Naylor (1972) identified the Olkaria area as the remnant of an old caldera complex, subsequently cut by north-south trending normal rift faulting that provided the loci for later eruptions of rhyolitic and pumice domes now exposed in the Ol'Njorowa Gorge. Later volcanic associated with the Olkaria volcano and the Ololbutot fault zone produced rhyolitic and pumiceous flows. Much of the area has been subsequently blanketed by a surface cover of young (Quaternary) ejecta, believed to have originated primarily from Longonot volcano and Mount Suswa. Areas of altered and warm ground are extensive throughout the Olkaria area, (Glover, 1972) and together with present surface manifestations show a close association with the dominant N-S structures (in the central Olkaria area), the ENE/WSW Olkaria fault zone and the inferred ring structure.

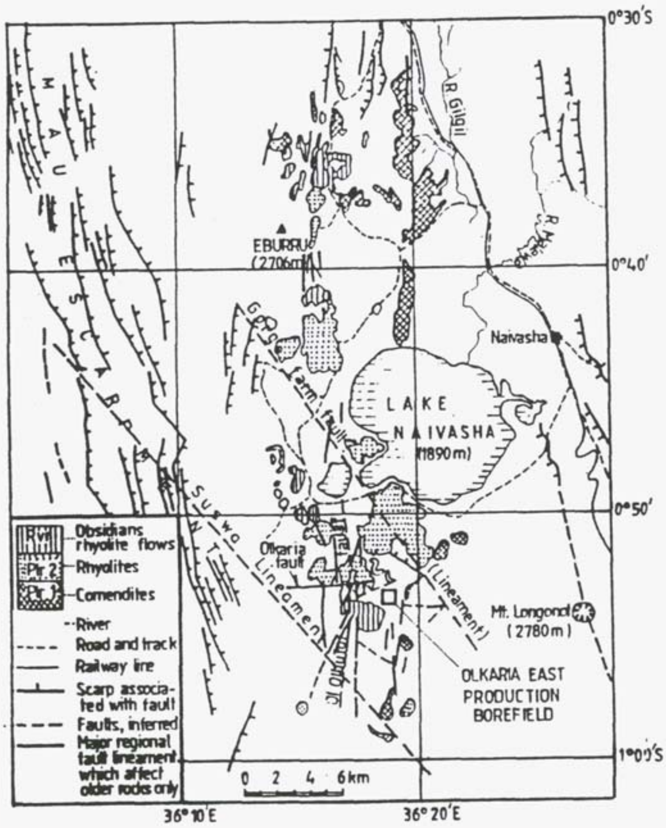

Figure 2 - The N-S Peralkaline Belt of volcanism

Although the *ring* structure theory is not universally accepted, (KRTA, 1984), later workers in this area support it (Clarke et al, 1990 and Mungania, 1992). In this paper the ring theory is surported and with a few modifications in the western area of the **Olkaria Geothermal** Field.

2.0 GEOLOGY

2.1 Structure

Figure 3 shows observed and inferred structures of the Olkaria Geothermal Field with a modification of the ring structure especially to the west where the ring has been enlarged. Some of the ring faults in this area were previously identified as N-striking faults. Most of the structures in this arca are associated with volcanic activity. The exception to this are the ENE-striking Olkaria fault zone and the WNW-striking fault zone

