Q_t yield, 10-3m3/s.

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