Geothermal Resources Council TRANSACTIONS, Vol. 19, October 1995

RESULTS OF INJECTION AND TRACER TESTS IN OLKARIA NORTH EAST FIELD IN KENYA

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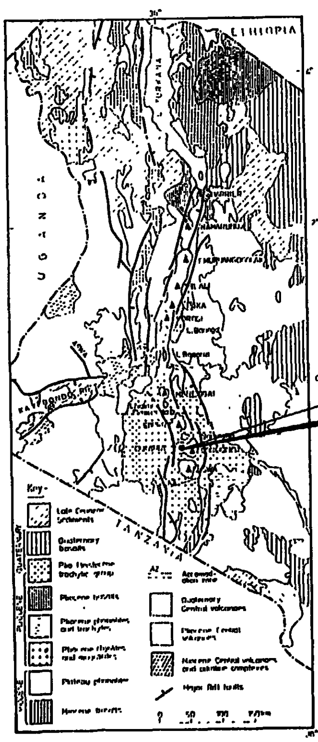
ABSTRACT

Tracer and injection tests were performed in the Olkaria North East Field with the objective to reduce uncertainity in the engineering design and to determine the suitability of well OW-704 as a re-injection well for the waste brine from the steam field during production. An organic dye (sodium fluorescein) was injected into well OW-704 as a slug. The tracer returns were observed in well OW-M2 which is 580m deep, 620m from well OW-704 and well OW-716 which is 900m from well OW-704. The other wells on discharge, OW-714, and OW-725 did not show any tracer returns. However, other chemical constituents suggested, that well OW-716 experienced a chemical breakthrough earlier than OW-M2. Tracer return velocities of 0.31m/hr and 1.3m/hr were observed. Results of the tracer and injection tests indicate that OW-704 may be used as a re-injection well provided a close monitoring program is put in place.

INTRODUCTION

The location of Olkaria North East(N.E.) field is shown in Fig 1 and it is part of the greater Olkaria volcanic complex to the South of Lake Naivasha, in the East Africa Rift Valley in Kenya (G.G. Muchemi, 1992). The North East Field, Figure 2, is to the North of the East Production Field which is currently on production. Twenty-nine(29) wells have been drilled in the field and these include well OW-X2, which is an exploration well, and well OW- R2 which is proposed as an edge field re-injection well.

The N.E. field is expected to commence production soon, and the preliminary final steam field design indicated that all the waste brine would be re-injected in deep well(s). This is in conformity with the World Bank Environmental Directive 4.0 and the Memoradum Of Understanding between KWS (Kenya Wildlife Service) and KPC (Kenya Power Company).



Map showing the Rift Volcanics and Quaternary volcanoes in Kenya

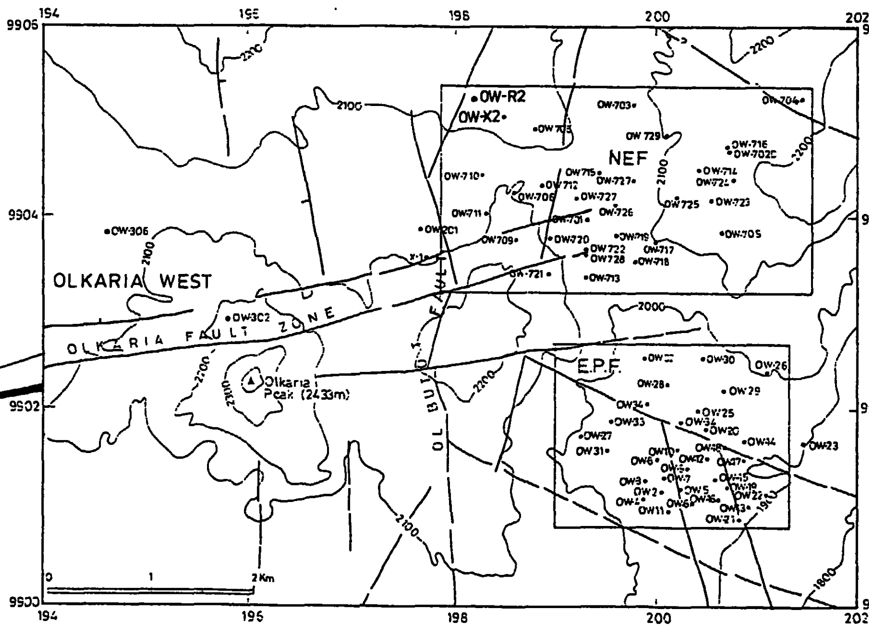


Fig. 1 Structural map of Olkaria Geothermal field showing well sites.

