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OVERVIEW OF GEOTHERMAL DEVELOPMENT AT OLKARIA IN KENYA

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ABSTRACT

The Olkaria geothermal field has been under continuous development since 1970. A feasibility study, completed in 1976, after six wells had been drilled and tested, indicated that development of the Olkaria field was feasible. The feasibility study was followed by production drilling and the construction of three 15 MW generating units. The first unit was brought on stream in July 1981, the second in December, 1982, and the third unit is scheduled to be completed in early 1985. The current output of 19 productive wells is equivalent to 46 MW_e.

Distribution of fumaroles and resistivity surveys indicate an areal extent of some 80 km^2 for the Olkaria geothermal field. Gas chemistry of fumaroles indicates comparable underground temperatures over the whole field, 200-250°C. The capacity of the resource has been estimated to be 500-1000 MW electric for a production period of 25 years.

Most of the drilling has been confined to a small part of the geothermal field. Here maximum recorded downhole temperature is 339°C and temperatures follow the boiling point curve with depth. A thin steam zone at 240°C is observed in the top of the reservoir at approximately 600-700 m depth. The reservoir fluid is dilute, of the sodium chloride type, contains chloride in the range of 200-700 ppm. The reservoir rocks consist of a sequence of near horizontal lavas and tuffs of trachytic composition, but basaltic andesites have also been identified. The drilled rocks at Olkaria are of relatively low permeability, the average yield of wells being equivalent to about 2.5 MW_e.

Exploratory drilling is presently in progress in the Olkaria field, the aim being to locate new production areas within the field. Three holes have been completed and the forth and last hole under the present plan is being drilled.

INTRODUCTION

The VIRKIR Consulting Group Ltd. has been engaged in consultation for geothermal development at Olkaria since 1976, first in collaboration with SWECO in Stockholm and later with Merz and McLellan in Newcastle. VIRKIR's participation has involved assessment of the reservoir characteristics, siting of wells and design of wellhead equipment and the steam supply system. This article focuses on the reservoir aspects but it describes also how the flow characteristics of wells affected decision on the design of the steam supply system and turbine inlet pressure.

The reservoir data have been mostly collected by experts of the Kenya Power Company Ltd. Interpretation has been jointly by these experts and VIRKIR experts. Various aspects of the geothermal development at Olkaria and detailed evaluation of the scientific data has been described in numerous reports, mostly of the Kenya Power Company Ltd. Some key references include Bhogal (1980), Bodvarsson and Pruess (1981), Brown (1981), Glover (1972), Kenya Power Company (1977, 1979, 1980, 1981, 1982, 1983a), McCann (1974), Muna (1982), Mwangi (1982), Naylor (1972), Ndombi (1980), Nganga (1982), Noble and Ojiambo (1975), Odongo (1983), Ojiambo et al. (1982), UN-EAPL (1972, 1976), and Waruingi (1983).

The Olkaria Geothermal Project has been financed by the Kenyan Government, the World Bank, the Commonwealth Development Corporation, and the European Investment Bank.

OVERALL FIELD CHARACTERISTICS

The Olkaria geothermal field is located in the Gregory Rift Valley, 5-10 km south of Lake Naivasha and some 100 km northwest of Nairobi (Fig. 1). The Olkaria geothermal system is considered to be related to a mature central volcano near the western marginal faults of the Rift Valley. The geothermal field occupies the greater part of a caldera or ring structure which is at least 80 km^2 in size (Naylor, 1972; KPC, 1979). There has been some disagreement on the existence of the ring structure (KPC, 1981) which is mostly inferred from circular arrangement of comendite domes (Fig. 2). A fissure zone, active both tectonically and volcanologically, trends N-S through the western part of the inferred ring structure. WSW-striking faults have been observed in the area. Recent evidence from drillings indicates

