Geophysical Surveys of The Geothermal System of The Lakes District Rift, Ethiopia

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- The formation of the rift was preceded by a long period of uplift which is related to rise of hot low density material from the mantle and formation of the transitional layer at the base of the crust (Kazmin 1980). So large magma chambers and intrusive bodies are most likely to occur at shallow depths in the crust in association with silicic and intermediate volcanoes, and provide sources of heat from the long lived hydrothermal systems in the rift.

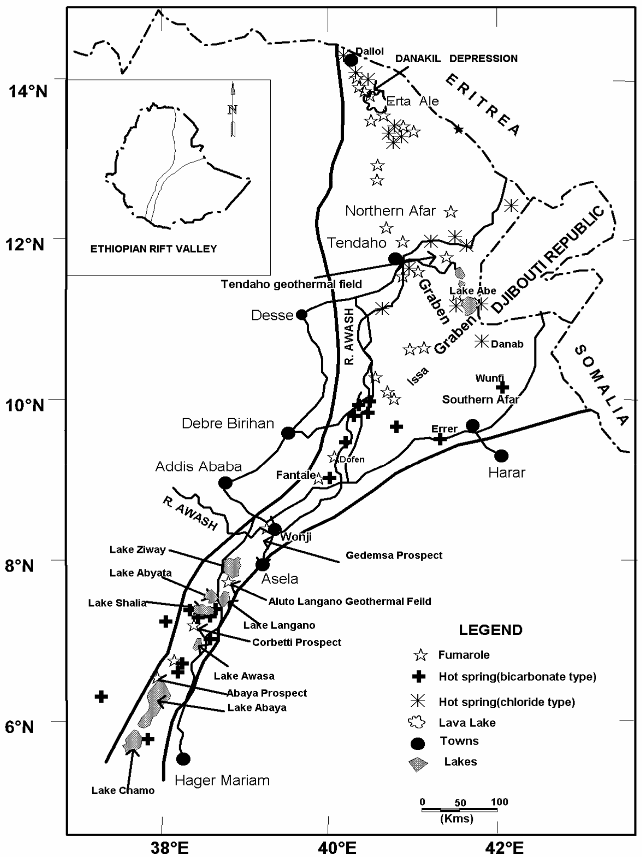


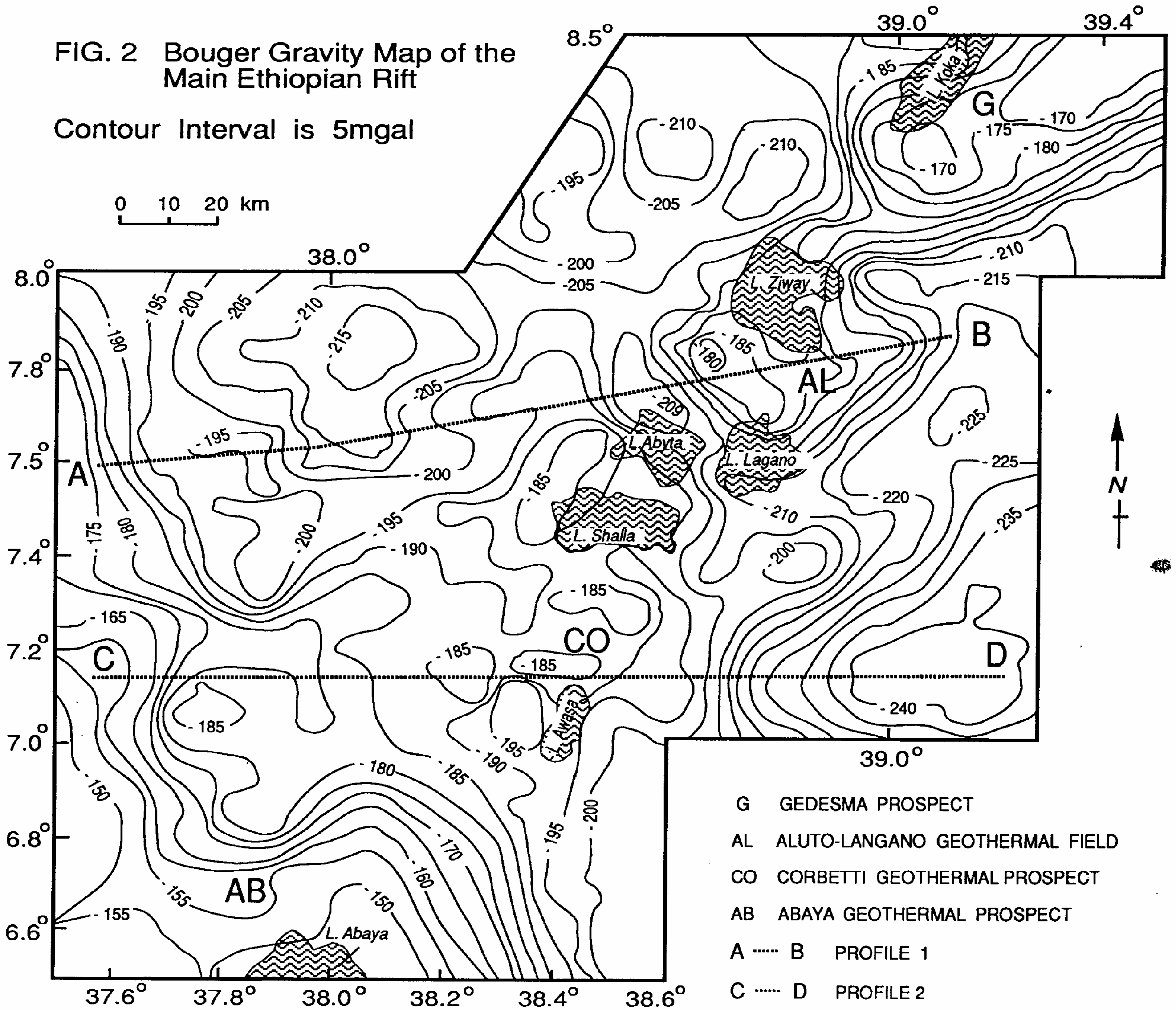
Figure 1. Geothermal fields,prospact areas and Geothermal features in the Ethiopian Rift Valley. (Modified form UNDP 1973)

