NATURAL STATE MODELS FOR GEOTHERMAL SYSTEMS: CASE STUDY, OLKARIA GEOTHERMAL SYSTEM IN KENYA.

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SUMMARY -In the study of the behavior of geothermal systems particularly in the exploitation state, it is important to understand the natural state conditions of the system. Natural state modelling of geothermal systems provide information that serve as the basis for exploitation models that may later be developed.

1. INTRODUCTION

The natural state of a geothermal system refers to the condition of the system before any form of exploitation or use takes place. A natural state model of a geothermal system then refers to the mathematical representation of the physical behaviour of the system before exploitation. In the mathematical representation, we set up a computer model which represents approximately, the permeability structure,(these are areas in the system with low, medium and high permeability), heat inputs that represent magma chambers underlying the reservoir at correct locations and finally fluid inputs of real reservoir. If the above parameters are located with some good degree of accuracy in the actual reservoir; the simulated behaviour of the model can be used to predict the performance of the real reservoir over a given period of time.

2. AIMS OF MODELLING

A successful computer model is the one that will nearly duplicate the behaviour of the geothermal system before exploitation. The model should account for all major physical processes that take place in the system. Some of these processes include: mass transport, conductive and convective heat transfer, boiling and condensation (Bodversson *et. al.* **1984).** The aims of natural state modelling are:

(i) To develop a conceptual model of the field, i.e a good understanding of the physical behaviour of the system.
(ii) The model should be able to measure the natural mass and heat moving in the system and
(iii) The model should serve as a basis for modelling studies of the system when it is being exploited.

3. METHODOLOGY

In the natural state of the system we need to know the three-dimensional structure of the system, that is permeability in the **x, y** and z directions (although vertical permeability is difficult to measure, O'Sullivan *et. al.* **1989),** the temperature distribution in the system which is a good indicator of the hot fluids moving and is directly related to the permeability structure. In order to set up a natural state model, we require data for approximate three-dimensional temperature distribution, location and magnitude of surface outflows of both heat and mass and correct pressures. The natural state model set up to approximate the permeability structure is based on the conceptual model of the field with heat input at the bottom equal to the total output of heat at the surface.

4. NATURAL STATE MODEL FOR OLKARIA GEOTHERMAL SYSTEM.

A plan view of the mesh used in the computer model is shown in figure **4.1**

The surface of the field is divided into rectangles and squares large enough to include all the features in the conceptual model. The mesh, which consists of **8** layers with **49** blocks in each layer, covers an area of 22km^2 which includes all the production and exploration wells. The large mesh size is chosen so as to encompass the whole of the convective system that is believed to exist and to model the natural state conditions of the system before it was exploited. The blocks are of different sizes as shown in figure **4.2**

The 2km. by 2km. grid squares were chosen for blocks named **2, 3, 4, 5, 6, 9, 10,** 11, **12, 13, 16, 17, 18, 19,** 20, **23, 24, 25, 26, 27** and **30, 31, 32, 33, 34.** The **6km** by **6km** square grids were

