ASSESSMENT OF TOPOGRAPHIC LINEAMENTS ACROSS ROTORUA GEOTHERMAL FIELD, NEW ZEALAND

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SUMMARY - Topographic lineaments were identified and traced from digital topographic data (25m grid) over the Rotorua area in the Taupo Volcanic Zone (TVZ), central North Island of New Zealand. Assuming that the lineaments represent faults and fractures, the result is presented as the variation of 'fault and fracture density' (FFD) defined as total length of lineaments per unit area (km/km^2). The study did not reveal any coherent high FFD zone associated with the Rotorua geothermal field. A topographic correction was attempted by fitting a logarithmic function to the plot of average topographic gradient against FFD values, but this failed to enhance the FFD over the field where the terrain is almost flat. There are strong relationships between high FFD zones and some major faults mapped in the Rotorua area.

1. INTRODUCTION

In many geothermal systems, permeable zones are often associated with geological structures. In New Zealand, the relationship between faults and productive drillholes has been well established in some geothermal fields in the Taupo Volcanic Zone (TVZ) (e.g. Grindley, 1965; Grindley and Browne, 1975).

Many geological structures have recognisable topographic expressions. For example, the Paeroa Fault Zone in the central TVZ was first-recognised fiom its prominent *scarps* (Hochstetter, 1864). On a smaller scale, most of the faults mapped across the Wairakei (Grindley, 1965a) and Orakei Korako fields (Lloyd, 1972) are traceable as lineaments on a detailed topographic maps of the area. Hence, a careful analysis of topographic data can be useful in recognising structural elements. Soengkono (1999a, 2000) conducted such analyses over the Te Kopia and Mokai geothermal fields in the TVZ. Topographic lineaments were traced from a set of digital topographic data (25m grid). The results detailed the distribution and pattern of faults and fractures across the studied areas. A parameter named 'fault and fracture density' (FFD), defined as total length of lineaments per unit area (km/km^2), was introduced. This parameter can be contoured to indicate variation of faulting and fracturing intensity. At Te Kopia and Mokai a relationship exists between high FFD ($>3\ km/km^2$) and deeper permeable zones.

In this study, a similar analysis was conducted over the Rotorua geothermal field. The relationship between FFD and topographic gradient was assessed and a correction for topography was applied to the FFD data.

2. ROTORUA GEOTHERMAL FIELD

The Rotorua geothermal field is situated at Rotorua city in the central North Island of New Zealand. It lies in the south part of the Rotorua caldera (Fig. 1), which collapsed during and after an ignimbrite eruption 140 ka ago (Wood, 1992). Rotorua is a liquid dominated, high-temperature system, exhibiting a variety of surface thermal manifestations which include the last remaining major geysers in New Zealand. The geothermal field covers an area of about $12km^2$, extending into Lake Rotorua (Fig. 1). A large part of the field lies in a flat area formed by lacustrine and fluvial sediments. The geothermal reservoir is mostly associated with aquifers within an ignimbrite formation and the upper parts of buried rhyolite domes (Wood, 1992).

3. ANALYSES OF TOPOGRAPHIC LINEAMENTS

Topographic lineaments were traced from 25m grid digital topographic data over the area shown in Fig. 1 not occupied by lakes. The procedure used to identify and trace the lineaments is described by Soengkono (1999b). Fig. 2 shows the topographic lineaments over the study area presented together with contours of FFD determined using $1x1km^2$ grid size. Only a few lineaments were identified over the flat area of the Rotorua field covered by lacustrine and fluvial sediments. These include the Kuirau fault and the eastern end of the ICBF (Fig. 1) mapped by Wood (1992).

The lineaments in Fig. 2 were plotted on a rosette diagram (Fig. 3) which shows main structural directions trending NE-SW, N-S, NW-SE and E-W. These directions are consistent with the faults mapped (Fig. 1). Bayrante (1984) suggested that