GRAVITY SURVEYS

- The main Ethiopian rift is characterized by a high absolute Bouguer gravity anomaly superimposed on part of the long wave length negative Bouguer gravity anomaly of the Ethiopian rift. Sowerbutts (1969) and Girdler et al (1969) have discerned the long wave length Bouguer anomalies over other parts of the east African rift system and considered that the negative anomalies are due to an asthenolith or body of low density material at the base of the lithosphere which extends under the whole of the east African plateau but which is shallower beneath the rift. On this is superimposed a relative positive axial gravity anomaly on which are smaller local relative gravity highs and lows.

FIG. 2 Bouger Gravity Map of the Main Ethiopian Rift

Contour Interval is 5mgal



- The Wonji fault system (Mohr 1967a, 1967c) is a zone of intense faulting which extends from the Chamo-Abaya area to Lake Abe in the central Afar and farther to the north across the Danakil uplift to the Red Sea. It can be clearly seen from the sharp gravity gradients starting from the NW of Aluto-Langano geothermal field extending NE-wards.

- Comparison of the eastern and western rift margins of the central rift (between 70 and 80 N) shows a broader negative anomaly over the eastern rift margin. This anomaly is ascribed to either low density asthenospheric material at the base of the lithosphere or in the upper mantle under the eastern plateau as isostatic compensation i.e. the eastern plateau is compensated at depth by mass deficiencies (Searle and Gouin 1972), Sowerbutts (1969) or due to thick low density volcanics (tuffs) under the plateaus since the fissure and the central eruptions of the trachytes and ignimbrites that covered the plateaus have their sources situated chiefly at the rift margins (Mohr 1968) or a combination of both.

2D GRAVITY MODELLING

- The positive residual gravity anomalies overlying Aluto volcano and Corbetti Caldera could not be accounted for entirely by structures above the basement. It was necessary to postulate denser intrusives deeper in the crust. In the modelling a density of 3.0gm/cm3 was used for intrusive bodies derived from the upper mantle and emplaced in the crust at a shallow depth due to extensional rifting and consequent thinning for the crust under the rift. These bodies may still be hot and thus could be the origin of the geothermal anomaly in the area. This is consistent with the ideas of Searle (1972) who noticed three major zones of intrusion in this part of the rift. The central zone lies approximately along the axis of the rift floor and the local peaks of this central zone correspond to the positions of the Wonji fault belt. Two secondary zones of intrusion are indicated by the models along the margins of the rift.Thermal features, fumaroles/steam vents and altered grounds are abundant on the Aluto, Chebi, Urji and Danshe volcanoes. Hot springs are restricted to Lakes Chitu, Shalla, Langano and Tulu-Gudo Island in Lake Ziway.