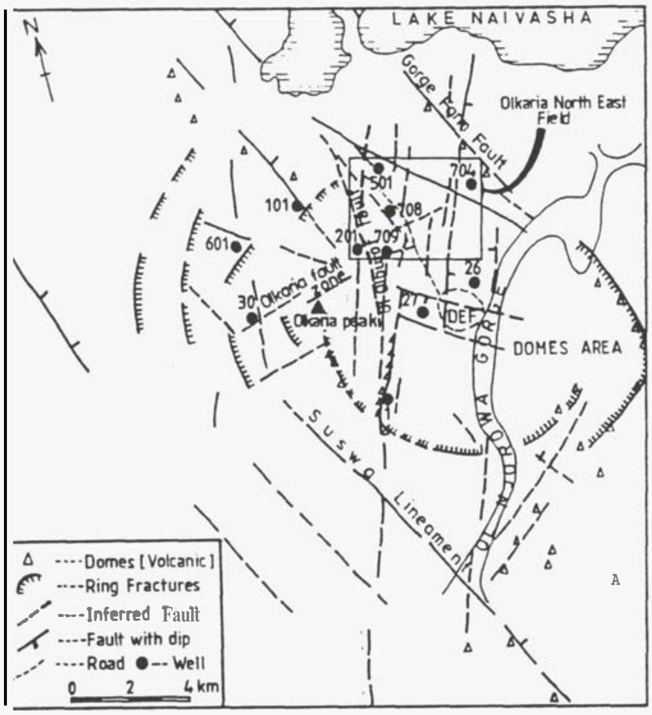

Figure 3- Structural map of the Olkaria Geothermal Field

passing through the East Production Field. Mungania, 1992, believes this fault system (WNW-striking fault zone) to be regional and possibly the precursor of Olkaria complex, Mount Longonot and Kijabe Hill. In Figure 4 are shown the structures that pass through the Olkaria NE Field. Of note here is the absence of the N-striking faults, with the exception of the Ololbutot fault, and the presence of the NNE-striking faults that are not evident in the west. In the Olkaria North East Field, fumaroles and altered ground occur only along the Ololbntot fault and the prominent NNE-striking faults.

Stratigraphic interpretation indicates two fault systems in the Olkaria NE Field. These faults have a NNW-SSE and NNE-SSW trends respectively and coincide with the trends observed in this area on the surface. Temperature contours in this field show a NNW trend. However, the high producing wells lie on an E-W trend along the Olkaria Fault Zone (Haukwa, 1993).

2.2 Lithostratigraphy

An E-W stratigraphic correlation through the Olkaria North East Field is shown in Figures *5.* The rocks encountered downhole are broadly similar to those found in the rest of the Olkaria Geothermal Field and are all of volcanic origin, These include; pyroclastics, tuffs,

Figure 4 - The Olkaria NE Field

5. Surface to 1600 m.a.s.l.; Mainly acid volcanics consisting of pumiceous ash, tuffs and alkali-rhyolites. The lower part of this zone has thin intercalations of riebeckite rich trachytes that continue into the basalt zone bellow. In this zone the pumice tuffs and pyroclastics are dominant by volume over the rhyolites. The rhyolites occur mainly in descret units that do not correlate across the field.

with high volcanic glass content are the most altered. Among the lavas, the rhyolites are the least altered except where they are banded with volcanic glass. The porphyritic trachytes show a higher intensity of alteration than the fine grained non-porphyritic types. Here the sanidine phenocrysts show a higher intensity of alteration than the fine groundmass. The basalts due to their good porosity and bulk chemistry are the most extensively altered lava rocks.

The hydrothermal alteration assemblage includes; kaolinite, interlayered chlorite-biotite, biotite, hydrobiotite, chlorite-illite, fluorite, stilbite, sphene,