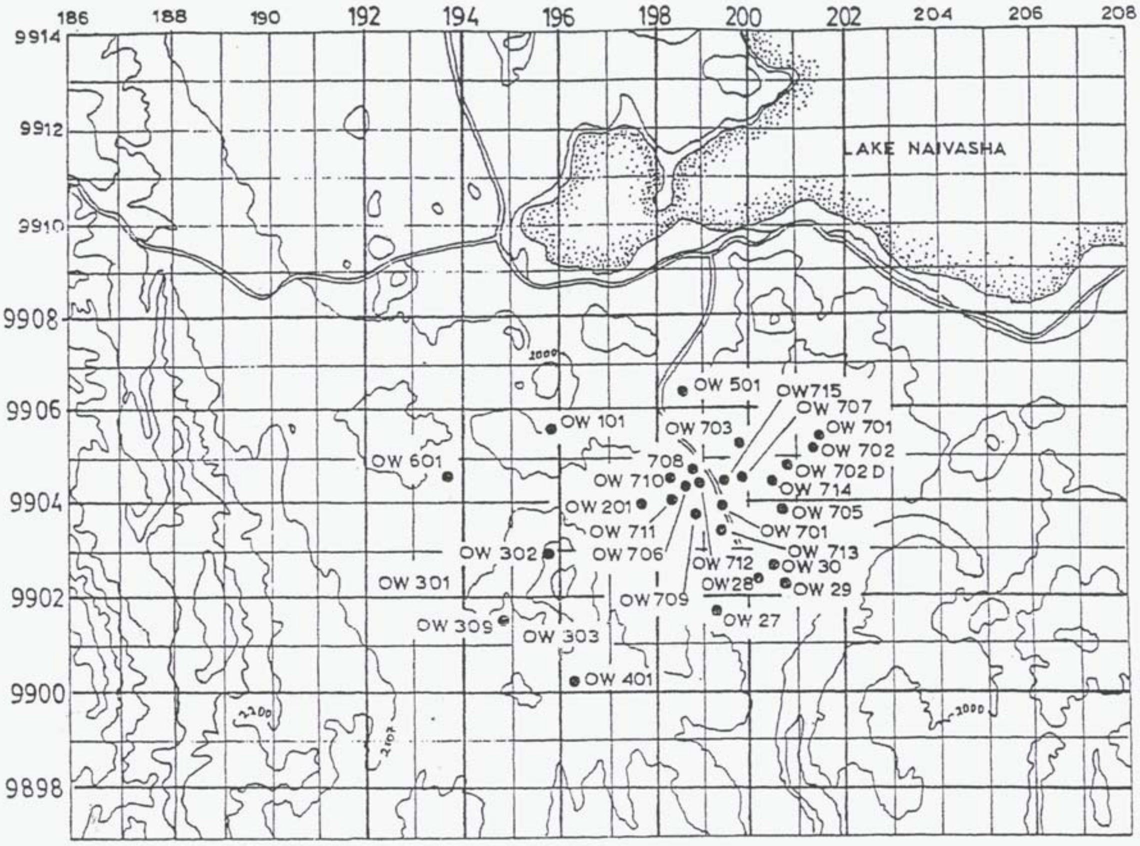

Figure **4.1** Olkaria Geothermal field and layout of the grid for the computer model.

chosen for blocks 36, **42** ,**43** and **49.** The rest **of** the blocks are 2km by 6km rectangular grids. The smaller blocks in the model are used in order to increase the definition needed in the reservoir for better control of the. reservoir parameters. The model is three-dimensional in space (figure **4.3)** in order to model the deepest feed zones as found in wells in Olkaria. The reservoir which is taken to have a thickness of 1550m starts from about 1600m a.s.l. down to 50 m.a.s.l (Manyonge, 1997) The thickness of each layer is as summarized in Table **4.1**

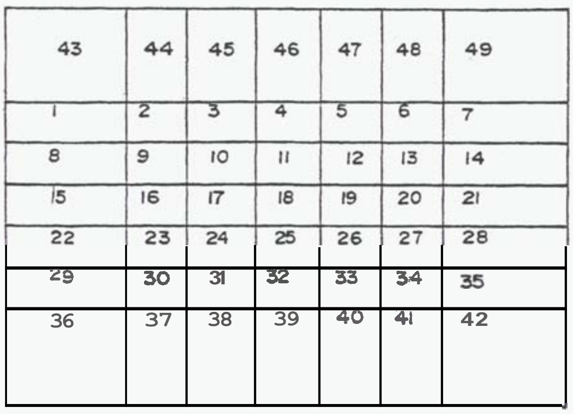

Figure **4.2:** Sizes of grid Blocks

The natural state model simulates the natural reservoir conditions before exploitation. A match is obtained with the actual natural state data obtained before the reservoir was exploited. This natural state model can then be used as a framework on which an exploitation model can be developed.

The natural state was set up using the permeability structure and rocks properties as shown in Table **4.2** with heat input of varying magnitude at some elements in the bottom layer.

The rock properties in the Table **4.2** are the average for the rock formation in Olkaria and are taken from the Geology and Reservoir Engineering data at Olkaria. The different layers represent rocks of variable permeabilities. Horizontal permeabilities range from **1-20** darcy metres. The permeabilities in the layer B,C,D and G were assigned values based upon those determined by the model for Olkaria East field (Bodvarsson *et.al.* 1987) rather than those inferred from well tests because of the uncertainity in the well test analysis. The horizontal permeabilities (x- and y- directions) were adjusted to values

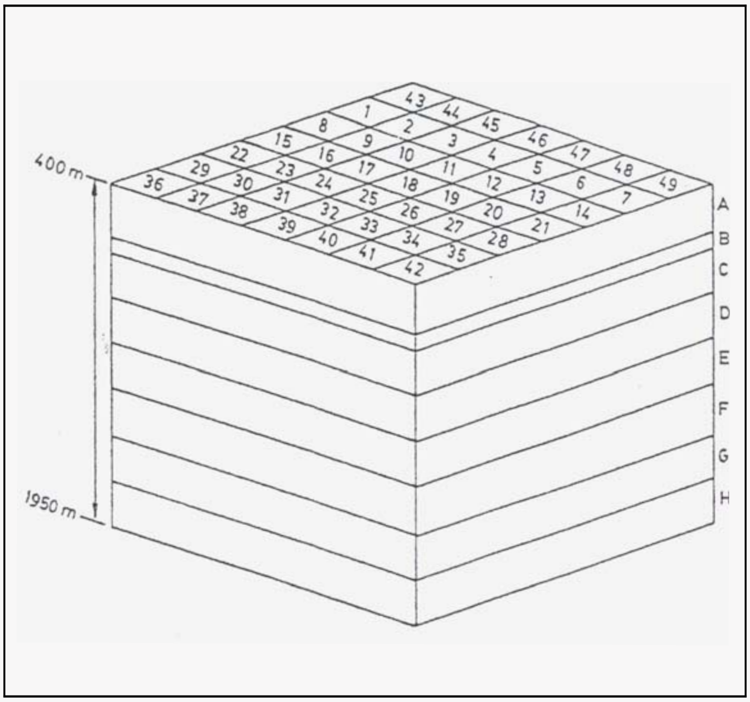

Figure **4.3: 3-D** Model Structure for Olkaria Geothermal field.

