3-D VISUALISATION OF TEMPERATURE DISTRIBUTION IN THE KIZILDERE GEOTHERMAL FIELD

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SUMMARY – In this study, a 3D visualisation of the temperature distribution within the Kizildere geothermal field is built using 3D interpolation and extrapolation techniques. The 3D visualization is illustrated. Cross-sections and 3D volume extractions from the main 3D visualisation are carried out in different locations to give a better insight into the field. In addition, the use of a grid block system produces a better estimation of the stored heat energy and heat volume for power generation from the Kizildere geothermal field. Models and measured temperature profiles of Well KD-3 and Well KD-6 are also shown.

1. INTRODUCTION

Actual measurements of the properties of subsurface resources (water, geothermal, or oil) are very scattered and limited to the drilled wells. In addition, these natural properties do not have a normal distribution, which complicates the interpretation and can make visualisation difficult. As a result, engineers and scientist sometimes have difficulty in conjecturing the subsurface structures. Producing a 3 dimensional visualisation of these properties and features can help to overcome some of these difficulties.

However, 3D visualisation only partly solves the problem; consequently, a way of expressing these properties and features mathematically must be found.

In this study, 3D temperature distribution profiles are built using temperature data obtained from the wells of the Kizildere geothermal field, and the results are presented as coloured or greyscale illustrations. Other features of the software enable estimates to be made of the stored heat energy and reservoir volume in a certain temperature range, and the results are reported.

2. METHODOLOGY

Before this study, 2D temperature distribution for the Kizildere geothermal field (Serpen, 2000) had been obtained using the 2D interpolation method of Kriging (spherical variogram model). As known, temperature distributions can be constructed in x-y, y-z, and x-z planes for 2D interpolations. However, the relationship between temperature data across 3 dimensions is not represented across 2 dimensional interpolations. Therefore, a 3 dimensional interpolation is needed to give a more realistic estimation of temperature distribution. Therefore, 3 dimensional interpolation and extrapolation techniques were used, cross sections were taken in directions perpendicular to the axis, and cubic volumes were extracted from the main interpolated 3D temperature distribution cube. Two methods, Kriging, and Inverse Distance, were used for data interpolations and extrapolations. Temperature distribution can be presented visually using greyscale or colour options. The use of colour or greyscale for the display allows the inter-relationships and patterns within the interpolation results to be easily observed, with colour acting like a fourth dimension in the visualisations.

In a recent similar study (Satman et al., 2002), three different methods; Inverse Distance, Kriging, and Triangulation, were tested. A comparison of these methods showed that the best results were obtained using the Inverse Distance method, which gives more weight to data from wells close to each other, and which have direct measurements. When using the Kriging method, it was difficult to define a 3 dimensional variogram model to represent the existing temperature data, and significant differences were observed among the interpolations done by the accepted variogram model. Therefore, the Kriging interpolation method was not preferred.

In this study, the 3 dimensional Inverse Distance interpolation method is used. Hot, warm and cold areas within a geothermal system are defined by taking cross-sections in different directions from 3 dimensional temperature distributions. Although there are similarities between previous 2 dimensional cross-sections, and 2 dimensional cross-sections obtained from 3D interpolations, it is believed that, if there are sufficient data in a given volume, the 3D interpolation obtained by the Inverse Distance method provides more reliable results compared to those produced by 2D interpolations.

3. APPLICATION IN KIZILDERE FIELD

Within the context of this study, the temperature profiles of 22 wells were used. The wells are scattered over an area of about 15 km^2 within the Kizildere geothermal field. All profiles used the first temperature measurements of the wells, and therefore a construction of the original, or natural, temperature distributions was attempted. Nine of the wells are concentrated in one area, once considered to be the main production section. The well depths range from 300 m to 2300 m.

Figure 1 shows a 3D interpolation of the temperature distribution for the Kizildere geothermal field. This cube can be turned over and viewed from any angle.

Figure 2 illustrates a 3D visualisation after removing a prism with a height of 2000 m. The deepest well, R-1, is seen in this figure. It can also be observed that three, clearly separate hot zones exist, and that hot water is rising towards the east in every zone. The highest temperature is found at the bottom of Well R-2, and the hottest zone extends towards the east where no wells have yet been drilled. The same hot zone can be found at relatively shallow levels.

These observations extend the limits of the Kizildere geothermal field beyond the formerly known boundaries; not only laterally, but also vertically. Figures 3, 4 and 5 show cross-sections taken in N-S and E-W directions and also at 500 m below sea level, respectively.