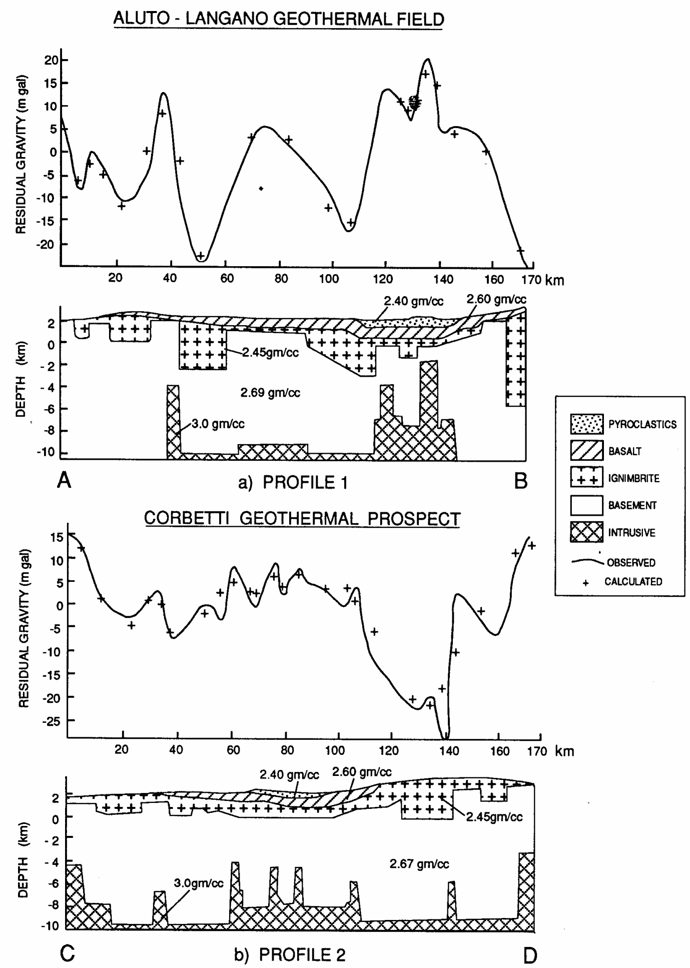


FIG. 5 2D GRAVITY MODEL

ELECTRICAL RESISTIVITY SURVEYS

ALUTO-LANGANO GEOTHERMAL FIELD

- The dipole-dipole map for N=6 (Fig 6) shows a N-S low resistivity zone covering a wide area from Lake Ziway to Lake Shalla. The hot water infiltration is influenced by the local N-S ground water movement. There is a 5Ωm resistivity zone along the west Langano fault zone which serves as the main conduit for the hot fluid to flow from Aluto volcano/Ziway lake area down to Lake Shalla. Schlumberger resistivity contour map for AB/2=1000m (Fig7) also shows the low resistivity anomaly areas already outlined by the dipole-dipole technique around the western and southern foothills of Aluto volcano.