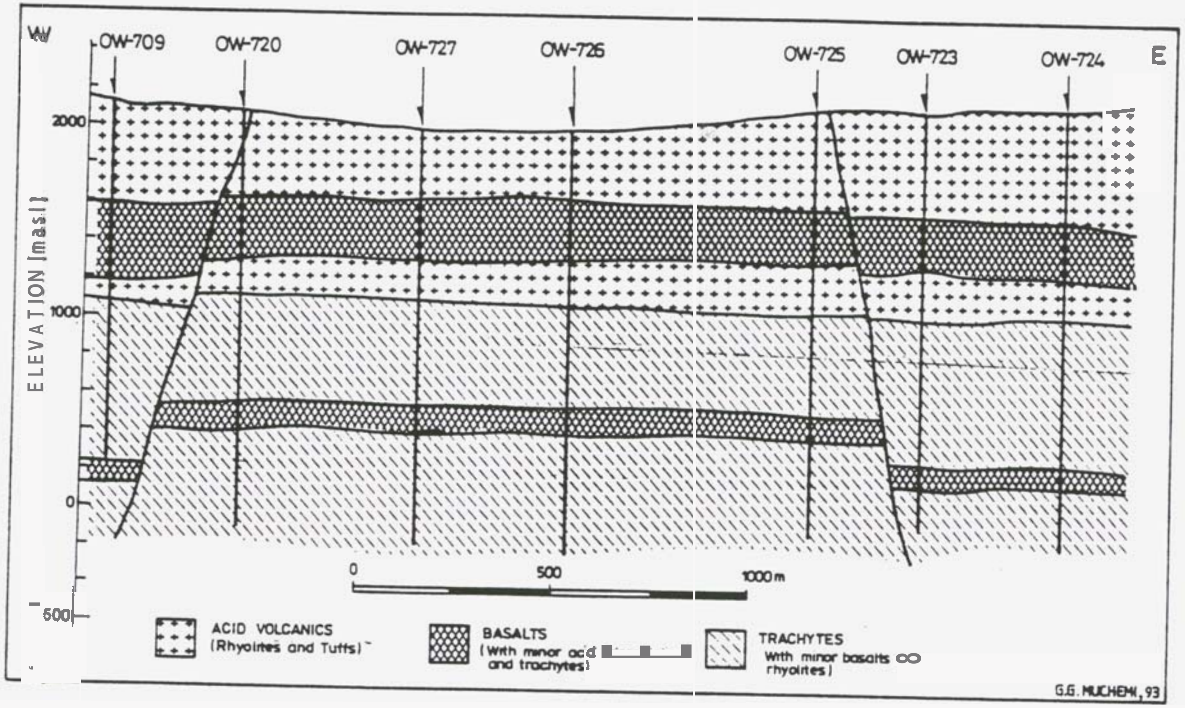

Figure 5 - An East-West stratigraphic correlation

4. 1600-1300 m.a.s.l.; Mainly olivine basalt and minor basaltic pyroclastics. The top of this zone also contains thin beds of trachytes

3. 1300-1000 m.a.s.l.; Mainly tuffs and alkali rhyolites.

2. 1000-600 m.a.s.l.; Mainly an alkali-feldspar and

chlorite, smectite-chlorite, illite, illite-smectite, smectite, epidote, calcite, quartz, Fe-oxides, wairakite, adularia, albite, pyrite leucoxene, actinolite, garnet, and talc (Muchemi, 1992). Clay minerals were determined only by x-ray diffraction analyses and petrographic examination and hence, therefore some of this clays especially the micas have not been fully identified.

Figure 6 Shows the correlation of clay minerals, calcite and epidote with measured temperature and calculated water rest level across the field. It can be seen that the calcite and epidote levels correlate reasonably well with the 200°C measured temperature isotherm and the water rest level. The 250°C measured temperature isotherm is considerably deeper than the epidote isotherm.

this zone ends at about 1750-1600 m.a.s.l. In the eastern sector around well OW-716, this zone does not exist. However, it enlarges westwards into the central zone.

4. Interlayered chlorite-biotite zone occurs only in the western and eastern sectors as shown in Figure 6. In the eastern sector this zone extends to about 300 m.a.s.l. In this zone chlorite is rare although zones of biotite occur.