To check the validity of the interpolation results, temperature profiles at known points (well locations) are built after interpolation with the model. Figures 6 and 7 illustrate the comparative temperature profiles obtained from the model and the real measurements in Well KD-3 and Well KD-6, respectively. Note that the temperature data of Wells KD-3 and KD-6 had not been used in the interpolation and extrapolations.

As seen in Well KD-3, the measured profile and the model profile do not match in the upper section. This well is situated in the north-eastern part of the field, on a topographically high location. At this section of the field, not much data is available except for Wells KD-I 11, KD-4 and KD-12, which are situated at similar, distant, high locations. As a consequence, the upper 200 m section of this well does not provide a good match due to insufficient data. A much better match is obtained for Well KD-6 that is situated in the central area of the field.

The cube shown in Figure 1 has a volume of approximately 28.6 km^3. By using grid numbers and their assigned temperatures, the stored heat for the indicated volume is calculated as 1.05 E16 kJ. The porosity and reference temperature are assumed to be 7% and 180°C respectively.

Assuming a reference temperature of 180°C for conventional power generation, the stored heat is computed as 2.02 E14 kJ, and the volume for this temperature range is found to be 7.75 km^3.

4. DISCUSSION

As seen fi-om the Kizildere geothermal field examples, 3D visualisations can be generated using 3D interpolation and extrapolation techniques. The advantage of software modelling is that it both interpolates the data - giving information on the locations where no data are available, and also creates 3D images. Ultimately, where more information is available, it provides better results in the interpolation of the data.

Extrapolations should be treated with some degree of caution, but a recent similar study on the Balcova geothermal field (Satman et al., 2002) provided an excellent temperature profile match for an exploration well (BD-8) outside the known area. Similarly, promising new areas have been observed for new wells in our study of the Kizildere geothermal field. These areas should be further checked using geophysical prospecting techniques.

Until now, only deterministic and stochastic estimations of the stored heat energy in the Kizildere geothermal system have been made. For these type of estimations, either deterministic or distribution parameters such as area, thickness and related temperatures of hot zones have been utilised. With the use of this new software, more realistic estimates of stored heat energy and their volumes are obtained.

In addition to the geothermal properties, geological features can also be represented using the software, and we are planning to visualise the 3D stratigraphy of the Kizildere geothermal system soon.

5. ACKNOWLEDGMENTS

We would like to thank the Kizildere Power Plant authorities for providing us with the data.

6. REFERENCES

Satman, A., Serpen, U., Onur, M. *(2002). Reservoir Engineering Study of Balcova-Narlidere Geothermal Area.* Report for Izmir City Council, Istanbul.

Serpen, U. (2000). Technical and Economical Evaluation of Kizildere Geothermal Field. PhD Dissertation Thesis, Graduate School of Istanbul Technical University, Istanbul.