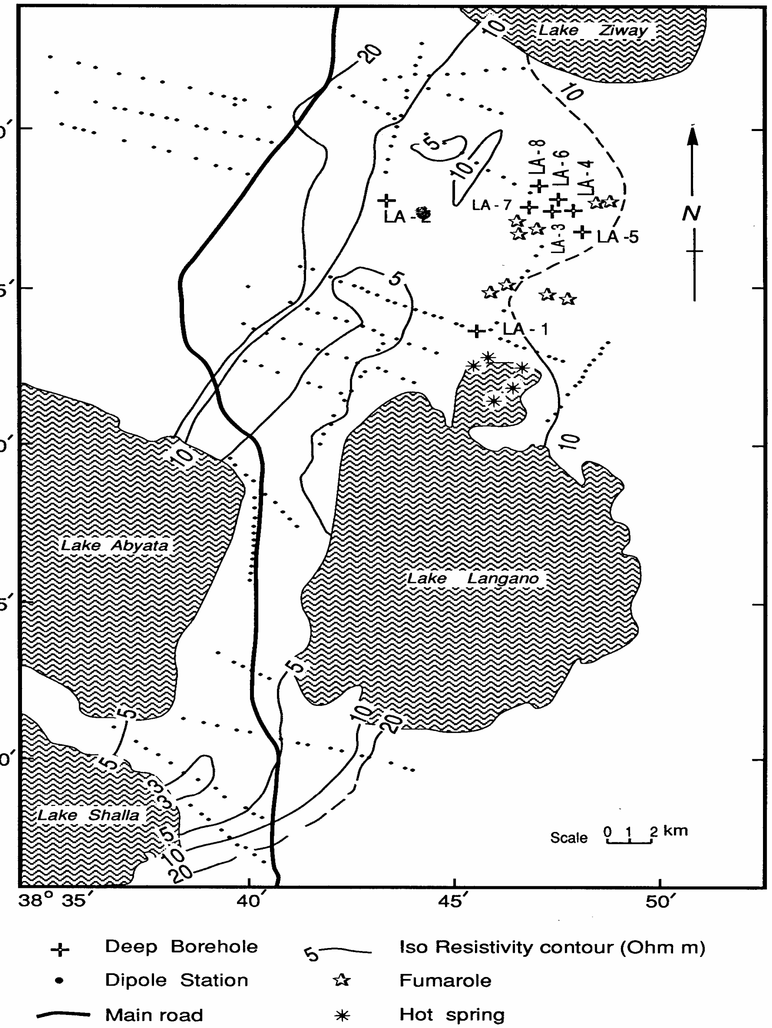


FIG. 6 Dipole - dipole resistivity map for N = 6, a = 500m

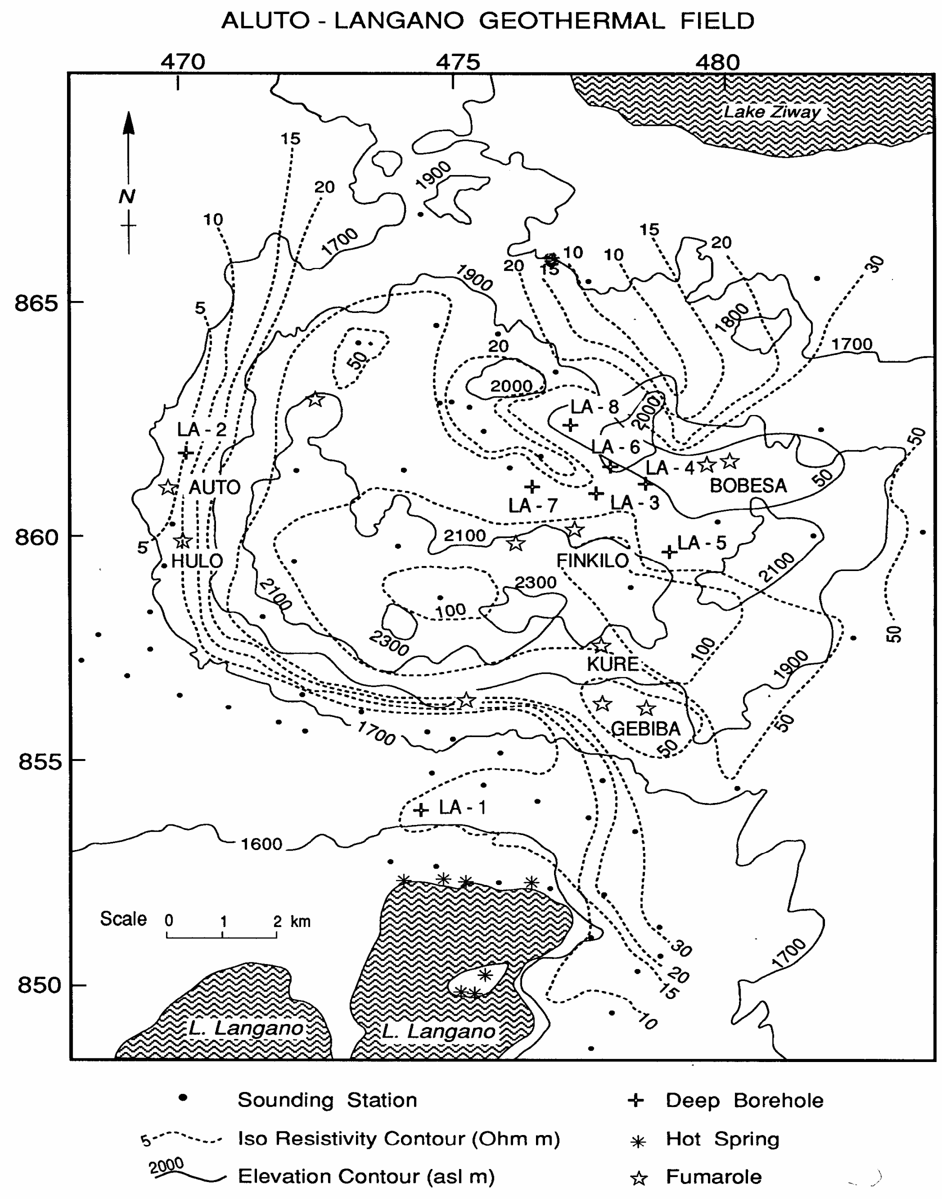
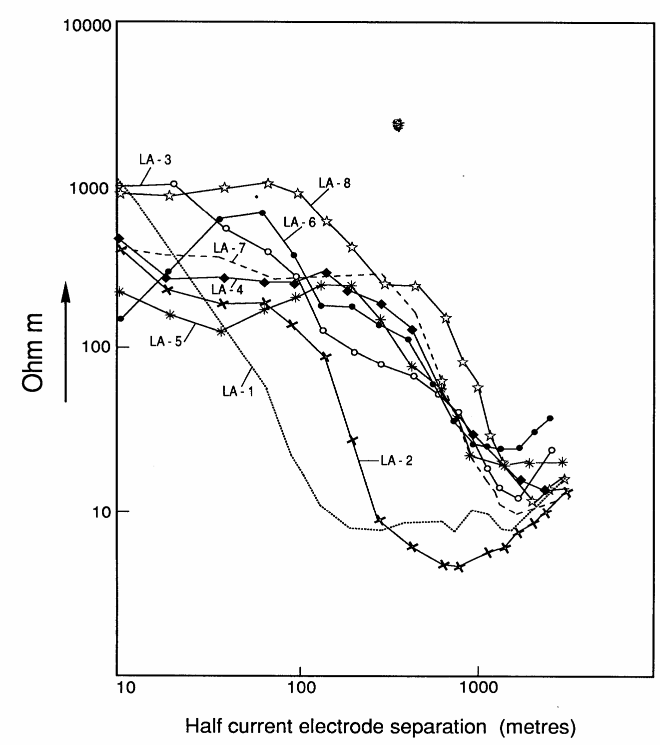


FIG. 7 Schlumberger Iso - Resistivity Map for $\frac{AB}{2}$ = 1000m

- On Aluto volcano, the top dry post-Aluto volcanic tuffs are characterized by high resistivities. But LA-6, which was located near to alteration grounds shows relatively low resistivity top layer. The resistivity curves show similar trends and slopes signifying similar resistivity structures between AB/2=120 and 1000m. They could be the effect of porous and permeable rhyolite lava and the underlying pre-Aluto basalt, which is highly altered and has a high temperature.