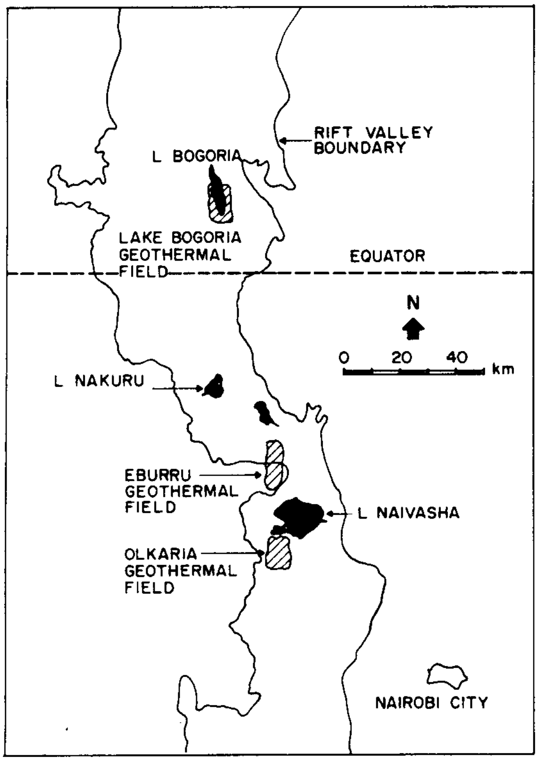

Fig. 1 Location of the Olkaria geothermal field in the Rift Valley.

that these faults may be major upflow zones.

The youngest volcanic eruption in the Olkaria area occurred some 300 ± 100 years ago producing the Ololbutot flow and several smaller flows on a crater line which coincides with the N-S fissure zone. It is not possible to predict when another volcanic eruption is due but very probably it will occur in the same fissure zone as previous eruptions.

The areal extent of the Olkaria geothermal field has been inferred on the basis of 1) the occurrence of fumaroles and hot ground, 2) anomalous shallow ground temperatures, and 3) anomalies of low bedrock resistivity (Noble and Ojiambo, 1975). A conservative estimate based on 1) and 2) lies in the range 50 km^2. Resistivity surveys strongly suggest a larger field, totalling about 80 km^2 (Fig. 2). Natural heat loss of the Olkaria system has been estimated by Glover (1972) to be 400 MW thermal corresponding to a steam flow of 140 kg/sec, or the steam required for 50 MW electric power production. Gas geothermometry results indicate that subsurface temperatures of 250°C and higher are to be expected over the entire field (KPC, 1983b). The area in the southern part of the field by the fissure swarm and near the first exploration hole represents a major upflow according to the most recent geothermometry interpretation (KPC, 1983b) as steam condensation in the upflow is here at minimum.

A critical review of available resistivity data carried out in 1980 favoured Schlumberger soundings as the most appropriate for evaluation of the deep resistivity structure (KPC, 1980). Re-interpretation of the deepest soundings revealed regional low resistivity in the south of the field below 2000 m and updoming to some 1400 m in the northwest. This updoming resistivity low is most likely due to hydrothermal alteration. It has been postulated that the northwest region is a primary upflow of the hottest reservoir fluid (KPC, 1980).

The catchment area to the north of the Olkaria field is over 3000 km^2. Mean annual precipitation within the catchment area varies between 650 and 1500 mm. Potential evaporation is estimated as 1700-2100 mm/year (McCann, 1974). The rain pattern is, however, such that an excess of water joins the ground water after losses by evaporation. Lake Naivasha is a fresh water lake. There is no surface outflow so underground seepage must occur and to the south. The subsurface drainage has been estimated as 8 m^3/sec and more than 4.7 m^3/sec have been estimated to recharge on average the Olkaria geothermal reservoir (McCann, 1974, Noble and Ojiambo, 1975). Calculations indicate that recharge into the Olkaria reservoir is not a limiting factor to exploitation, even considering a reasonably large geothermal power plant (UN-EAPL, 1976).

OUTLINE OF HISTORY OF DEVELOPMENT

Exploration of the Olkaria geothermal field was initiated in the year 1956 and has been continuous since 1970. The early exploration involved the drilling of two holes. High temperatures were encountered but attempts to bring the holes into production were not successful. In 1970 a geothermal exploration project was initiated in Kenya and was jointly financed by the United Nations Development Programme and the Kenyan Government. During 1971 and 1972 exploration was carried out in the Olkaria geothermal field. It consisted of geological mapping and geophysical and geochemical surveys as well as further investigations on the two exploration holes drilled in 1956-58. The surface exploration work was followed by a Technical Review Meeting to assess the exploration results. The Meeting recommended the drilling of four exploratory holes in the Olkaria field. Drilling started in 1973. The second hole was successful and further drilling was concentrated around that hole. By 1976 six holes had been drilled at Olkaria. The drilling was succeeded by a feasibility study the results of which indicated that development of the geothermal resource at Olkaria was attractive and Kenyan authorities decided to construct a 30 MW power plant of two 15 MW units with possible extension by the addition of a third 15 MW unit. The first unit was brought on stream in July, 1981, the second in December, 1982 and the third unit is scheduled to be commissioned in early 1985.