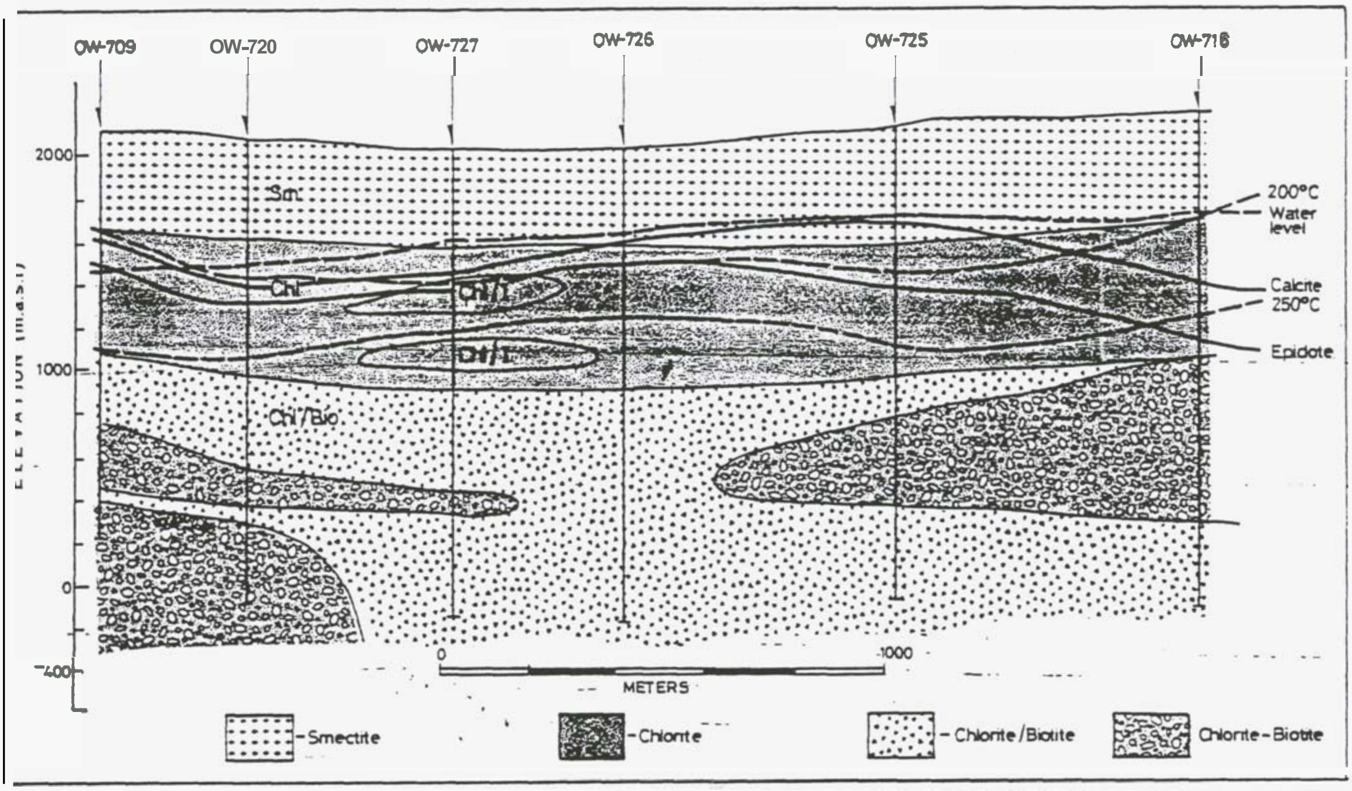

Figure 6 - Clay minerals and measured temperatures correlation

The clay minerals can roughly be grouped into four zones as shown below into, smectite, chlorite, chlorite and biotite, and interlayered chlorite-biotite zones respectively.

1. Smectite zone extends from the surface to about 1650 m.a.s.l. where chlorite first appears with the exception of wells OW-501 and well OW-703 where smectite occurs below this depth. In this zone illite occurs sporadically without a distinct pattern.

***2. Chlorite* zone** extends from 1650 m.a.s.l. to about **1000 m.a.s.l.** where biotite first appears. In the western and the eastern sectors the lower limit of this zone is shallower than in the central region. However, chlorite occurs in all wells to drilled depth. In this zone, illite also occurs more commonly and in some wells it is more dominant than chlorite. This is more so in wells in the central region.

3. Chlorite and biotite zone extends from 1000 m.a.s.l. to the bottom of the wells in the central region. In this zone biotite is the most dominant clay. However, chlorite is dominant in some zones. In the western sector

Clay temperatures show that temperatures are above 230°C below **1000 m.a.s.l.** In general it appears that temperatures deduced from clay minerals are elevated around well **OW-709, OW-720, and** OW-702/716 with a depression around well OW-726, and OW-727.

3.0 DISCUSSION

The lithology encountered in this field is similar to that encountered elsewhere in the Olkaria Geothermal Field with the exception of the thick trachyte *occurring* above the Upper basalt and thought to be the caprock (KRTA, 1984). In this area the trachytes occur as thin intercalations in the Upper Basalt and in the lower parts of the Acid Volcanics zone rhyolite zones. In the Olkaria North East Field the Upper basalt forms the caprock. This agrees well with the water rest level and the upper limit of the chlorite zone. The occurrence of acid volcanics from the surface to about 1600 m.a.s.l. indicates that the acid volcanism was the last phase of volcanic activity. This together with the proposed caldera indicates that a highly evolved magma chamber exists at depth. This intrusive is likely to be a segregated magma of granitic composition which is possibly still liquid at depth.