FIG. 8 Schlumberger sounding curves of deep well sites



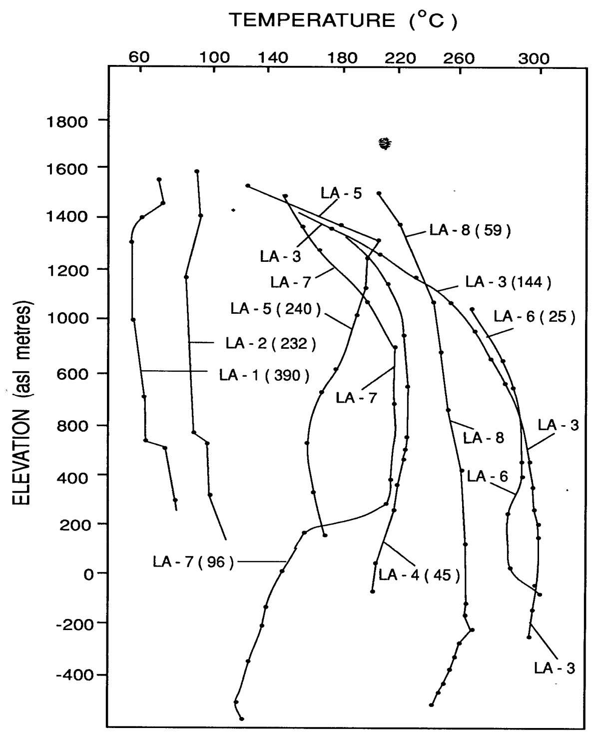
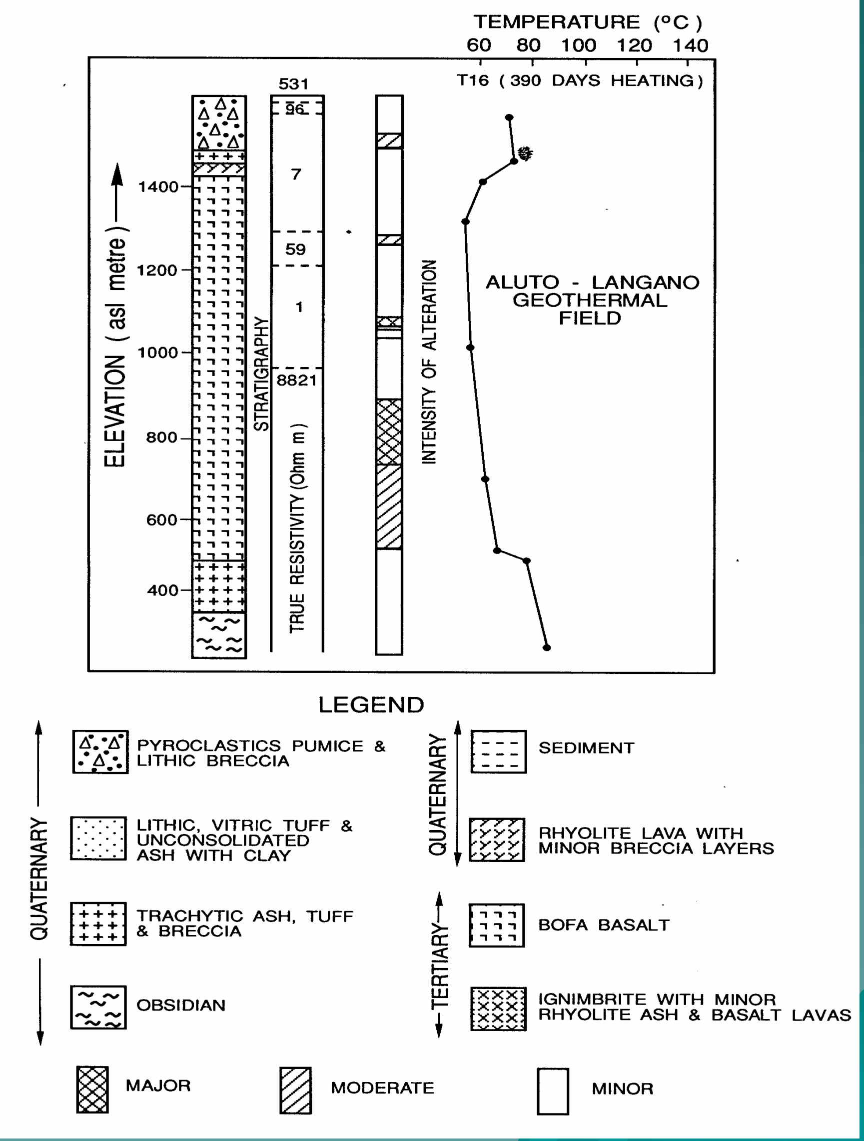


FIG. 9 Curves of measured temperatures in deep boreholes.
(144) - Heating time in days

- **Measured temperature-depth curves of the eight drilled wells are shown in Fig 9. LA-1 and LA-2 have low recorded temperatures. These wells were drilled on the outflow zones, at the foothills of Aluto volcano. Higher temperature gradients are recorded in the wells in the Bofa basalt sequence. Higher temperatures are shown in this basalt for all wells drilled on Aluto volcano which has a thickness of 1km. LA-3 and LA-6 have stablized at temperatures 320 and 3350c respectively. In general the curves show that near the contact of the Bofa basalt and Tertiary ignimbrite temperature reversals are observed in all wells except LA-3 and LA-6 on the volcano. This is probably due to the inflow of cold water through this permeable zone.**

- The high temperature in the basalt could be because of the fact that it is fractured with hot geothermal fluids that deposited alteration minerals in the fractures and these sealed off the permeability. It seems that the basalt retained the previous high temperature because of its poor conductivity and is still getting heat laterally from upflow zones.The temperatures in LA-3 and LA-6 (Figs 11 and 12) are higher in the Tertiary ignimbrite than in the basalt, unlike the other wells on the volcano since they were drilled along an active fault zone through which hot geothermal fluid ascends to the surface.