One re-injection site identified by the steamfield engineering designers was well OW-704, using short term injectivity tests. In order to ascertain the ability of the well to take in all the waste brine from the field, the injection and tracer tests were conceived. To attain the above objective the following aspects were considered:-i) the tracer return velocities, ii) the extent and effect of the injected fluid on the production wells in the vicinity of well OW-704 that may experience a thermal breakthrough, and iii) possible fluid paths.

Measurements made in wells during tracer tests provide the principal means of determining geothermal reservoir parameters. Understanding reservoir properties permits the development of better resource recovery strategies. Tracer result analysis reveals the structure of the reservoir flow paths, thereby allowing for appropriate injection strategy, which may add several years of useful life to a field.

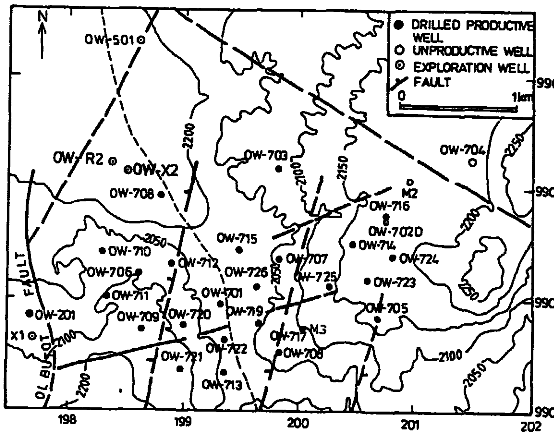


Fig.2 Olkaria North East field well location and structural map

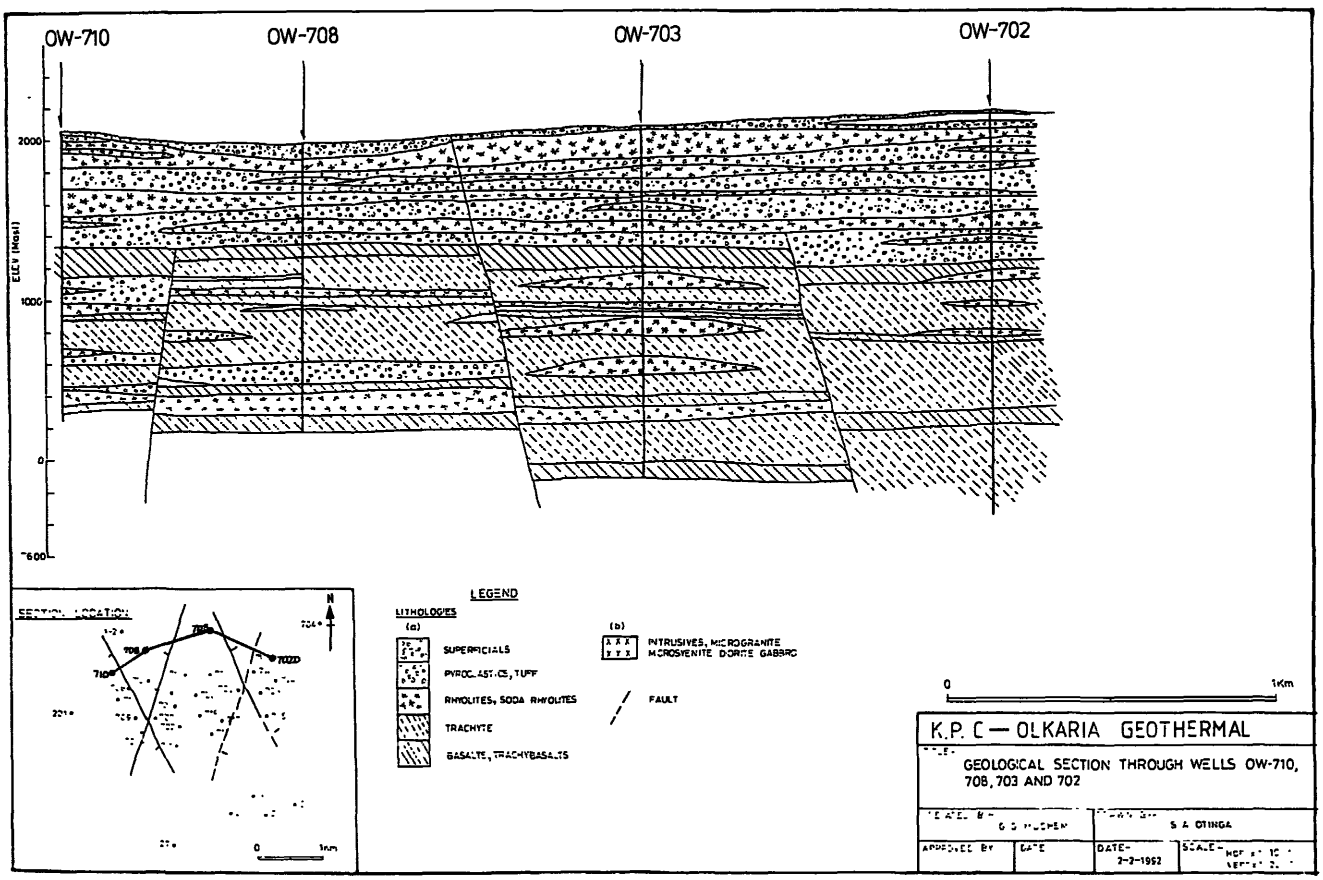


Fig. 3 Stratigraphic correlation

GEOLOGICAL STRUCTURE

Topographically the Olkaria North East field is comprised of high grounds to the East and West with a trough running N-S in the middle. The high grounds are composed of young commedite lava flows and ashes.

The subsurface lithology is similar to that encountered in other Olkaria wells. These include, pyroclastics deposits and tuffs, rhyolites, trachytes, and basalts. The top to 1400 masl is mainly composed of acid volcanics (rhyolites and pyroclastics), below these the dominant rocks are the trachytes with regular thin basalt flows.

The faults shown in Figure 2 are mainly extrapolations of inferred faults and volcanic lineaments. Combined with the stratigraphic correlation, (Figure 3), five structural trends are observed in the Olkaria NorthEast field. These are the NNE-SSW, NNW-SSE, the near E-W Olkaria fault zone, the N-S trending Ololbutot fault, and the NW-SE trending faults running through the Olkaria East Production Field (Muchemi, 1992).