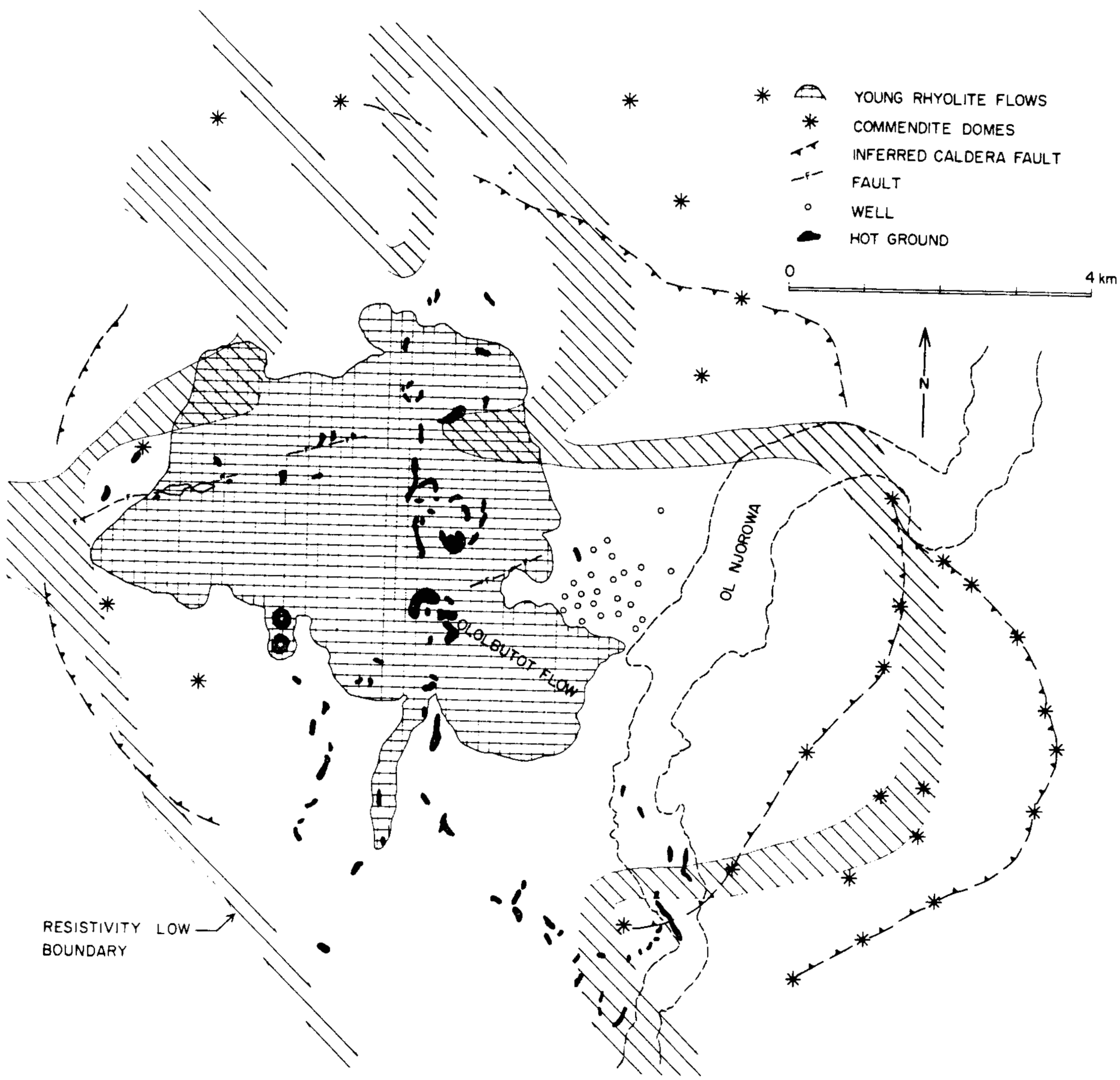

Fig. 2 Combined map showing geological feature and boundary of bedrock resistivity anomaly.