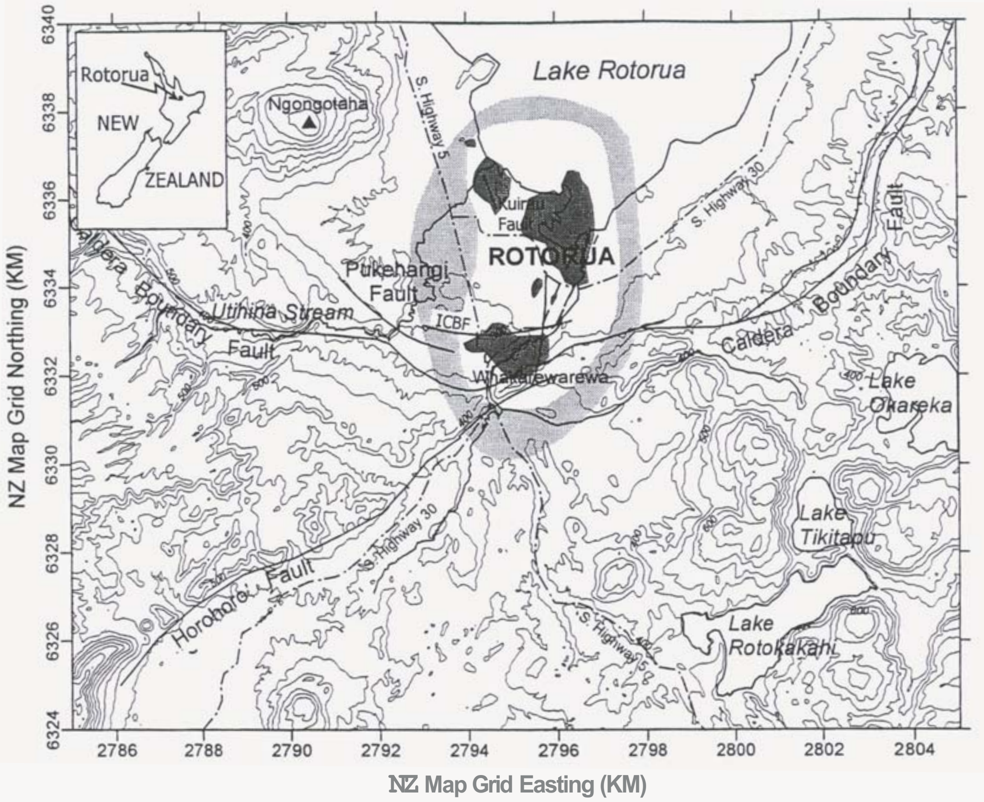

Figure 1. Topographic map of the Rotorua geothermal field, North Island, NZ; contour interval 50m. The boundary of the field, delineated from Schlumberger resistivity mapping (Bibby et al., 1992), is shown by light shading. Dark shades represent areas of surface thermal manifestations. Faults are from Wood (1992); ICBF is the Inner Caldera Boundary Fault.