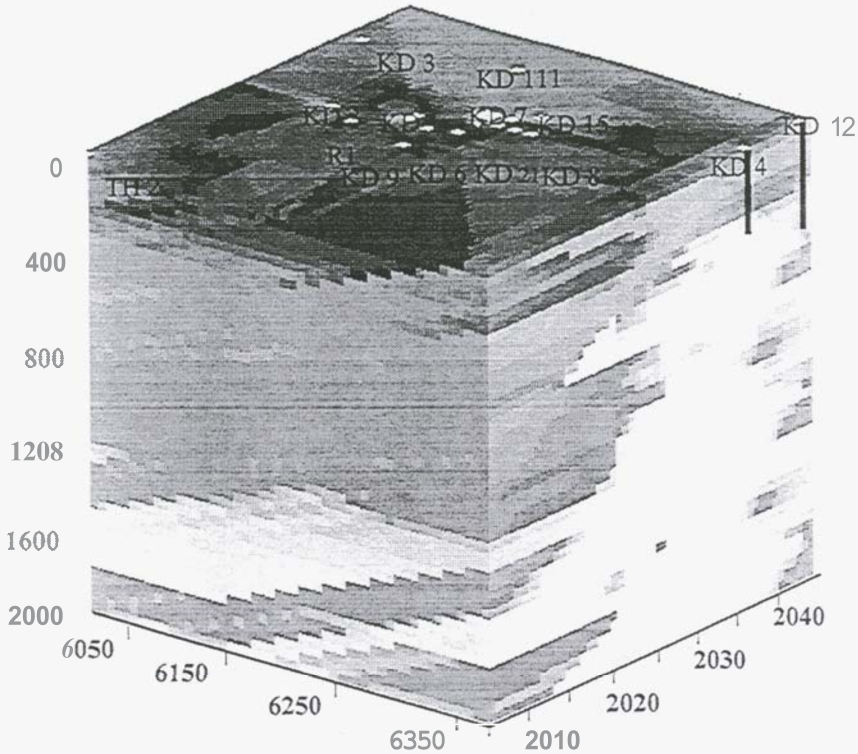

Figure 1 – 3D visualisation of Kizildere Geothermal System

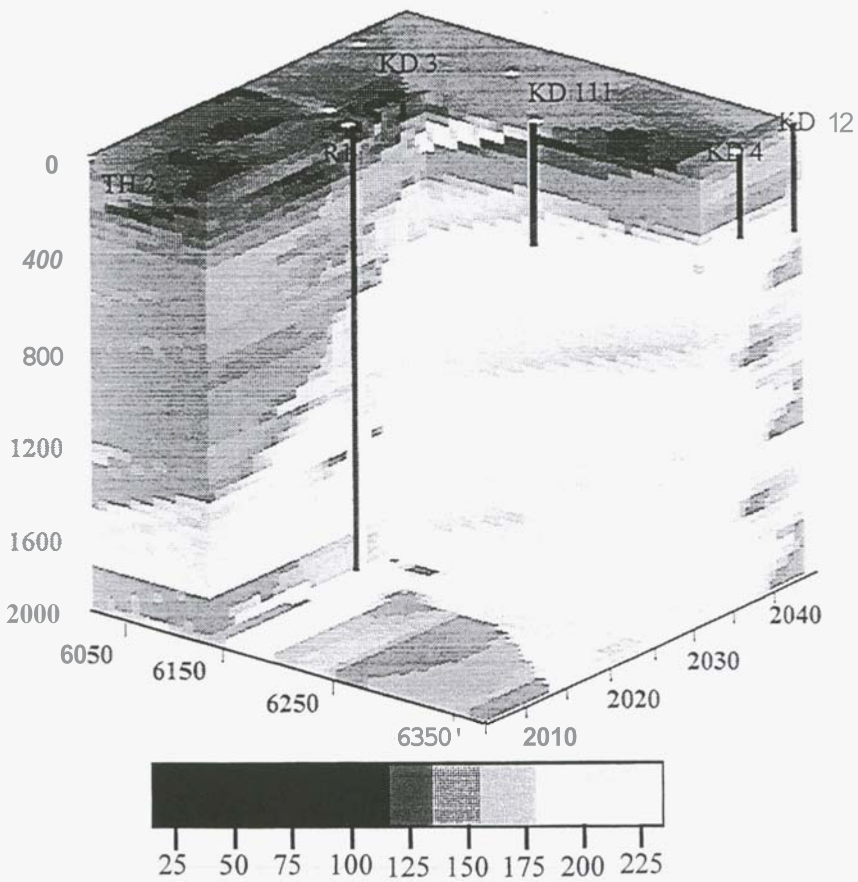

Figure **2** – Inside view of Kizildere Geothermal System