In 1980 the Kenya Power Company Ltd. organized a second Scientific Review Meeting, the aim of which was to give recommendations on exploration of the Olkaria geothermal field beyond the present production area. The Meeting recommended the drilling of exploration holes at four new sites to be followed by appraisal drilling where the exploration drillings were successful. Three of the exploration holes have now been completed and the fourth hole is being drilled.

THE BOREFIELD CHARACTERISTICS

After the successful drilling of the second exploratory hole (OW-2) in 1974 later appraisal and production drilling has been concentrated in that part of the Olkaria field. It was visualized that early demonstration of feasible use of the geothermal resource was desirable rather than more exploratory drilling in other parts of the Olkaria field that might have discovered better production areas. The present borefield is about 2 km^2 and now (November, 1983) 24 wells have been completed and the 25th well is being drilled. Of the 24 wells, 19 are productive yielding steam equivalent to 46 MW_e. The wells range in depth from 901 to 2485 m, most of them being in the range 1200-1400 m.

Physical State - Temperature and Pressure

In the production field perched salty aquifers are underlain by a shallow, low pressure steam zone at 1600-1700 m elevation (the borefield is at 1920-1950 masl). Between 1275 and 1625 masl liquid near boiling temperature controls the pressure. The observed temperature profile in this depth interval (Fig. 3) can be explained by the rise of steam through rock composed of layers of alternating poor and good permeability. In Fig. 3 one may recognise sections of linear gradients in aquicludes, boiling curve segments in layers of better permeability and intervals of constant temperature, where the fluid is convecting in layers of highest permeability.

At 1130-1275 m elevation the wells penetrate a steam zone near 240°C and 35 bars abs. pressure. The pressure gradient in this zone is controlled by the vapour phase although both phases, steam and water, are coexisting. Below 1130-1210 masl the wells reach a liquid dominated boiling water reservoir with a pressure potential corresponding to a rest water level of boiling water at 1550-1620 masl.

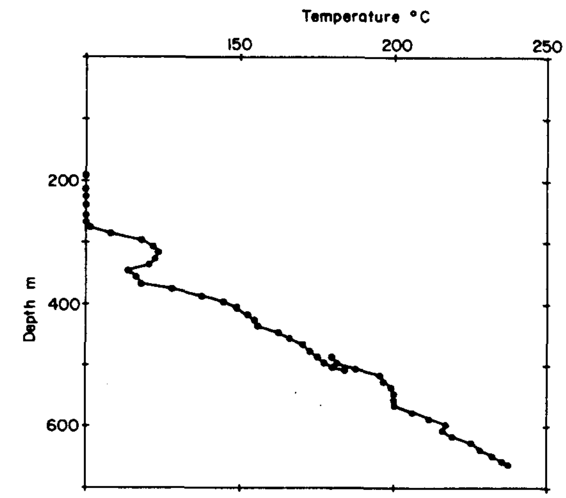

Fig. 3 Temperature in well OW-2 above the steam zone.

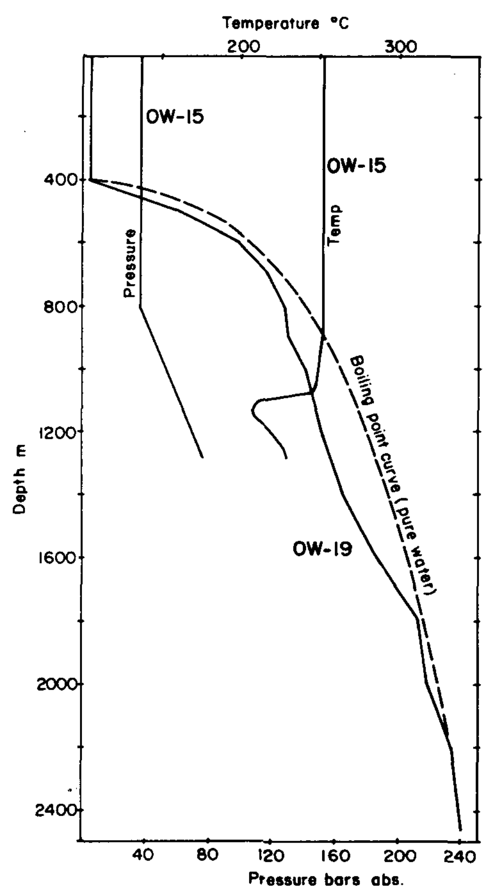

Fig. 4 Temperature and pressure profiles in selected wells. The logs for well OW-15 show the features characterising the steam zone and a temperature reversal below that zone considered to be due to cooling by injected water 21 days before the temperature run was taken.