METHODOLOGY

The injection of ambient lake water into well OW-704 commenced on 24th November 1993, and has continued to date, except for short periods when either the pumps or the water line were being serviced. The tracer, an organic dye, (sodium fluoresceine), was injected as a slug on 20th April 1994. Two hundred fifty kilograms (250kg) of the tracer was dissolved in 4 cubic meters (4000 l) of fresh lake water and injected into well OW-704 in 1½ hours, this was considered as a slug. The injection which had been stopped for the tracer injection was continued at an average flowrate of 120t/hr.

Three wells, OW-714, OW-716 and OW-725 were put on horizontal discharge in order to induce a preferential flow and/or, a pressure drawdown, which will be expected when the field is in production. The above wells, well OW-708 and well OW-M2 (a shallow well 580m deep) were monitored for any tracer returns or injected fluid breakthrough for a period of 7 months. Liquid samples were taken daily at the weirbox for wells OW-708, OW-714, and OW-725 while for well OW-716 which was discharging almost dry steam the water (carry-over) was collected at the brim of the cyclone separator. For well OW-M2 downhole samples were taken at 550m deep, using the Kylen Subsurface sampler.

The samples collected were analysed for Chloride, Conductivity, and for the Fluoresceine (tracer). Chloride analysis was done using the Mohr titration method, conductivity was determined using a conductivity meter, while the fluoresceine was analysed using a Perkin Elmer Luminiscence spectrophotometer, Model LS 30.

RESULTS

WELL OW-708

The well is 600m from well OW-R2 and 2700m from well OW-704. It was monitored from 9/3/94 to 06/6/94 after which it was shut-in. While discharging, samples were collected from the weirbox and analysed. The analysis results indicated that no tracer or injected fluid returns were discharged from the well as observed in Figure 4.