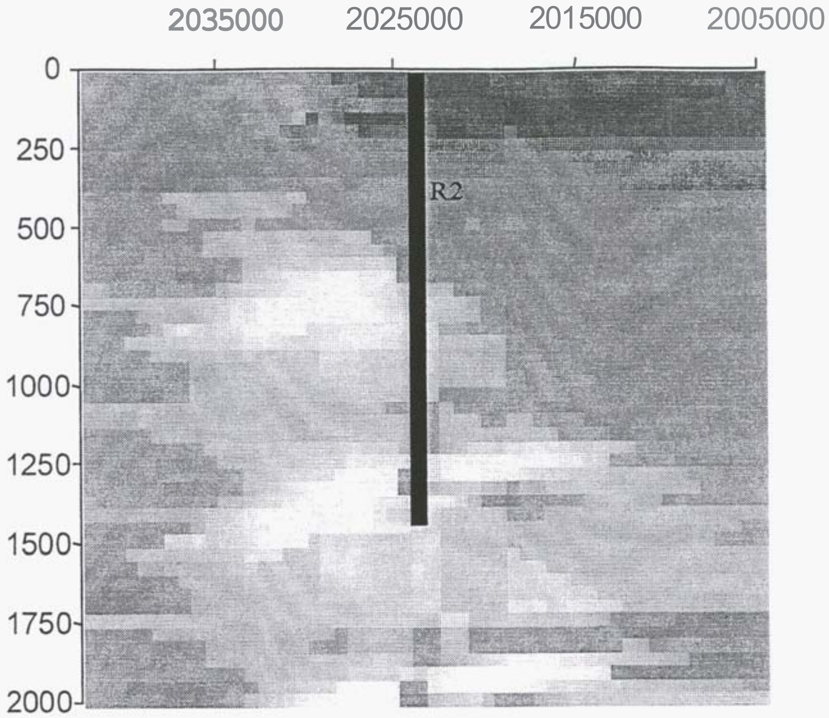

Figure 3 – NS cross section

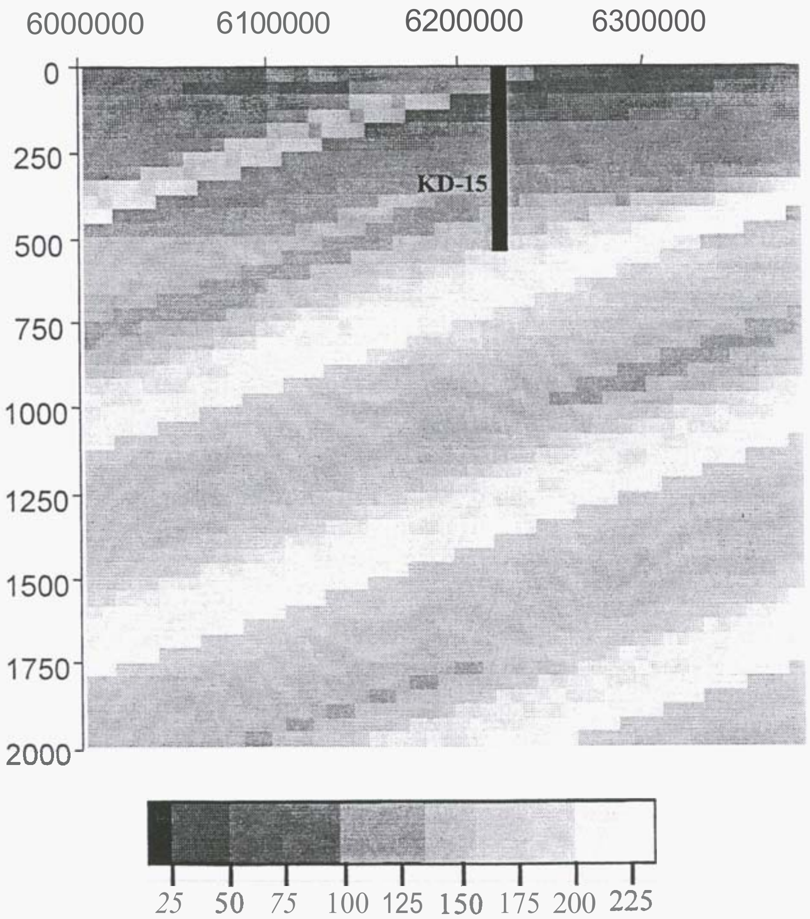

Figure 4 – EW cross section

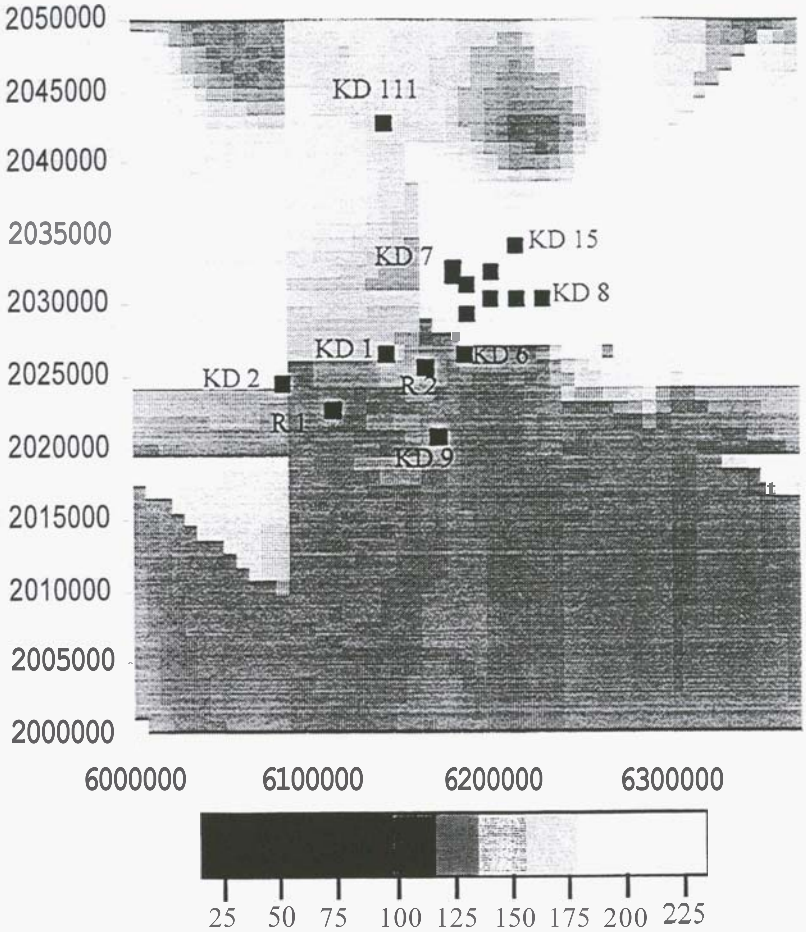

Figure 5 – Cross section taken from 500m elevation