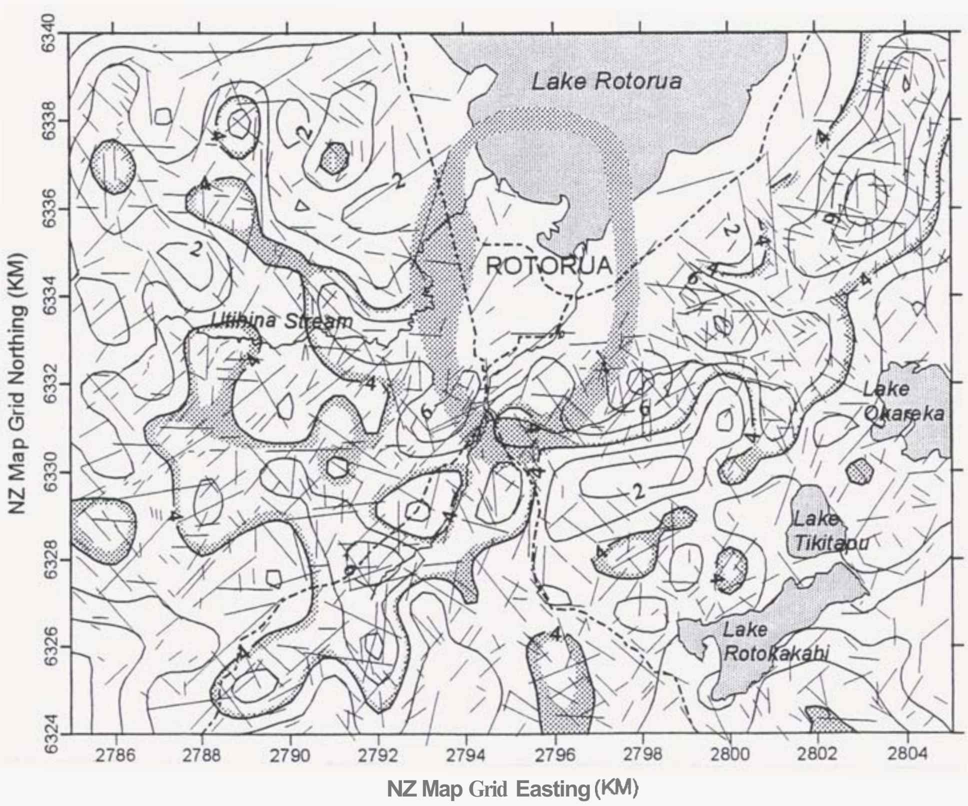

Figure 2. Topographic lineaments traced from digital elevation data (25m grid) and interpreted as faults and fractures. Contours of FFD (fault and fracture density; determined using a grid size of 1000 m), in km/km^2, are also shown.

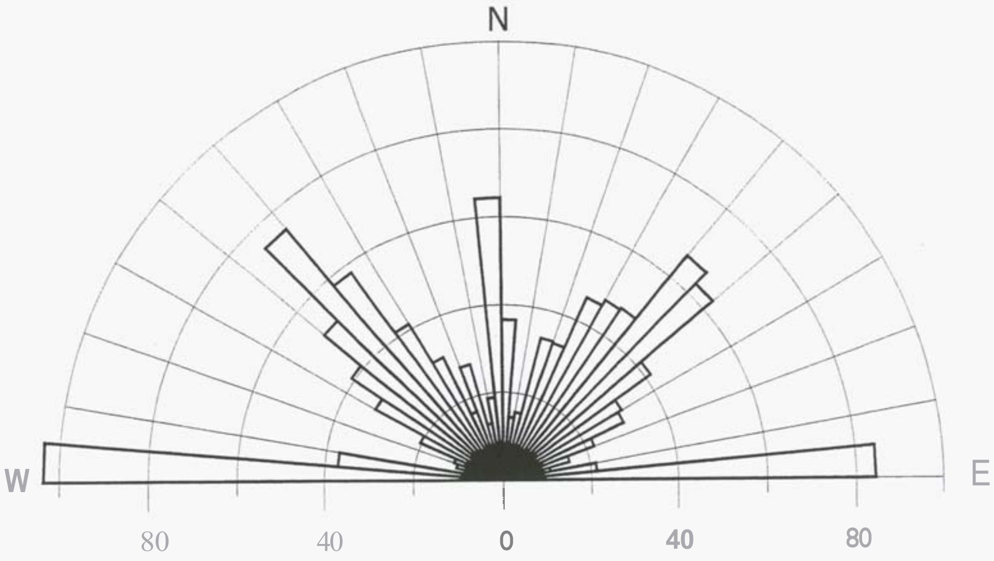

Figure 3. Rosette diagram of the lineaments shown in Fig. 2.

NE-SW regional faults and interlaced E-W faults related to caldera formation are controlling the hydrology of the Rotorua area. A control by a N-S structural feature of the upflowing geothermal fluids beneath Rotorua was suggested by Allis and Lumb (1992) based on the shape of resistivity anomaly across the field.

3.1 Relationship between FFD and topography

To assess the relationship between FFD and topography, an average topographic gradient (ATG) for each 1x1km^2 FFD grid was determined. The 1x1km^2 grid was sub-divided into sixteen 0.25x0.25km^2 sub-grids and topographic slopes (in m/km) were determined along the sides of each sub-grid from the ratio between the elevation difference (in m) and the side length of the sub-grid (0.25km). Thirty two topographic slopes were computed for each 1x1km^2 FFD grid and their average value was taken as the ATG for that grid.

Fig. 4 shows a plot of ATG against FFD values. The plot suggests that the effect of topography on FFD values becomes small for ATG values greater than 10 m/km. A logarithmic curve fitting the data is also shown. The curve was used to normalise the FFD values, by multiplying them with factors needed to bring the curve into a straight, horizontal line along the average FFD value of 4 km/km^2. A contour map of the normalised FFD values is shown in Fig. 5.