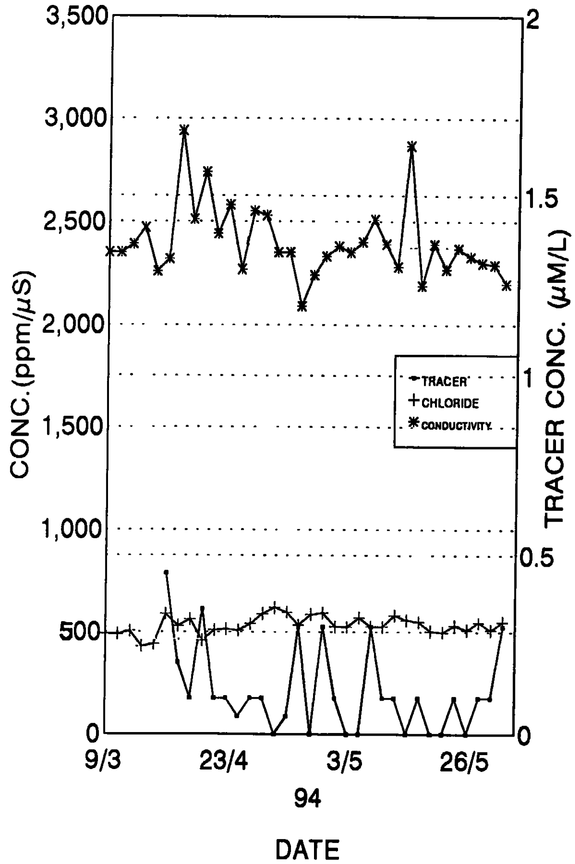


Fig. 4 TRACER AND CHEMICAL SPECIES VARIATION. OW-708

WELL OW-714

The well is 950m from well OW-704 and was monitored from 11/4/94 to 20/6/94, a total of 65 days. The analysis results indicate that there was no chemical or thermal breakthrough as observed from the chemical species and tracer return variation, Figure 5.

WELL OW-716

The well is 900m from well OW-704 and was monitored from 6/4/94 to 26/1/95, a total of 9 months. From Figure 6, it is evident that the well experienced a chemical breakthrough. Although the tracer was detected after 7 months, the other chemical tracers such as, conductivity, and chloride, clearly indicate that the injected water had mixed with the reservoir fluid much earlier. Physically, the well which was discharging almost dry steam currently discharges both steam and water. Fig.9 shows the variation of water flow versus time for two periods when the well was on discharge, in between the periods, the well was shut-in. The second period, the well was opened for the tracer and injection tests.