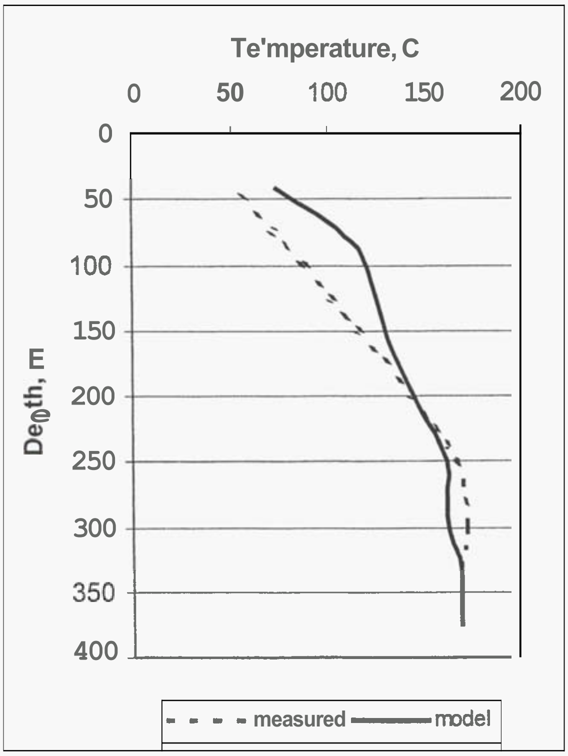

Figure 6 – Measured and model temperature profiles of KD-3.

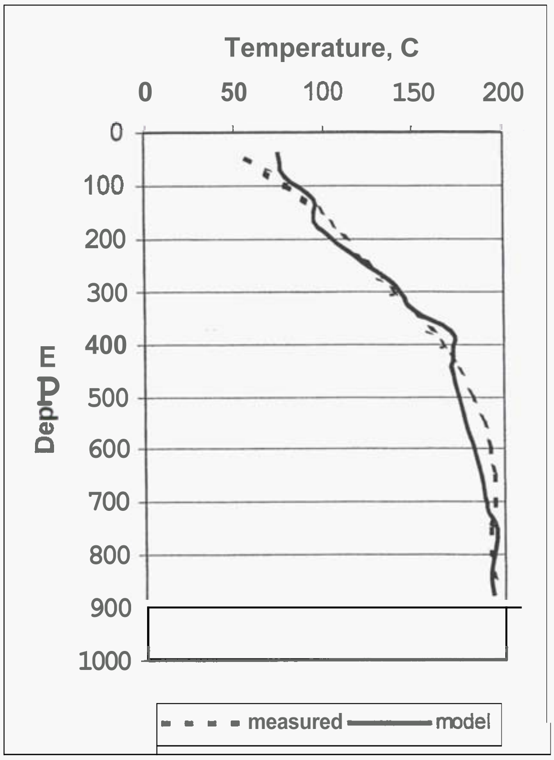

Figure 7 – Measured and model temperature profiles of KD-6.