Temperatures in the water reservoir appear to follow the boiling point curve at least to the drilled depth of 2485 m. This is not easily confirmed as most temperature logs are severely disturbed by cooling effects of injected water and cooling due to boiling in the formation during flow tests (Fig. 4). The highest recorded temperatures are 304°C at 1651 m depth in well OW-4 and 296°C and 339°C at 1600 m and 2460 m in wells OW-6 and OW-19 respectively. All are slightly below the boiling point for pure water at these depths but dissolved gases may have lowered the boiling temperature.

Pressure logs have been analysed to infer the pressure potential of the dominating aquifers in the water reservoir. These aquifers are found at various depths in wells. In order to obtain a common reference level for the pressure potential the level of the 35 bar abs. isobaric surface has been estimated assuming a vertical pressure gradient of hydrostatic water of boiling temperature. The isobaric surface is found to slope up towards north by 0.14 m/m indicating a lateral flow component from the north through the borefield.

Stratigraphy and Hydrothermal Alteration

The rocks penetrated by drillholes in the production area are exclusively volcanic except for the topmost 100-150 m. No significant sedimentary intercalations have been discovered. The stratigraphic sequence consists mostly of near horizontal lavas of fine grain and some tuffs. They are generally of trachytic composition but rhyolites have been identified. Less differentiated rocks, probably basaltic andesite are conspiceous at 500-700 m depth. They overlie the steam zone and probably act as caprock for the geothermal reservoir. Channelways for the geothermal fluid are probably lava contacts, scoria zones and coarse pyroclastic interbeds, but also contraction joints in the lavas.

The hydrothermal alteration of the reservoir rocks has been studied by Browne (1981). The mineral assemblage is that typically found in rocks altered by hydrothermal fluids above 200°C (see Browne, 1978). Prominent alteration minerals include chlorite, calcite, quartz, pyrite, fluorite, epidote, albite and adularia. Calcite occurs in greatest abundance above 600-800 m depth. As its formation is associated with boiling it is inferred that significant steam formation starts at this level. Epidote distribution, but this mineral forms at temperatures above about 250°C, indicates that the southernmost wells in the borefield are located on the periphery of the steam zone.

The abundance of adularia and albite in the altered rock has been used as a semiquantitative indicator of permeability (Browne, 1981). At Olkaria they are most abundant in the westernmost part of the borefield but here wells tend to be poor producers. It is expected that the amount of albite and adularia in altered rock is determined by the total quantity of water passing, together with water salinity and boiling, and may not represent present-day permeability. Alteration leads to reduction in permeability. In order to explain the positive correlation between albite and adularia abundance and permeability, observed in some geothermal fields (Browne, 1981) a mechanism which rejuvenates the permeability must be postulated such as tectonic movements. The apparent negative correlation between alteration and permeability at Olkaria would by this argument indicate insignificant tectonic movements in the present borefield.

Fluid Chemistry

Waters discharged from wells at Olkaria are of the sodium chloride type (Table 1). Compared with waters in geothermal systems located in acid volcanics in many other parts of the world the chloride concentrations are relatively low at Olkaria or in the range 200-500 ppm when correction has been made for steam loss. The concentrations of compatible major components, including gases, are governed by equilibria with alteration minerals in the rock.

An increase in the chloride concentrations is observed with increasing depth of the producing aquifers. Also chloride concentrations increase from south to north across the borefield. The positive relation observed between chloride levels and Na-K geothermometry temperatures have been taken to indicate that the northernmost wells are closest to a major upflow (KPC, 1982). The chloride-depth gradient is believed to have development by downward percolation of condensate from the steam zone into the boiling water reservoir as a result of heat loss through the caprock.

Permeability

Permeable zones have been identified by circulation losses during drilling, or inflow, as well as from analysis of pressure and temperature logs obtained during injection tests and recovery of temperature and pressure

Table 1. Composition of water and steam from selected wells at Olkaria at atmospheric pressure (0.8 bars abs.). From Muna (1982).