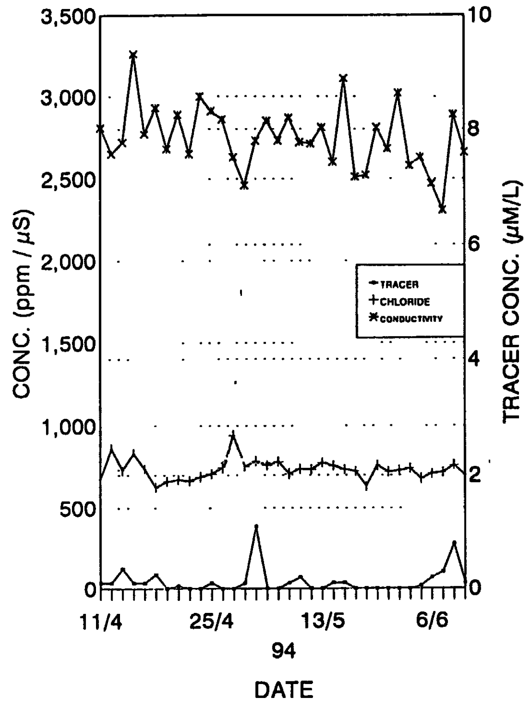


FIG 5 TRACER AND CHEMICAL SPECIES VARIATION. OW-714

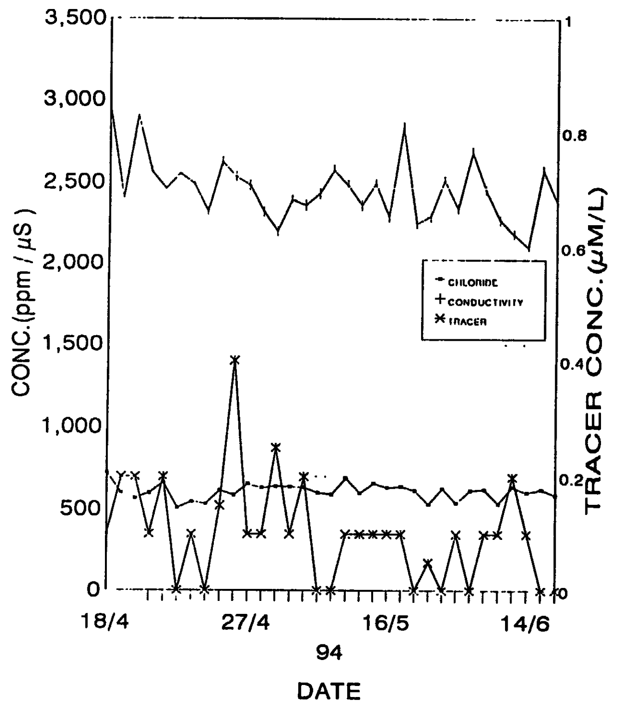


FIG.7 TRACER AND CHEMICAL SPECIES VARIATION. OW-725

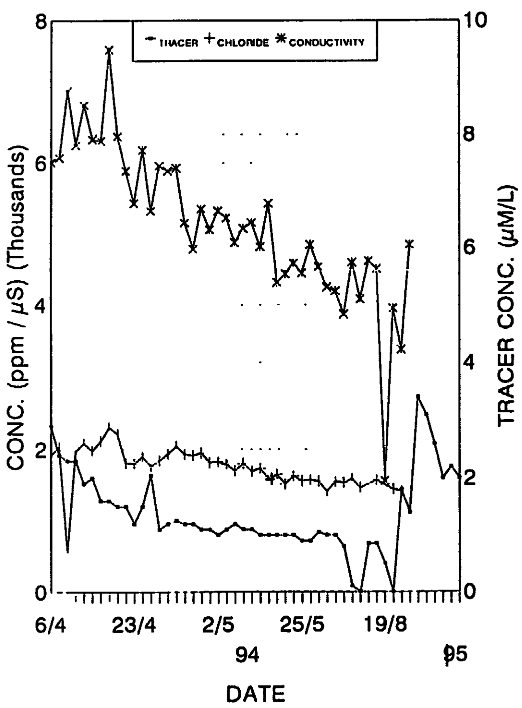


FIG 6 TRACER AND CHEMICAL SPECIES VARIATION. OW-716

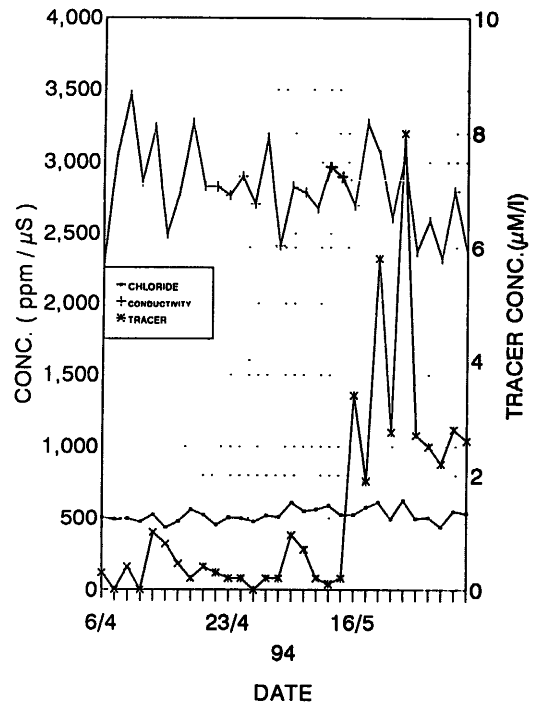


FIG 8 TRACER AND CHEMICAL SPECIES VARIATION. OW-M2 (550m)

WELL OW-725

The well is 1610m from well OW-704 and was monitored from 18/4/94 to 30/6/94, a total of 73 days. All indicators that were monitored, Figure 7, show that the well did not experience a thermal or chemical breakthrough.

