STRUCTURE OF THE BROADLANDS-OHAAKI GEOTHERMAL FIELD (NEW ZEALAND) BASED ON INTERPRETATION OF SEISMIC AND GRAVITY DATA

by

Stuart Henrys

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This thesis is dedicated to Estelle and Lorraine who have sacrificed the most and can still smile.

The D.S.I.R. seismic recording vehicle located in front of the Ohaaki Pool during the recording of seismic reflection line 3. The photograph was taken looking northwest.

Abstract

The structure of the Broadlands-Ohaaki hot water geothermal field has been studied by analysis of seismic and gravity data.

The 1984 seismic survey provided 26 km of multifold (12-fold) reflection data and refraction data (up to 1 km) along 6 profiles in the vicinity of the geothermal field. Test data were acquired along 2 profiles of 1 km length and included a walk-away noise spread. An attempt was also made to record shear-waves (SV) along one profile with in-line horizontal geophones. Processing of reflection data indicated the importance of static corrections, velocity filtering and spectral balancing of the trace amplitude spectrum before deconvolution.

Delay times from the analysis of refracted (first) arrivals outline areas of anomalous low velocity that coincide with areas of highest surface temperatures (>50°C at 15 m depth). Ray trace modelling of travel times near the Ohaaki Pool delineate an anomalously low-velocity zone to a depth of 200 m. The frequency and amplitude of the recorded signals near the Ohaaki Pool are attenuated in comparison to field records from outside areas with high surface temperatures. Converted shear-waves indicate that Poisson's ratio is low (0.17 to 0.20) in this area. These effects are consistent with a steam/water zone occurring close to the surface

Common-mid-point derived velocities and ray-tracing inversion of reflecting horizons were used to determine the 3-dimensional velocity distribution beneath the geothermal field. A low-velocity zone, in which velocities are 10-20% lower inside the geothermal field, coincides with the region of highest signal attenuation (Q<20), the productive borefield, and the region of highest fluid temperature (>250°C at 1000 m depth)

The seismic stratigraphy of the volcanic units was established using drill hole data and synthetic seismograms. The top and bottom of the Ohaaki Rhyolite and Broadlands Dacite account for the major reflecting horizons with occasional less strong reflections from the top of the Rangitaiki Ignimbrite. However, even strong reflectors are not coherent across any single section and the top of the rhyolite and dacite flows may show up with strong reflections at one part of the profile, but elsewhere with weak or no reflections. The limited success in enhancing signal quality below 500-700 m depth is attributed to a combination of noise generated in the low velocity surface layer and the complexity of the geological structure at depth.

Analysis of noise characteristics of the Broadlands-Ohaaki reflection data included computation of synthetic seismograms and spectral analysis of recorded seismograms. Theoretical modelling of near-surface structures showed that prominent low-frequency noise trains observed in field data are due to waves trapped in the surface layer that are excited by direct waves from shallow (5-10 m) shots. A very rapid increase in seismic wavespeed occurs at the water table and causes the surface layer to act as a waveguide which traps low-

frequency Rayleigh waves and air-coupled Rayleigh waves visible on near offset traces. Compressional energy is also efficiently converted into shear-waves (SV) and is dominant as reverberating reflected refracted energy at far offsets (>400 m). In addition, there is resonant coupling between the surface waves and multiple reflections. Surface-consistent spectral analysis indicates that variation in receiver response is a function of the thickness of the low-velocity layer.

Reinterpretation of refraction data (1968 survey) by ray-trace modelling elucidated new structural and stratigraphic details which tie in with well data and confirms the velocity structure established from reflection data. Near offset refracted arrivals clearly define the top of the Ohaaki Rhyolite (2200-2800 m/sec) in the western part of the field and the top of the Broadlands Dacite (2650-3200 m/sec) in the east. Longer offset (>3 km) travel times could be modelled as arrivals from the top of the Rautawiri Breccia and Rangitaiki Ignimbrite (velocities between 2800 m/sec and 3800 m/sec). Arrivals from greywacke basement (4500 m/sec) could only be detected in the east outside the geothermal field coming from depths less than 1.0 km.

A 3-dimensional interpretation of residual gravity anomalies was also attempted since the seismic sections and detailed well data provide strong constraints. Isodensity and isoporosity contours of the Rautawiri Breccia, Waiora Formation and the Ohaaki Rhyolite reveal areas of high density and low porosity corresponding to the productive regions of the borefield. This density increase is caused by alteration and mineralisation.

The detailed interpretation models allow the construction of basement contour and isopach maps. Basement structural-contours show that the basement surface is very complex with significant vertical displacement along a series of predominantly northwest-southeast trending normal faults of limited horizontal extent and with no evidence of significant cross faulting. The basement reaches a maximum depth of 2300 m b.s.l west of the geothermal field. East of the geothermal field the basement rises along a series of northeast-southwest trending normal faults including the Kaingaroa Fault. Isopachs of the productive Rautawiri Breccia and Waiora Formation indicate that the thickest sequence of these units lies to the north and south of the geothermal field apart from at least two structurally controlled depressions inside the field where the thickness of the Rautawiri Breccia is greater than 500 m. Elsewhere, the combined total thickness of these units is less than 400 m.

The Broadlands Dacite dome extends over an area of about 16 km^2. A magnetic high associated with the Broadlands Dacite is caused by the unaltered, normally magnetised dacite east of the resistivity boundary. Isopachs of the Ohaaki Rhyolite indicate that its thickness increases to the northwest. This finding cannot be reconciled with an earlier concept of a localised Ohaaki dome structure which required a localised feeder dyke within the field. The Ohaaki Rhyolite is probably part of a more extensive chain of rhyolites outcropping to the north and west.

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