	OW-6	OW-10	OW-12
Water phase (ppm)			
pH/°C	9.25/20	8.58/20	9.10/20
SiO_2	762.0	734.0	880
B	5.6	8.0	6.4
Na	495.0	734.0	476.0
K	70.2	147.4	72.2
Ca	0.82	0.92	0.62
Mg	0.009	0.032	0.018
$CO_2{}^a$	48.8	34.4	71.1
SO_4	38.6	30.1	44.1
H_2S^a	2.9	0.62	1.46
Cl	482.2	1140.2	629.9
F	49.5	57.0	67.5
Steam phase (immoles/kg steam)			
CO_2	62.24	41.71	38.00
H_2S^a	10.91	5.12	5.09
H_2	5.67	4.02	5.14
CH_4	0.78	0.42	1.69
$N_2{}^b$	0.98	1.38	0.98
Discharge enth.J/g	2316	2378	2209

[a]Total carbonate and total sulphide.
[b]Residual gas.

after completion of the wells.

Most of the wells have encountered permeable horizons within the steam zone at 600-800 m depth. This corresponds with the bottom of the basaltic-andesite series and the top of the underlying rhyolites. Many other wells have encountered aquifers at 1000-1150 m depth in trachyte lavas within the boiling water reservoir. Some wells have also penetrated permeable zones at 900-1000 m depth. Only three wells penetrate significantly below 1400 m. Of these only one well, OW-19, has struck a significant aquifer below this depth, or at 1500 m.

Transmissivity (permeability-thickness product) has been estimated by several methods. They include pressure build-up during injection of water of constant flow rate and pressure fall off after injection is stopped. Also by recording drawdown of pressure in producing aquifers under stable discharge conditions and by studying the gradual recovery of that pressure to undisturbed values after the well has been closed. There is often considerable discrepancy between the results of the different test methods but interpretation in a two phase reservoir is complicated. Values obtained for the transmissivity in individual wells lie generally in the range 1-5 Darcy-meters but the highest values recorded are 13 Dm for well OW-12.

These results show, compared with many other exploited geothermal fields, that permeability is relatively low at Olkaria, at least within the present borefield.

Well Performance

Most of the wells are fed by a number of aquifers at different levels. Clearly many wells have a significant contribution from the steam zone. Wells dominated by feeders in the steam zone show rapid build up of shut-in pressure to about 35 bars. On the other hand wells dominated by aquifers in the water reservoir have a tendency to build up higher wellhead pressures. The flow from these latter group of wells shows little decline with rising wellhead pressures up to 20 bars whereas wells dominated by feeders in the steam zone cannot maintain their output at such a high wellhead pressure.

The enthalpy of the well discharges is variable, although high on average, or about 2200 J/g. A few wells discharge practically dry steam. During the early periods of discharge the enthalpy may correspond with that of steam saturated water at the respective aquifer temperature but its value gradually rises within a few weeks to about 2000 J/g or more.

The steam flow from the wells is low on the whole as would be expected from the low reservoir permeability. For exploitable wells it lies in the range 10-60 tonnes/hour at 6 bars abs. wellhead pressure, the weighted average being about 25 tonnes/hour. During the 2 year production period of the Olkaria geothermal power station some wells have shown decline in output by as much as 20% whereas other wells have remained stable. The cause has not yet been satisfactorily explained.

The best wells are located on a rather narrow belt on either side of a ravine running N-S and immediately east of the power station. It may be that this ravine is the surface expression of a fracture zone.

Conceptual Field Model

The main features of a model for the present borefield are as follows: Boiling water reservoir is overlain by a steam zone of 50-150 m thickness capped by a sequence of basaltic-andesite lavas. There is a strong component of lateral flow through the borefield from north to south as indicated by the pressure gradient and fluid chemistry, possibly from a major upflow along the WSW trending fault just north of the borefield. During the lateral movement of the fluid, boiling and phase separation occurs, leading to the formation of the steam zone. The lateral movement from the major upflow may be concentrated on a N-S trending fracture zone represented by a topographical ravine immediately east of the power station. Heat loss through the cap rock causes some steam condensation and descending condensate produces rather strong salinity gradient in the uppermost part of the hot water reservoir as well as a gradient in the direction of the flow.

