SEISMIC ACTIVITY NEAR WAIRAKEI GEOTHERMAL FIELD, NEW ZEALAND

T.M. Hunt and J.H. Latter
Geophysics Division, D.S.I.R.

ABSTRACT

A 5-week survey showed that seismic activity near Wairakei Geothermal Field took place mainly at shallow (<3 km) depths, was confined to that part of the field within the Taupo Fault Belt, and occurred in swarms. No earthquakes occurred in the main production borefield, or in an area of ground subsidence adjacent to the borefield. It is concluded that no activity is associated with exploitation of the fields seismic activity in the Wairakei area is broadly similar to that in other parts of the belt. It is suggested that for fields under steady-state operation there is no seismic activity related directly to exploitation and exploitation does not affect any background, regional activity.

INTRODUCTION

Wairakei Geothermal Field is a large hydrothermal area underlain by a nearly horizontal, Quaternary, volcanic and clastic rock sequence and is situated in the Central Volcanic Region of New Zealand. Within this region, near the field, are two main structural features: a belt of active normal faulting – the Taupo Fault Belt and a major structural depression – the Taupo-Reporoa Basin. Both the field, as defined by resistivity measurements, and the main production borefield lie across a zone at the junction of these features (Pig. 1).

Power production from the borefield began in 1958 and has remained almost constant at about 150 MW for a decade; this makes Wairakei the third largest geothermal scheme in terms of power production, after The Geysers (California) and Lardarello (Italy). The Wairakei power station is operated as a base-load station; the amount of water (both liquid and gas phases) drawn from the ground is nearly constant throughout the day and night. The amount drawn, including natural losses, reached a peak value of 2.7 Mg/s in 1964 and has declined steadily since then to a present value of 1.7 Mg/s. Waste water from the station is not reinjected but discharged into the Waikato River. Since production commenced more than 10^{12} kg of water has been drawn from the field and, despite almost total recharge since 1966, significant ground subsidence has occurred. However, the subsidence is not centred on the borefield, but in an area about 1 km to the northeast (Fig. 3); in the period 1964–1974 the maximum subsidence was ~5 m. The subsidence was first noticed in 1956 and has continued at an increasing rate since that time up to the time of the last measurements in 1974.

SEISMIC ACTIVITY IN GEOTHERMAL FIELDS

Many recent studies have shown that seismic activity, and in particular microearthquake activity, occurs in and near to geothermal areas. Most of the activity occurs in, or very close to, the geothermal areas, or in associated tectonic zones, and at shallow depths (<5 km). The earthquakes typically occur in swarms; the seismic energy is released over a period of several days and in many shocks. The cause8 of the earthquakes, and tteir