Table **4.1**:Layer thicknesses.

Layers	Numbers of Elements	Thickness (m)
A	**49**	**250**
B	**49**	100
C	**49**	**200**
D	**49**	**200**
E	**49**	**200**
F	**49**	**200**
G	**49**	**200**
H	**49**	**200**

Table **4.2:** Material properties for reservoir layers.

Layers	Density (kg/m^3)	HeatCap (J/kgK)	Therm. Cond. (W/mK)	Poro sity
A	2500	20	2.5	**0.1**
B	2500	20	**2.5**	**0.1**
C	2500	20	2.5	**0.1**
D	2500	20	2.5	**0.1**
E	2500	20	**2.5**	0.1
F	2500	20	2.5	0.1
G	2500	20	2.5	**0.1**
H	2500	20	2.5	0.1

between 1×10^{-15} and 20×10^{-15} m^2 or **1-20** milli darcy as these gave a reasonable match to the observed temperatures in the field. Porosity, density, thermal conductivity and heat capacity of the various reservoir rock units (layers) were held constant with values as shown in Table **4.2.** Simulations were run over a period of **3000** years, equivalent to development of the geothermal system over geological time. The model that best reproduced the observed data before exploitation is the natural state model of the Olkaria geothermal system. Comparisons between observed and calculated temperature profiles for typical wells in Olkaria are as shown in figure **4.4.** The observed data for wells in Olkaria were obtained from the GD Manager (Geothermal Development Data gathered and stored) and available at GENZIL (Geothermal Energy New Zealand) and KPC (Kenya Power Company) in Olkaria.

5. CONCLUSION

The graph in Figure **4.4** shows good agreement at most **of** the depths values. The final run conditions for the natural state model can provide initial and boundary conditions for production models.

6. ACKNOWLEDGEMENTS

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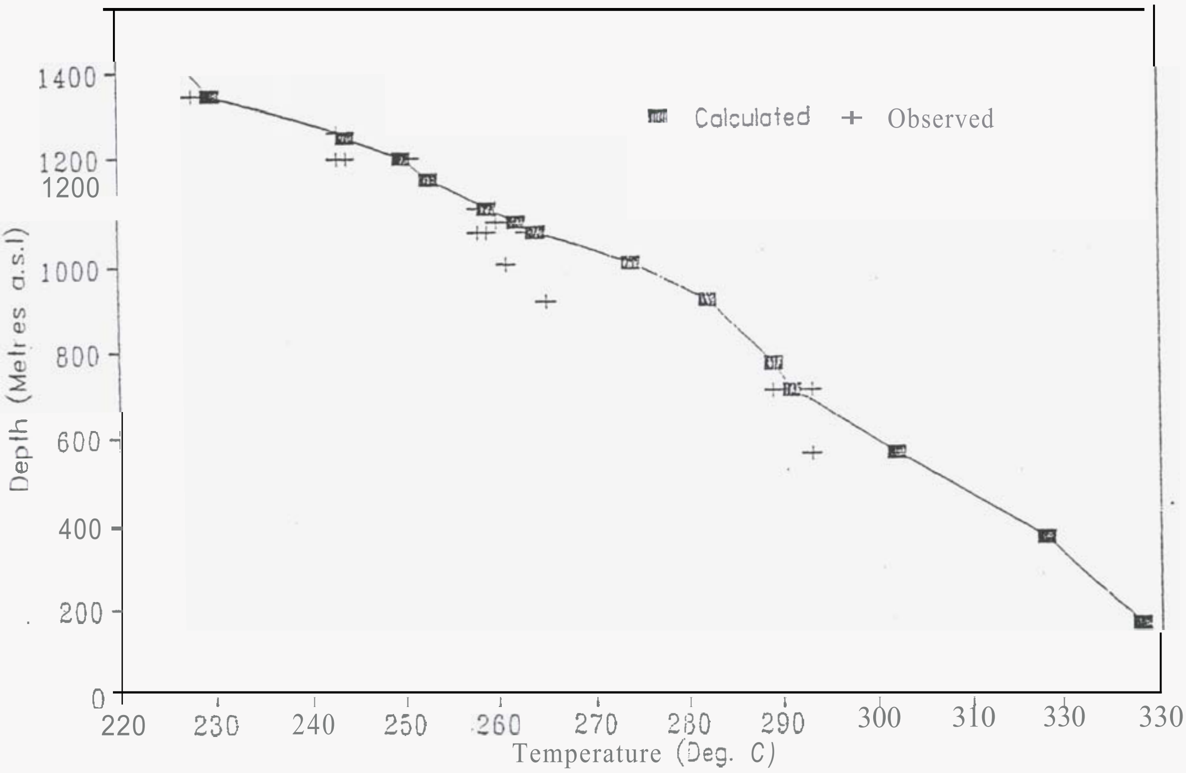

Figure 4.4: Temperature profile for natural state of Olkaria geothermal system.

7. REFERENCES'

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