Generating Capacity of the Reservoir

The longevity of the reservoir around the present borefield has been predicted by numerical simulation (Bodvarsson and Pruess, 1981). The approach taken was to assume that the pressure declines uniformly throughout the borefield as a consequence of fluid extraction. The borefield was thus modelled as one block within which there are no spatial variations in pressure. The recharge into the reservoir was accurately modelled. Furthermore the fluid mass in the steam zone was neglected and the reservoir fluid was extracted from the uppermost 550 m of the water reservoir.

The results of the numerical simulation study showed that the most critical factors controlling the generating capacity are horizontal and vertical permeabilities. Fig. 5 shows examples of predicted pressure decline for different assumed vertical permeability values. From the simulation studies and available data on transmissivity it was concluded that the geothermal reservoir around the present borefield can supply steam for the 45 MW power plant over at least 30 years (KPC, 1982).

THE STEAM SUPPLY SYSTEM

A wellhead separator and wellhead silencer is installed at each well. The steam is piped from the separator to the power station passing through a moisture separator prior to admission to the turbines. Steam pressure is controlled accurately by automatic exhaust valves located near the power house and blowing excess steam to atmosphere. The water from the silencers is discharged into special infiltration ponds.

The steam supply system was designed to accomodate the observed well characteristics as well as the predicted response of the reservoir to the production load. The water fraction in the well descharges was low and it was anticipated that it would decrease still with time. It was, therefore, not attractive to exploit this water phase by a second flash at low pressure. The admission pressure to the turbines was selected at 5 bars abs. by making a compromise between hardware economy and the cost of steam winning with due regard to possible future decline in wellhead pressure and steam flow due to reservoir drawdown.

FUTURE DEVELOPMENT

In December, 1980, the Kenya Power Company Ltd. organized a Scientific Review Meeting the aim of which was to assess all available data on the Olkaria geothermal field and forward recommendations for exploration and development beyond the present 45 MW power station. The Meeting recommended the drilling of deep (2500 m) exploratory holes at four new sites to be followed by appraisal drilling where there was success. Successful exploratory hole was defined as one that discharged sufficient steam to generate at least 4 MW electric. At this time (November, 1983) exploratory holes have been drilled at three of these sites and drilling is in progress at the last site. It is visualized that appraisal drilling will be

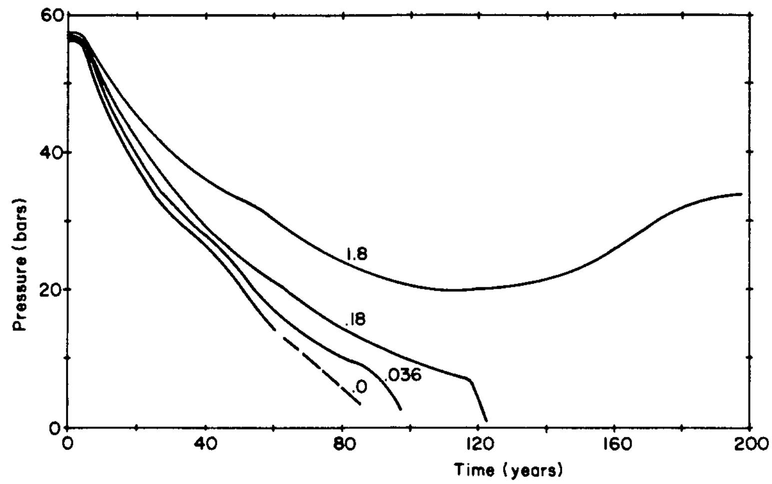

Fig. 5 An example of predicted pressure decline in the borefield. The following assumptions were made: Production area 2 km^2. Reservoir area 12 km^2. Horizontal transmissivity 4.0 Darcy-meters. Figures on graph show vertical permeability in mD. Corey relative permeability curves were used. From Bodvarsson and Pruess (1981).

commenced after thorough evaluation of the exploratory well data and it is anticipated that units of 30 MW will be suitable for economy reasons and market requirements.

Kenya does not possess fossil fuel reserves and most of the economically attractive hydropower schemes have already been developed. In view of this and the successful development at Olkaria, geothermal resources will, we believe, play an increasingly important role in Kenya's power generation.

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REFERENCES

Bhogal,P.S. (1980), "Electrical Resistivity Investigations at the Olkaria Geothermal Field, Kenya", Geothermal Resources Council, Transactions, 4, 9-12.