WELL OW-M2

The well is a shallow monitoring well drilled to 580m, and it is located 620m from OW-704. It was monitored from 6/4/94 to 20/6/94 and since no surface discharge could be obtained, downhole samples were collected to monitor for any breakthrough. Tracer breakthrough was observed on 16/5/94, Figure 8, three major peaks can be seen on the variation. This may be interpreted to suggest that there were three major flow paths through which the tracer propagated.

DISCUSSION

As shown by the results above, the fluid injected in well OW-704 was able to permeate through the formation to some of the wells such as OW-716, and OW-M2. From the geological structure and the stratigraphy it is suggested that the fluid paths are the interpreted faults and the lithological contacts.

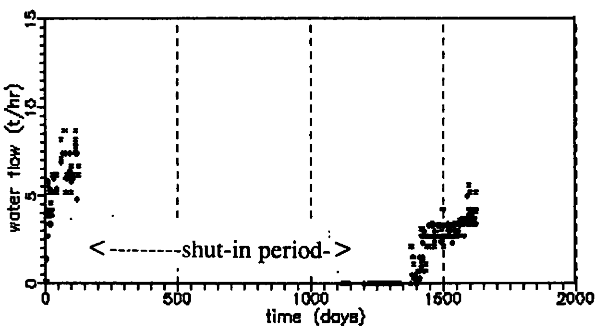


Fig. 9 OW-716 WATER FLOW FROM 9.12.90 TO 18.5.95

The fluid discharged from well OW-716 was diluted about 1.8 times from the initial and final chloride concentrations weighted against similar computation from the conductivity values. This may be interpreted to imply that the injected water not only mixed with the reservoir fluid but also increased the water fraction (which was previously immobile) significantly to be discharged at the weirbox. The amount of time taken for this observation to be made was approximately 4 months. This corresponds to a fluid return velocity of about 0.31 m/hr.

The tracer return velocity for well OW-M2 was 1.03 m/hr. This implies that there could be some structural barriers and/or formation inhomogeneity between wells OW-M2 and OW-716 to account for the discrepancy between the two velocity values. There seems to be other barriers between well OW-716 and wells OW-714 and OW-725, as the tracer did not reach the latter wells. This implies that the faulting system may be quite complex in the area.

The return velocity values are comparable to values obtained in some geothermal fields in the world, Olkaria East Production Field in Kenya; 1.5-3.5 m/hr (Karingithi C.W. 1993. Ambusso W.J. 1993) ; Broadlands Ohaaki in New Zealand; 0.3 m/hr (McCabbe W.J.1993). However, the values are relatively low compared to other geothermal fields, eg, Wairakei in New Zealand; 16-21 m/hr (Glover R.G. et al 1993); Palinpinon in Philipines; 5.6-16.5 m/hr (Urbino M.E.G.et al,1986).

CONCLUSION

The tracer and injection tests for the eastern sector of Olkaria Northeast Field were successful. Organic dye, Fluoreseine, tracer return velocity and natural chemical tracer velocity of 1.03m/hr and 0.31m/hr respectively were evaluated. Fluoresceine was detected in well OW-M2 while in well OW-716 injected fluid was detected indicating a thermal breakthrough in these two wells. The impact of the injected fluid to the output characteristics of well OW-716, though not conclusive indicate a moderate reduction in enthalpy, moderate decline in steam flowrate and an increase in water flowrate.

The injected fluid may have permeated through the formation along lithological contacts, faults, and fissures. The well OW-704 may be used as a reinjection well on condition that a close monitoring programme is put in place for the neighbouring producing wells. Alternative reinjection wells must be in place, in case a severe thermal breakthrough, which may be detrimental to the above wells is observed.

ACKNOWLEDGEMENT

I wish to thank the Kenya Power Company management for granting permission to publish this paper. The efforts that were put by both the geochemistry and the reservoir engineering crews towards the success of the programme are highly appreciated. Special thanks to the members of staff who were involved in monitoring of the wells, sampling and analysis of the samples collected.

I would also wish to thank my colleagues who edited and contributed to the paper.

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