FIG. 10 Correlation of Stratigraphy, Resistivity, Intensity of Alteration,and Measured Temperature of LA - 1



ALUTO - LANGANO GEOTHERMAL FIELD

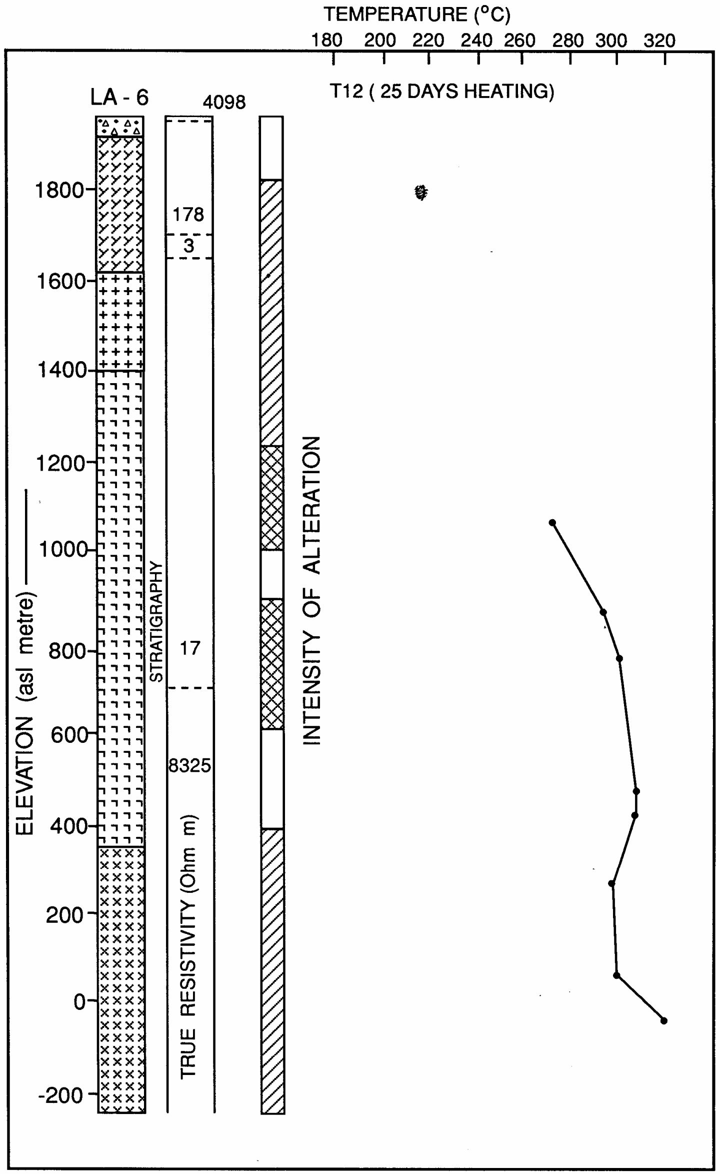


FIG. 11 Correlation of Stratigraphy,Resistivity,Intensity of Alteration, and Measured Temperature of LA-6. Legend as in FIG.10