Bödvarsson, G. and Pruess K. (1981), "Olkaria Geothermal Field - Numerical Studies of the Generating Capacity of the Reservoir," A report prepared for the Kenya Power Company Ltd.

Browne, P.R.L. (1981), "Petrographic Study of Cuttings from Ten Wells Drilled at the Olkaria Geothermal Field, Kenya," Geothermal Institute, University of Auckland, NZ. Report for KPC, Nov., 1981.

Browne, P.R.L. (1978), "Hydrothermal Alteration in Active Geothermal Fields", Ann. Rev. Earth Planet. Sci. 6, 229-250.

Glover, R.I. (1972), "Chemical Characteristics of Water and Steam Discharges in the Rift Valley," UN Geothermal Resources Exploration Project Report.

The Kenya Power Company Ltd. (1977), "Report on Geothermal Development at Olkaria," prepared by Merz and McLellan and Virkir Ltd., Oct., 1977.

The Kenya Power Company Ltd. (1979), "Progress Report on Steam Production," prepared by Merz and McLellan and Virkir Ltd., Apr., 1979.

The Kenya Power Company Ltd. (1980), "Scientific Review of Olkaria Geothermal Reservoir," A report prepared for the Scientific Review Meeting by GENZL, Nov., 1980.

The Kenya Power Company Ltd. (1981), "Recommendations for Further Geothermal Exploration at Olkaria," A report prepared by Merz and McLellan and Virkir Ltd., May, 1981.

The Kenya Power Company Ltd. (1982), "Status Report on Steam Production," A report prepared by Merz and McLellan and Virkir Ltd., May, 1982.

The Kenya Power Company Ltd. (1983a), "Status Report on Steam Production," A report prepared by Merz and McLellan and Virkir Ltd., Jan., 1983.

Mwangi, M.N. (1982), "Two-Dimensional Interpretation of Schlumberger Soundings and Head-On Data with Examples from Eyjafjordur Iceland, and Olkaria, Kenya," United Nations University Geothermal Training Programme, Iceland, Report 1982-9, 72 pp.

Naylor, W.I. (1972), "The Geology of the Eburru and Olkaria Geothermal Prospects," UN Geothermal Resources Exploration Project Report.

Ndombi, J.M. (1981), "The Structure of the Shallow Crust Beneath Olkaria Geothermal Field, Kenya," Deduced from Gravity Studies, J. Volc. Geothermal Research, 9, 237-251.

Nganga, J.N. (1982), "Comparison of Drilling in High Temperature Fields in Olkaria, Kenya, and Krafla, Iceland," United Nations University Geothermal Training Programme, Iceland, Report 1982-10, 59 pp.

The Kenya Power Company Ltd. (1983b), "Status Report on Steam Production," A report prepared by Merz and McLellan and Virkir Ltd., Nov., 1983.

McCann, D.L. (1974), "Hydrogeologic Investigations of the Rift Valley Catchments," UN Geothermal Resources Exploration Project Report.

Muna, Z.W. (1982), "Chemistry of Well Discharges in the Olkaria Geothermal Field, Kenya," United Nations University Geothermal Training Programme, Iceland, Report 1982-8, 38 pp.

Noble, J.W. and Ojiambo, S.B. (1975), "Geothermal Exploration in Kenya," In Proceedings of the Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco 20-29 May, 1975, 1, 189-204.

Odongo, M.E.O. (1983), "Geological Report of OW-1 Well," Kenya Power Company Ltd. Geothermal Project Report GL/OW/1/013.

Ojiambo, S.B., Odongo, M.E.O., Maina, S.K. and Haukwa, C.B. (1982), "First Year Operation Experience of the Olkaria Geothermal Power Station," Kenya Power Company Ltd. Geothermal Project Report.

United Nations - East African Power and Lighting Company (1972), "Report of Technical Review Meeting, December, 1972," UN Geothermal Resources Exploration Project Report.

United Nations - East African Power and Lighting Company (1976), "Feasibility Report for the Olkaria Geothermal Project," prepared by Sweco and Virkir Ltd., Dec., 1976.

Warningi, S.N. (1983), "Two Years Production Period at the Olkaria Geothermal Field, Kenya," Kenya Power Company Ltd. Geothermal Project Report.