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Characterization of deep ground geothermal field in Jiahe Coal Mine

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ABSTRACT

Research into the characteristics of geothermal fields is important for the control of heat damage in mines. Based on measured geothermal data of boreholes from −200 m to −1200 m in a Jiahe Coal Mine, we demonstrate non-linear but increasing relations of both geo-temperatures and geothermal gradients with increases depth. Numerically, we fitted the relationship between geo-temperatures and depth, a first-order exponential decay curve, formulated as: $T(h) = -4.975 + 23.08 \times \exp(-h/1736.1)$.

1. Introduction

The geothermal field of a mine is in the shallow part of the earth crest, affected by deep geothermal and regional geologic structures and disturbed by factors such as the activities of underground water and local heat sources [1–6]. Therefore, the condition of different geothermal fields is not only affected by various geotectonic elements and depth, but also by the different geologic structures of the shallow part of the earth crest, given the same geotectonic elements and geothermal backgrounds at the same depth. Factors which strongly disturb a geothermal field may cause significant changes in the field [7–10].

The Jiahe Coal Mine, located in the Xuzhou mining area, is classified into substratum depressions in terms of its geothermal field. Its geology is characterized by large and medium sized settlement zones, situated in a stable platform block, with deep crystal substrates. Paleozoic, Mesozoic and Cenozoic erathem sedimentary basins have been formed over it [11–13]. Actual measured data in this mine show that, in general, no heat damage occurs when mining depth is less than −500 to −600 m, but may occur when mining occurs at even lower levels.

Analysis of the characteristics of this geothermal field is important for providing direction and information in order to control heat damage. We present a case study conducted in this mine, to investigate the characteristics of its geothermal field and obtaining a theoretical knowledge base for heat damage control in deep mining.

2. Characteristics of a deep geothermal field in the Jiahe Coal Mine

In order to analyze the distribution of the geothermal field between −200 m and −1200 m in the Jiahe Coal Mine, 22 holes were bored to different depths for temperature measurements within the mining field. These measurements are presented in Table 1.

2.1. Analysis of characteristics on geothermal change

Curves showing geothermal changes for each hole from −200 m to −1200 m have been drawn from Table 1. We only show four curves, all with similar characteristics.

The data from Table 1 have been plotted as Fig. 1 showing sharp geothermal temperature increases with increasing depth. These increases are nonlinear.

Using data from Table 1 can also be used to show geothermal variation in ground temperatures at depths from −200 m to −1200 m (see Fig. 2).

As shown in Curve 5, each stratum in a certain depth has its range of temperature changes respectively, which shows uniform distribution features of the geothermal temperature within each rock stratum. Oscillating trend can be seen from geothermal temperature change curves in the specific depth and the fluctuation level is increased with the increase of depth, that is, geothermal temperature surges with the increase of mining depth, which means nonlinear increase for geothermal gradient.

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Table 1
Temperature contrasts at same depths (°C).

Well	Depth										
	−200 (m)	−300 (m)	−400 (m)	−500 (m)	−600 (m)	−700 (m)	−800 (m)	−900 (m)	−1000 (m)	−1100 (m)	−1200 (m)
18-12	20.9	22.4	24.2	25.8	27.8	29.4	31.5	33.9			
18-14	22.6	23.7	25.2	26.7	28.3	30.2	32.2	34.2	36.3	37.9	40.4
Sup9	22.7	23.8	24.9	26.2	27.4	28.8	30.7	33.0			
19-9	22.4	23.8	25.3	26.9	28.4	29.9	31.3				
20-3	22.1	23.4	25.6	27.8	30.0	32.9					
20-10	23.2	24.1	25.4	27.1	29.0	30.9	32.9	34.8	36.7	38.9	41.2
20-11	20.9	22.3	23.9	26.1	27.8	30.4	32.6	34.7	38.9	41.9	
Sup10	23.4	24.6	26.0	27.5	29.5	31.6	34.1	36.7			
Sup11	22.0	23.5	25.0	26.9	28.6	30.1	31.3	33.3	35.8		
21-5	21.6	23.5	25.4	27.1	28.8	30.5					
22-9	22.8	24.5	25.6	27.8	29.8	31.3	33.0	34.7	36.4	38.9	42.2
22-12	23.5	24.9	26.5	28.0	29.9	31.9	34.1	36.1	38.0	39.1	41.2
Sup13	21.4	23.0	25.3	27.6	29.2	31.8	34.0	37.4			
23-7	21.4	23.0	25.0	27.0	29.0						
23-11	22.3	23.5	24.8	26.4	28.1	30.1	32.3	34.2	36.2	38.0	40.0
23-12	21.9	23.5	25.2	26.9	28.9	31.0	32.8	34.6	36.3	38.4	40.7
Sup6		22.5	24.2	26.0	27.7	29.6	31.5	34.0	36.3		
Sup15	24.3	25.4	26.6	27.8	29.2	31.1	33.2	34.7			
Sup16	23.9	25.3	26.9	28.6	30.0	32.0	33.8	35.8	38.3	41.5	
24-9	21.9	25.3	25.2	27.1	29.1	30.9	32.8	34.6	36.5	38.5	
26-10	23.5	25.2	26.4	27.8	29.6	31.5	33.4	35.1	37.0	38.9	41.0
26-9	21.1	22.4	26.4	28.7	30.9	33.0	35.8	38.4	42.3		
Difference	3.4	3.3	2.7	2.8	2.5	2.6	3.4	3.7	2.4	4.4	2.2