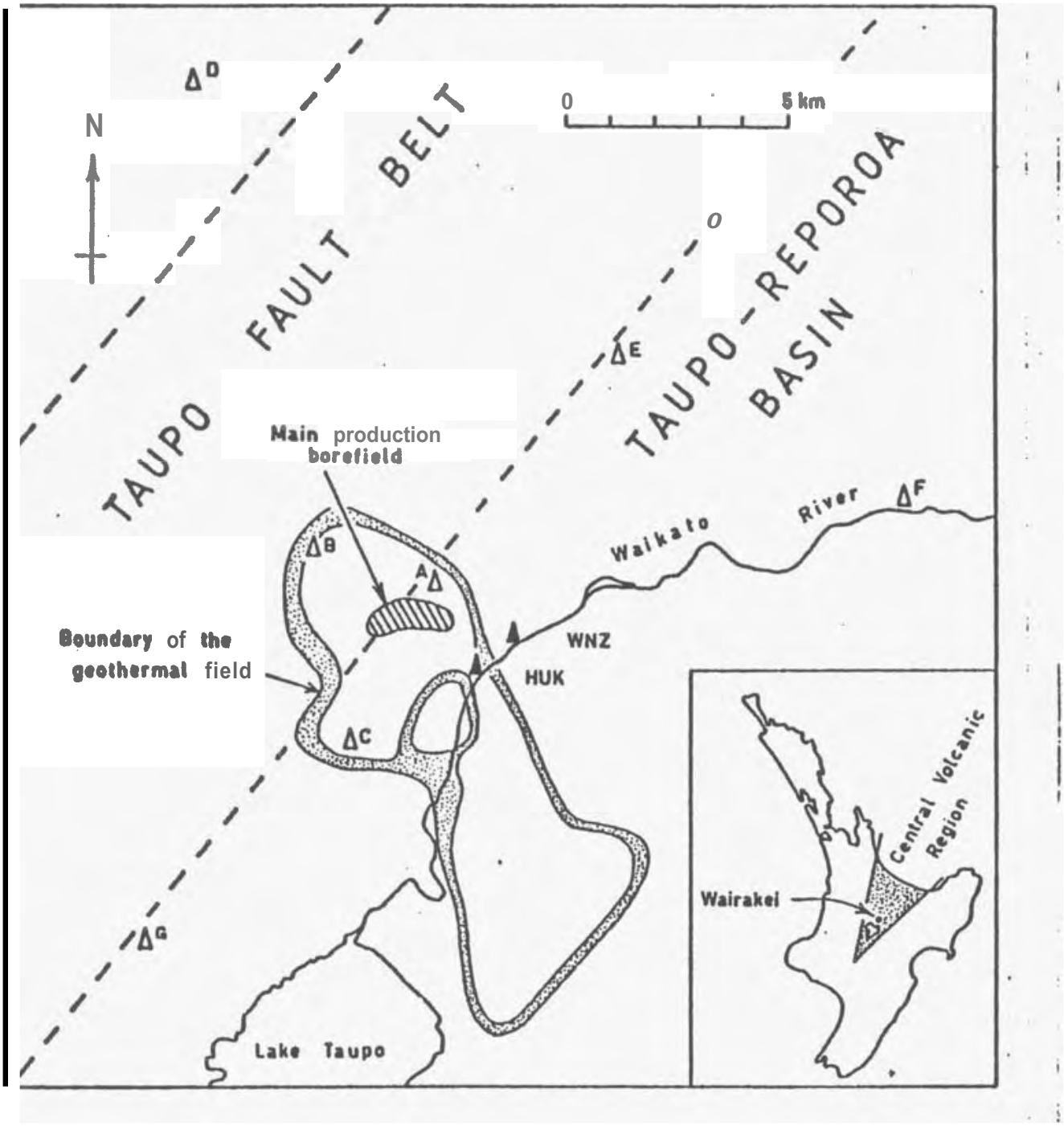

Fig. 1: Location and extent of Wairakei Geothermal Field. Broken lines indicate the approximate locations of the boundaries of major structural features. The zone of stippling indicates the boundary of the field and corresponds to the zone between the apparent resistivity contours of 10 and 20Ωm. Triangles indicate the locations of seismographs used in this survey: portable instruments are indicated by open triangles and permanent instruments by solid triangles.

relationship to exploitation of geothermal areaa, are not yet certain.

Apart from three studies at The Geysers, no investigations haw been made of seismic activity in a geothermal field under significant exploitation. However, during these studies, The Geysers field was under development and total power production was not constant, but increasing. To determine the seismic activity associated with a field under *constant* power production we conducted a microearthquake survey of Wairakei Geothermal Field.

INSTRUMENTATION AND SURVEY DETAILS

A network was set up consisting of six portable seismographs and two permanent stations (HUK & WNZ), all with vertical component seismometers, at the nine locations shown in Fig. 1. The network was operated for five weeks; froa 1978 May 1 to 1978 June 7. . The magnification of the portable instruments was between 10^5 and 10^6.

SURVEY RESULTS

Number of earthquakes and rates *of occurrence*

Locations (epicentres) were found for 28 earthquakes within 20 km of Wairakei; events were also recorded at one or two stations for which locations could not be determined. The located earthquakes were not uniformly distributed in time; they occurred in three groups (Fig. 2). The greatest number of events located in one day was 3 and this occurred on 3 occasions.

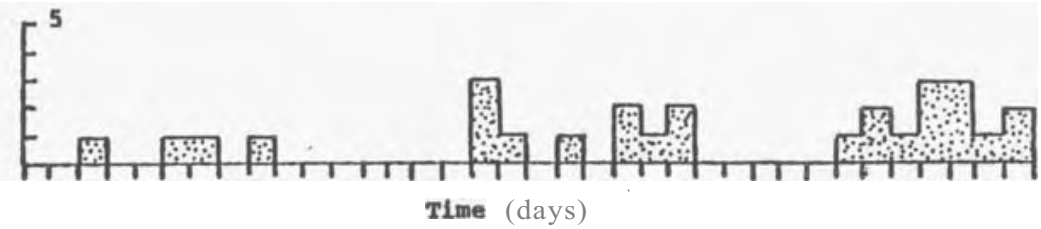

Fig. 2: Time distribution of earthquake. located during the survey. Note that there is a distribution in time into three groups; the epicentres for each group however are not located in any particular area.