ALUTO - LANGANO GEOTHERMAL FIELD

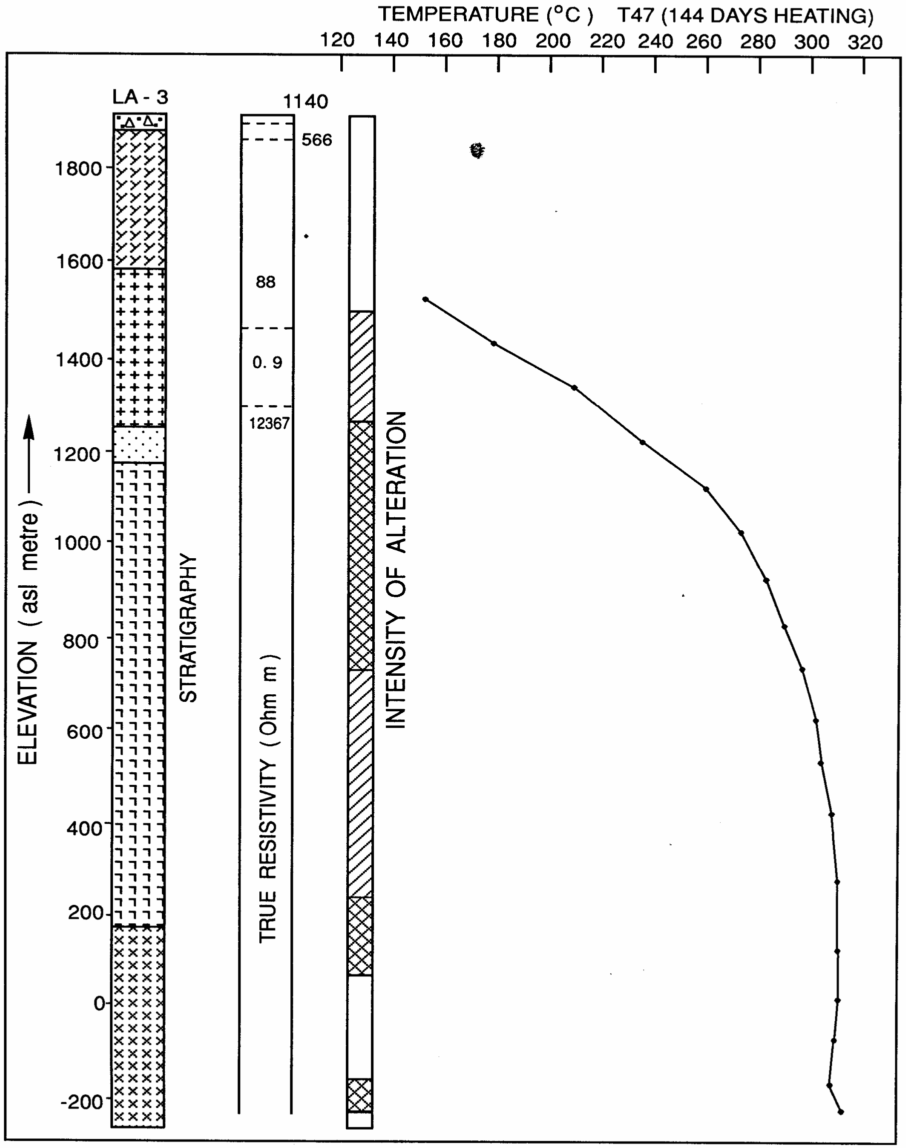


FIG. 12 Correlation of Stratigraphy ,Resistvity, Intensity of Alteration, and Measured Temperature of LA - 3. Legend as in FIG. 10

CORBETTI GEOTHERMAL PROSPECT

- The dipole-dipole map for N=5 (Fig 14) shows a low resistivity zone bounded by a 10Ωm resistivity contour between Corbetti caldera and Lake Shalla.

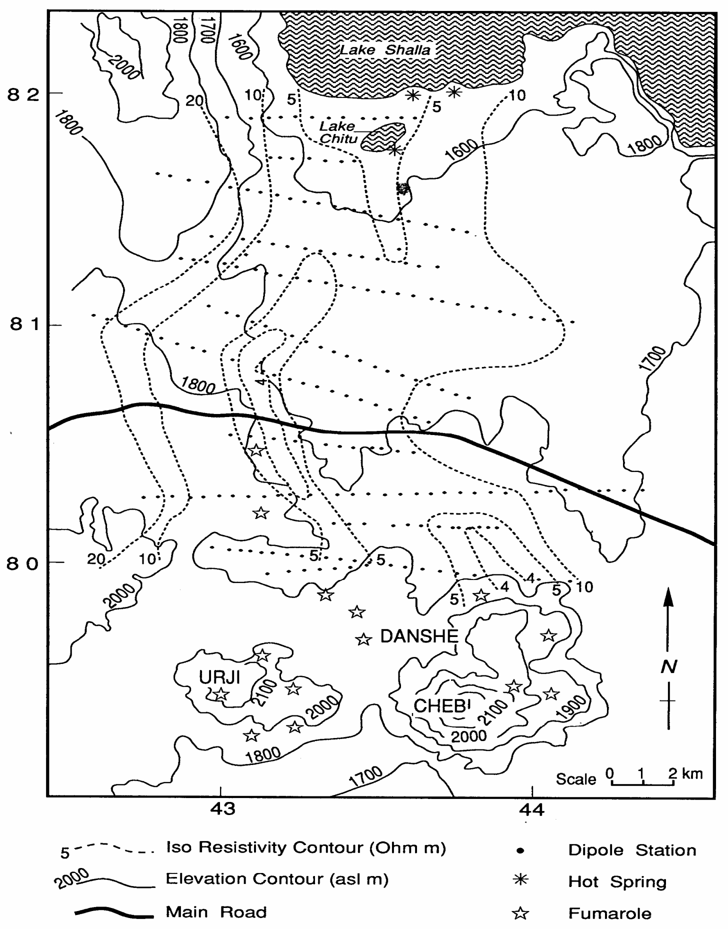


FIG. 14 Corbetti Geothermal Prospect
Dipole - dipole Resistivity Map for N = 5, a = 500m

- Schlumberger resistivity contours for AB/2=1470m (Fig 15) show the limit of the low resistivity zone towards Corbetti caldera indicated by the dipole-dipole results. A low resistivity zone opens from Corbetti caldera to Lake Shalla.