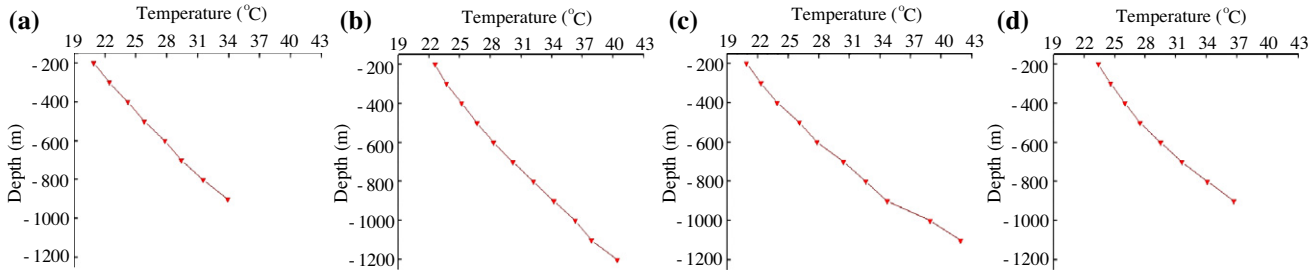

Fig. 1. Variation in ground temperature. (a) Well 18–12, (b) Well 18–14, (c) Well 20–11, (d) Well Sup10.

2.2. Analysis of characteristic on geothermal gradient change

Geothermal gradient is the direct reason for heat transfer [14]. Heat transfer among strata increases with the increase of geothermal gradient, which results in more evident heat exchange [15]. Therefore, in order to get a clearer picture about the distribution of geothermal temperature in Jiahe Coal Mine, geothermal gradient of each hole are listed statistically in Table 2.

Curve of geothermal gradient change of each hole from −200 m to −1200 m can be obtained from Table 2. Only four curves are shown in this paper since similar change characteristics for all the curves.

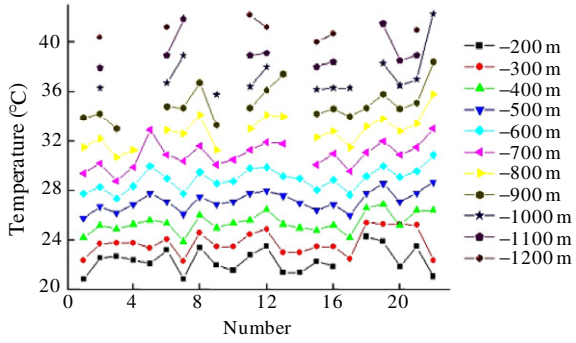

Fig. 2. Variation in ground temperature at different depths.

According to the analysis on the curves from Fig. 3a–d, geothermal gradient generally shows nonlinear increase with the increase of stratum depth.

The curve of geothermal gradient change from −200 m to −1200 m in Jiahe Coal Mine can also be available based on the data in Table 2 (see Fig. 4).

As shown in Fig. 4, most of geothermal gradient values are at the range of 1.0 °C/100 m and 2.5 °C/100 m, indicating that geothermal changes from −200 m to −1200 m in Jiahe Coal Mine are well-proportioned. According to further analysis of the changes of geothermal gradient curves from different depth, geothermal gradient increases with increase of depth and nonlinear increase can be seen from the curve.

3. Relationship between geothermal temperature and the depth of deep parts in Jiahe Coal Mine

From data obtained in the Jiahe Coal Mine and given the analysis of changes in geothermal temperatures and geothermal gradients, we fitted numerically a first order exponential attenuation curve. Fig. 5 shows the relationship between the geothermal temperature and depth of the mine, which is expressed as:

$$T(h) = -4.975 + 23.08 \times \exp(-h/1736.1) \quad (1)$$