Rates of occurrence-of all events were significantly higher at stations within the field than at those outside (Table 1). The high rates within the field are attributed to very mall earthquakes, with magnitudes le88 than 0.4, and which could not be located.

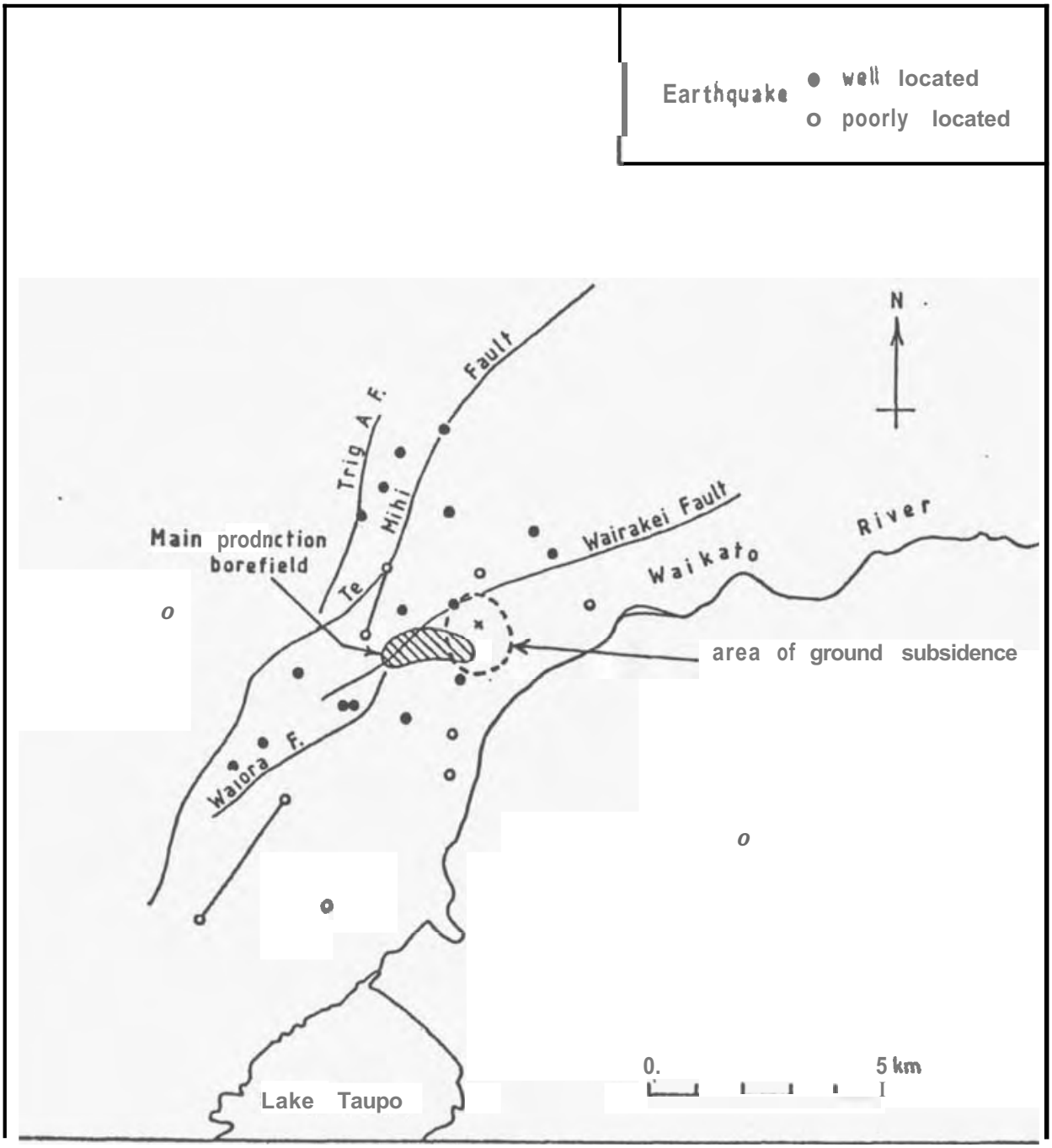

Fig. 3: Location of epicentres of earthquakes located during the survey period. In two cases, two alternative epicentres were obtained for an earthquake; these are shown joined by a solid line. The area enclosed by a broken line corresponds to ground which subsided by more than *0.5* m in the period 1964-1974; the maximum subsidence in this period was about 5 m and was located at the point marked by a cross. Ground outside the area indicated has subsided in places, but by no more than *0.5* m in this period. Note that no epicentre lies within the main production borefield or the indicated *area* of ground subsidence so indicated.