The lower trachyte and basalts *occurring* 600 m.a.s.l. are believed to be the Tertiary Volcanics that form the basement of the Central Rift Valley and are exposed on the flanks of the Rift Valley (**Mungania,** 1992). The build-up of the Olkaria Complex begun with the eruption of the Upper Trachyte which resulted in a central shield volcano. This was followed by eruption of tuffs *occurring* between 1300-1000 m.a.s.l. from a segregated and evolved magma chamber below the shield volcano. This rapid withdrawal of material from the magma chamber resulted in an initial caldera collapse. This was followed by eruption of the Upper Basalts during a period of magma chamber replenishment. This possibly led to further collapse. Further segregation followed by eruption of rhyolites and tuffs increased the collapse. The last phase of eruption along the N-S trending faults and the ring fracture faults produced material that infiied the caldera and created the present topography. Most of these material was subsequently blanketed by ash falls from Mount Longonot and Suswa.

The Occurrence of Recent lavas, fumaroles and hot grounds along the N-S, the ENE (Olkaria fault zone) and the WNW trending faults and the *ring* fractures, indicates that these structures are the youngest in this area and form the main upflow zones. The NNW trend of temperature contours indicates that the NNW-striking faults form the main fluid barriers due to dyke intrusions along these faults. The ring fractures also form fluid bamers especially to the east and to the south. The N-S trending Ololbutot fault also forms an east west fluid barrier because of its long history of volcanic activity. These barriers are broken by the Olkaria fault zone and the WNW-striking fault zones and thus inter connecting the whole of the Olkaria Geothermal Field. In the Olkaria North East Field the NNE-striking faults and the N-S trending faults are good well targets as they are the youngest faults.

The occurrence of illite in this field indicates that there exists a condensate or cool fluids which has mixed with the hot chloride fluids in this area. These is further supported by the occurrence of smectite at deeper levels in well OW-703 and OW-501 than in the other wells in this area. The occurrence of smectite at deeper levels in well OW-501 and OW-703 indicates that there is an incursion of cool fluids from the north. The occurrence of biotite, garnet, talc and amphiboles indicates that temperatures in the range of 300-400^{0}C have existed in this area.

The Occurrence of biotite at a shallower depth around wells OW-709, OW-720, and OW-702/716 together with the occurrence of the interlayered chlorite-biotite in the western and eastern sectors indicates that these areas are the possible up-flow zones. This, however does not exactly agree with the measured temperatures which shows elevated temperatures around well OW-727 and OW-726. These wells, however, are drilled along the Olkaria fault which connects the eastern and western sectors. Other wells in this sector agree with the model discussed above and do not show elevated temperatures.

4.0 CONCLUSIONS

1. The lithology encountered in Olkaria Northeast Field is broadly similar to that of the rest of Olkaria Geothermal Field.

2. Acid volcanism is the latest volcanic phase.

4. About six fracture/fault systems occur and include a ring structure described as a caldera. The main up-flows are in the region of OW-709 and OW-716.

5. The hydrothermal alteration mineral assemblage indicates that the field has experienced temperatures in excess of 300^{0}C .

6. There is mixing of condensate and chloride fluids in this field and also a cool inflow from the north.

5.0 REFERENCES

Clarke, et al (1990); The Geology of Longonot **Volcano,** The Greater Olkaria Volcanic Complex and Adjacent Areas; UK/KEN. Govt. Technical Cooperation Project, report no. BGSGENKEN/5.

Glover, R.B. (1972); Chemical Characteristics of Water and Steam Discharges in the Rift Valley ; UNDP/KEN. Govt. Geothermal Resources Exploration. Project report.

KPC (1984); Background Report for Scientific and Technical Review Meeting Nov. 1984; Prepared by KRTA Ltd.

Muchemi, G.G (1992); The geology of the Olkaria North East field. KPC report.

Mwangi, M.N.,and Bromley, CJ., 1987; A review of the geophysical model of the Olkaria Geothermal Field. KPC report no. GP/OW/012.

Naylor, W.I. (1972); The Geology of the Olkaria and Eburru Prospects; UNDP/KEN. Govt. Geothermal Resources Exploration Project report.

Odongo, M.E.O. (1982); A short description of the Penetrated Lithological column based on Revised Logs of wells 2, 3, 4, 5 and 6.

Strecker, et al (1990); Rotation of extension direction in the central Kenya Rift.

Mungania, J., 1992; The Geology of the Domes Area. KPC report.