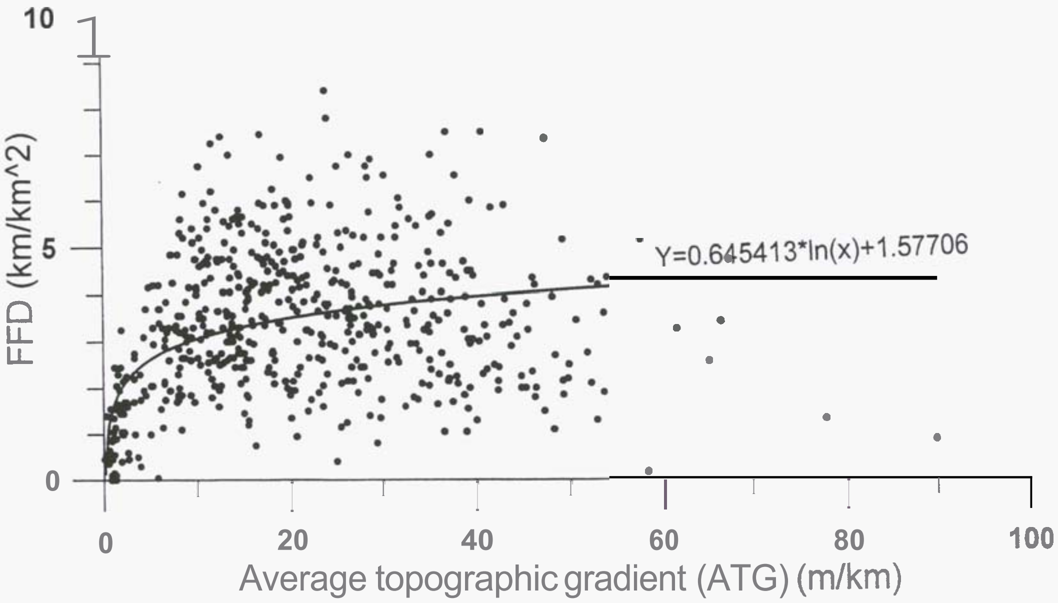

Figure 4. A plot of average topographic gradients against FFD values.

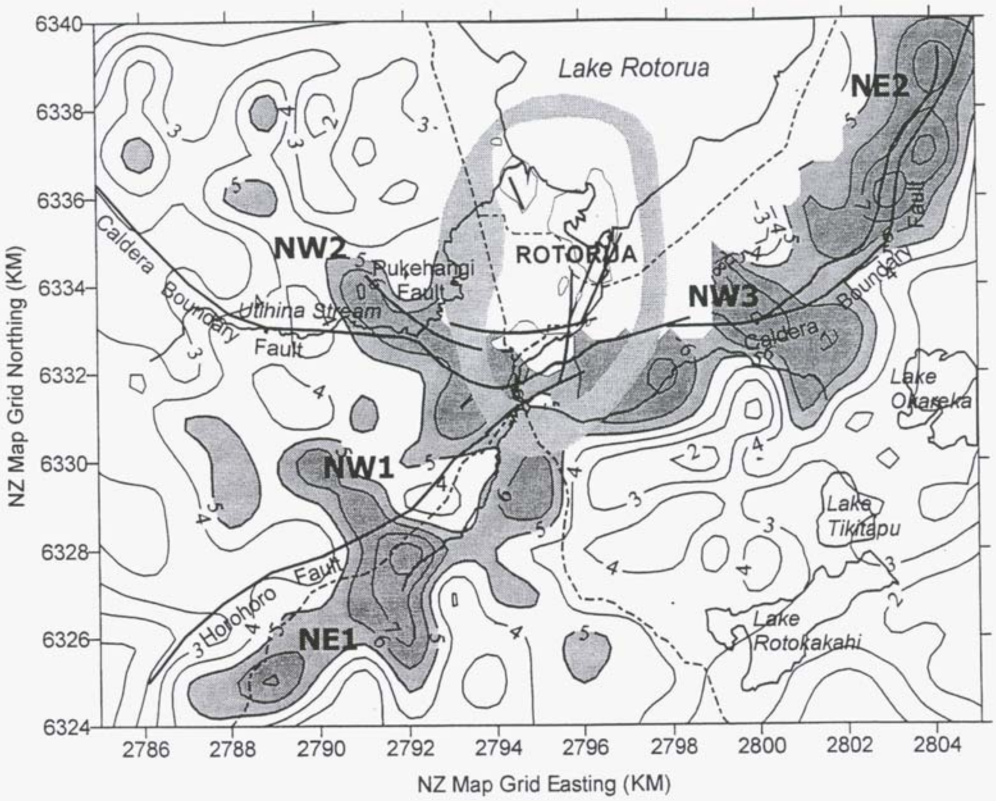

Figure 5. Contour map of FFD values corrected for topography (nonnalised using the logarithmic curve shown in Fig. 4). Contour values are in km/km^2. Areas with FFD $\geq$4 km/km^2 are indicated by shading.