Table 1: Rates of occurrence of events at seismograph stations inside and outside Wairakei Geothermal Field, 1978 May 2 - June 7. The rates are for events with a trace amplitude (0-peak) >2 mm, normalised to an attenuation setting of 36 dB, and with S-P intervals <3 s (<20 km distant). Refer to Fig. 1 for station locations.

	Inside Wairakei Field			Outside Wairakei Field			
Station;	A	B	C	D	E	F	G
No. of events recorded	18	32	3	2	5	24	2
No. of events/day	6.6	2.2	3.2	0.17	0.74	0.71	0.1

Locations and depths

The epicentres of the earthquakes located are shown in Fig. 3; they are scattered over the area enclosed by the network, and are not concentrated in the main production borefield, the area of ground subsidence, or along a particular fault. A few epicentres, however, lie on or close (<0.5 km) to the surface trace of faults, particularly the Wairakei, Te Mihi, and Waiora Faults. Most earthquakes were located within the Taupo Fault Belt, and north and west of the Waikato River. Most earthquakes originated at shallow depths; certainly within the volcano-clastic sequence (<about 3 km), and probably above the Wairakei Ignimbrite Formation (<0.7 km).

Magnitudes and b-values

The magnitudes of events recorded ranged from -1.9 to +2.25; those for events located from -1.5 to 42.25.

The value for the coefficient b, for events with magnitudes greater than 0.5 and with epicentres within 20 km of Wairakei, was 0.9 - 0.5. A b-value of 0.7 - 0.2 was obtained for events within 6.5 km of Wairakei and having magnitudes greater than -1.35. These values of b are typical for tectonic earthquakes; volcanic earthquakes, and earthquakes taking place in very inhomogeneous material, generally have values greater than 1.

GROUND SUBSIDENCE AND SEISMIC ACTIVITY

Although ground subsidence adjacent to the field is clearly related to exploitation, the reasons for it are uncertain. McNabb (1975) has suggested that it may be a manifestation of thermal contraction resulting from an intrusion of cold water into hot rock along the boundary of the field; alternatively it may be due to draining of rocks at shallow depths (less than about 100 m) because of withdrawal of water from rocks at deeper levels (>500 m) in the production zone. If the subsidence results from thermal contraction then seismic activity might be expected to be more intense in this area than elsewhere. No such effect was observed during our survey. On the other hand, if the subsidence was due to draining of near-surface rocks, it should have ceased shortly after the recharge reached 90% in 1966 (Hunt 1977), but this has not occurred. The present survey has been unable to resolve the cause of the subsidence, only to establish that there is no seismic activity associated with it.

DISCUSSION

In a study of microearthquakes in a neighbouring part of the central North Island, Evison et al (1976) found that; (a) microearthquakes are very frequent in the Taupo Fault Belt and very infrequent in the Taupo-Reporoa Basin; (b) the distribution of microearthquakes did not correlate with areas of geothermal activity; (c) much of the seismic activity in the Taupo Fault belt occurred as swarms; and (d) the swarm earthquakes had shallow focal depths (<6 km). The results of our survey are in agreement with their findings. Most earthquakes we located lay within the Taupo Fault Belt, none appeared to be related directly to tho Wairakei Geotheml Field, and their tate of occurrence was similar to that of swarm earthquakes, and occurred spasmodically. The results of our survey suggest earthquake activity in the vicinity of Wairakei Geothermal Field is broadly similar to that in adjacent parts qf the Taupo Fault Belt. This suggests that there is no activity related directly to the field, which at present is under rteady-state operation, and that operation of the field does not affect background regional activity.

Extending the results to other geothermal fields, we postulate that there will be little or no activity related directly to exploitation of fields under steady-state operation. Seismic activity near fields under development however is likely to be quite different; large and rapid changes in pressure and mass, at depth, in much fields may well cause variations in local activity. and we recommend that activity in geothermal field8 under development, such am Ohaki (Broadlands) be closely monitored.

FURTHER WORK

We are still examining the survey data and will report elsewhere on the above results in greater detail, and on focal mechanism and S-wave attenuation.

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