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A case study of the modeling of a hydrothermal reservoir: Khankala deposit of geothermal waters

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ABSTRACT

In 2013 the Grozny State Oil Technical University together with members of the "Geothermal resources" consortium started a pilot project to build a geothermal plant on the basis of the most promising XIII layer of the Khankala thermal waters deposit. Planned capacity of the projected facility is 22.8 GJ/h, which will heat a greenhouse complex. Geostatistical analysis and numerical simulations are required for achieving sustainability in exploitation of the resource and in order to define new drilling sites. In this paper intrinsic random functions of *k* order kriging (IRF-k) is used for the XIII layer map creation and estimation of the temperature distribution within it. The results obtained by geostatistical approach are used for numerical simulation of the hydro-thermal process relied to reinjection of cold thermal water back into the productive layer. The work carried out allows highlighting the most promising zones for exploitation and shows that the geothermal water temperature in the production well starts to decrease after 6 years.

1. Introduction

Geostatistical analysis and simulation is now widely applied in geosciences in order to study complex phenomena. In geothermy, initial data, as a rule, are obtained from irregularly located wells, which complicate interpolation and extrapolation of different parameters in order to model the behavior of a geothermal reservoir. Thus, a geostatistical approach is useful for mapping the reservoir itself, as well as describing permeability, porosity, salinity, transmissivity, temperature, etc., A major task for geostatistics here is to improve the reliability of the mapping of the reservoir's geometry and the spatial distribution of its characteristics. These descriptions are extremely important for the design of the wells and their further exploitation.

In the current paper, geostatistical analysis is applied to the existing data on the Khankala deposit of geothermal waters (Russia) in order to define new drilling sites.

The Khankala deposit is located 10 km to the south–east from the city of Grozny (Fig.1). The deposit has a layered structure and contains multiple layers of Chocrack and Karagan horizons of middle Miocene sandstones, interlayered with clays. Tectonically, the deposit occupies the southeastern plunge of the Octyabrsk anticline bordered by two co-axial major faults.

The field was actively developed from 1974 to 1994, but its exploitation was ended due to the beginning of the war in Chechnya. In 2013 the Grozny State Oil Technical University together with members of the "Geothermal resources" consortium started a pilot project to build a geothermal plant on the basis of the most promising XIII layer of the Khankala deposit. The water temperature is about 100 °C. Planned capacity of the projected facility is 22.8 GJ/h, which will heat a greenhouse complex.

The drilling of a "doublet" is planned (Fig. 2), i.e., one production and one injection well with reinjection of all the cooled thermal water. A numerical model is needed to predict the evolution of the resource in order to study how the production temperature would decrease as a result of the recycling of the reinjected cold water.

2. Theory and methods

The aim of the work is to estimate the temperature distribution within the XIII layer of the Khankala deposit of thermal waters, develop a new structural map and make, by numerical simulation, a prognosis for deposit exploitation.

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Fig. 1. General map of the location of the Khankala deposit.

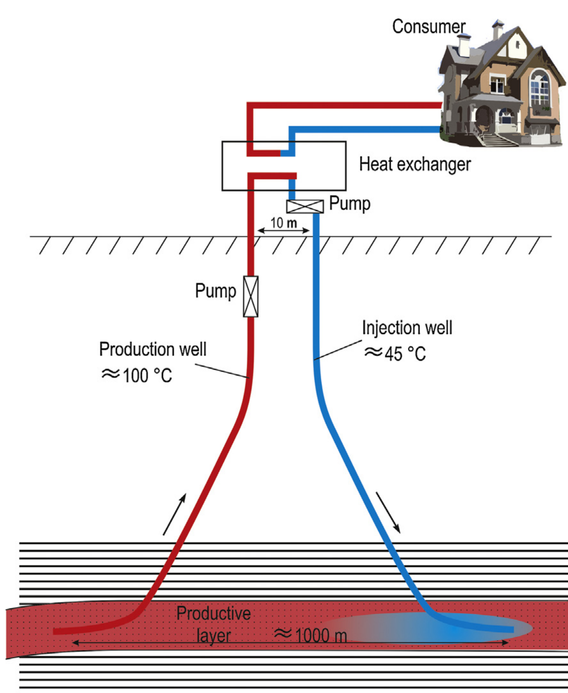

Fig. 2. "Doublet" used in geothermal water extraction-injection.

2.1. Geostatistics

A geostatistical analysis is used to estimate the geometry of the geothermal site.

This analysis is carried out using the ISATIS program (Géovariances, 2009). Intrinsic random functions of order k kriging (IRF-k) was used because of the nonstationarity in data.

The idea behind IRF-k, developed by Matheron (1973), is that it is possible to analyze the data considering some variations of the differences between data points to achieve a stationary covariance. Increments of order k are also called authorized linear combinations of order k ($k = 0$ indicates a difference $Z(x) - Z(x+h)$, $k = 1$ is an increment of an increment, etc., Usually k is not higher than 2). The increments filter out the mean ($k = 0$) or "drift", supposed to be expressed by a polynomial of order k of the coordinates. For example, in a two-dimensional space for filtering linear drift (for $k \geq 1$) $a_0 + a_1 x + a_2 y$, the conditions of authorization are (Chilès and Delfiner, 1999):

$$\sum_i \lambda_i = 0, \sum_i \lambda_i x_i = 0, \sum_i \lambda_i y_i = 0$$

A generalized covariance is used for the estimation. For an intrinsic random function $Z(x)$ of order k there is a symmetrical