4. DISCUSSION

Unlike the Te Kopia and Mokai fields (Soengkono, 1999a; 2000), the Rotorua field is not associated with a coherent zone of high FFD that can be defined from analysis of digital topographic data. The results (Fig. 5) show that a correction for topography using the curve shown in Fig. 4 did not significantly enhance the FFD over the flat area (ATG <2 m/km) occupied by the Rotorua field. However, some trends of high FFD associated' with major faults mapped in the study area were enhanced by the topographic correction.

One NE-SW FFD trend (NE1 in Fig. 5) is sub-parallel to the Horohoro fault. Bibby et al. (1992) suggested that active geothermal systems in the Rotorua area are aligned in a northeasten trend which can be extended to include the Horohoro hot springs near the southwestern end of the NE1 trend.

The eastern part of the Rotorua Caldera Boundary Fault (CBF) is clearly associated with the NW-SE trend of high FFD shown as NE2 in Fig. 5. No high FFD zone is associated with the eastern part of the CBF. However, the splinter Pukehangi fault is marked clearly by a well defined zone of high FFD (NW2 in Fig. 5).

The NW-SE trending high FFD zones shown as NW1 and NW2 are not associated with any of the major faults mapped in Fig. 1. The geology of the area (Wood, 1992) shows the NW3 zone is associated with recent lacustrine sediments, alluvium and tephra, that could mask evidence of any major fault system. However, only the southwestern end of the NW1 zone is associated with such a young sedimentary cover.

5. CONCLUSIONS

The analysis of topographic lineaments conducted in this study did not reveal any coherent high FFD zone associated with the Rotorua geothermal field. One of the possible reasons for this is that a large part of the Rotorua field lies on flat terrain covered by recent lacustrine and fluvial sediments.

A plot of average topographic gradients (ATG) against FFD values shows only a small effect of topography on FFD values for ATG >10 m/km. A topographic correction was attempted by fitting a logarithmic function to the ATG versus FFD plot, but the corection failed to enhance the FFD over the flat area of the Rotorua field where the ATG values are less than 2 m/km.

There are strong relationships between zones of high FFD and some major faults mapped across the Rotorua area.

6. REFERENCES

Allis, R. G. and Lumb, J. T. (1992). The Rotorua geothermal field, New Zealand: its physical setting, hydrology, and response to exploitation. *Geothermics* 21, 1/2, 7-24.

Bayrante, L.F. (1984). *Structural aspects of the S margin of the Rotorua Caldera and their implications to the Rotorua geothermal field, North Island, New Zealand.* Geothermal Institute Report 84.03, University of Auckland, New Zealand.

Bibby, H.M., Dawson, G.B., Rayner, H.H., Bennie, S.L., Bromley, C.J. (1992) Electrical resistivity and magnetic investigations of the geothermal systems in the Rotorua area, New Zealand. *Geothermics* 21, 1/2, 43-64.

Grindley, G.W. (1965). *The geology, structure, and exploitation of the Wairakei geothermal field, Taupo, New Zealand.* NZGS Bulletin 75. Department of Scientific and Industrial Research, New Zealand.

Grindley, G.W. and Browne, P.R.L. (1975). Structural and hydrological factors controlling permeabilities of some hot-water geothermal fields. *Proc. of 2nd UN Symposium on the Development and Use of Geothermal Resources,* 377-386.

Hochstetter, F. Von (1864). Geologie von Neu Seeland: *Beitrage zur Geologie der Provinzen Auckland und Nelson. Novara-Exped. Geol. Theil.* 1 (1): 274 pp. (Translated and edited by C.A. Fleming, 1959. Government Printer, Wellington, 320 pp.)

Lloyd, E.F. (1972). *Geology and hot springs oj Orakeikorako.* NZGS Bulletin 85. Department of Scientific and Industrial Research, New Zealand, 164 p.

Soengkono, S. (1999a). Te Kopia geothermal system (New Zealand) - The relationship between its structure and extent. *Geothermics* 2816, 1-18.

Soengkono, S. (1999b). Analysis of digital topographic data for exploration and assessment of geothermal systems. *Proc. 21st NZ Geothermal Workshop,* 163-167.

Soengkono, S. (2000). Assessment of faults and fractures at the Mokai geothennal field, Taupo Volcanic Zone, New Zealand. *Proc. World Geothermal Congress, Kyushu-Tohoku, Japan,* 1771-1776.

Wood, C.P. (1992). Geology of the Rotorua geothermal system. *Geothermics* 21, 1/2, 25-41.