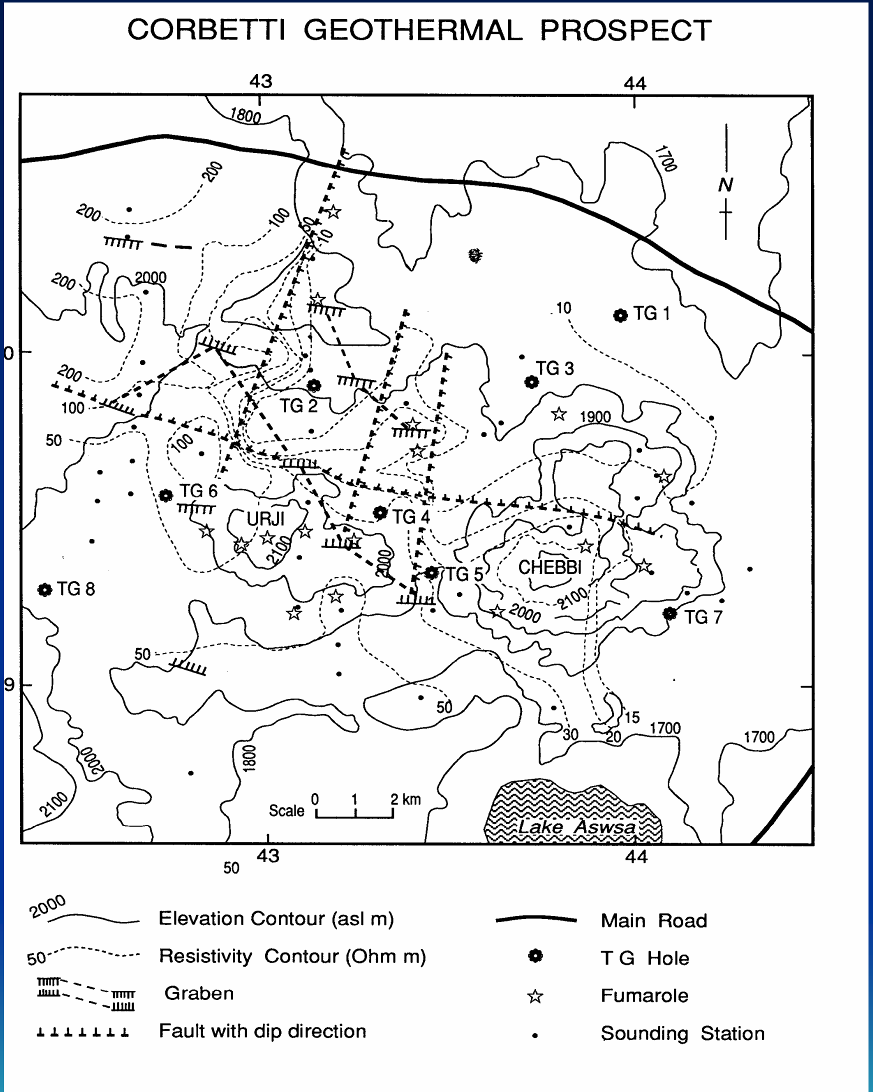


FIG. 15 Schlumberger Iso Resistivity Map for $\frac{AB}{2}$ = 1470m

- There is no thermal feature south of Corbetti Caldera. Ground water moving from Lake Awasa towards Lake Shalla heated by steam and hot water during migration through Corbetti caldera, could account for the geochemical conditions at the Chitu-Shalla springs.
- The results of temperature gradient holes (Fig 16) show that TG2 and TG 4 entered steam pockets for 130m (30-160m) and for 40m (40-80m) respectively. TG3 and TG6 show steam heated columns above the water table whereas TG1, 7 and 8 indicate lower conductivities near the bottom of the holes. The observations in the temperature gradient holes could not be used to site deep geothermal wells.

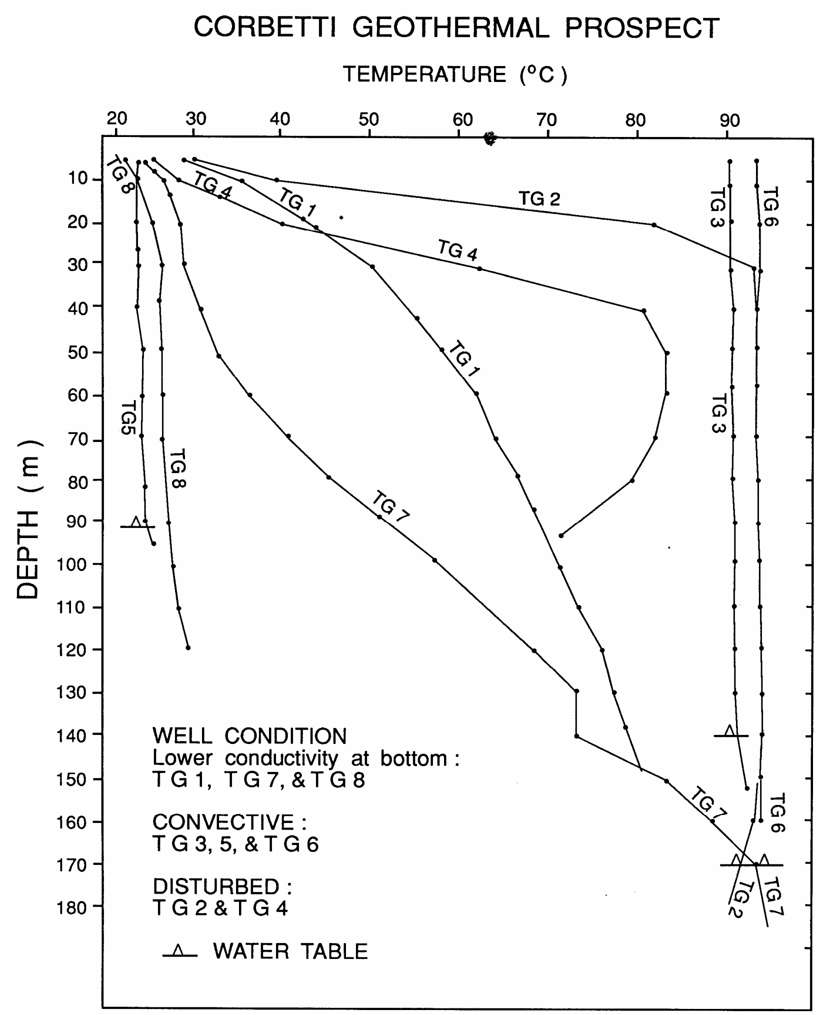


FIG. 16 Measured Temperatures in TG Wells NR 1 to 8

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