PHYSICAL MODEL OF THE WAIRAKEI GEOTHERMAL FIELD, CIRCA 1960

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ABSTRACT

The Wairakei Geothermal Field physical model is unique. The model is built of wood; it was constructed in the late 1950s or early 1960s and is thus one New Zealand's earliest physical models of geology; and it shows some features of the Wairakei Geothermal Field before the power production began in November 1958. These features include geological layers, well logs and temperature contours in area of the eastern and western borefields.

Temperature contours, mapped between 230°C and 255°C, demonstrated the utility of the physical model. Near-isothermal conditions in the eastern borefield were consistent with vertically-upwards flow of hot geothermal fluid to surface geothermal features whereas more variable ground temperatures in the western borefield were probably caused by mixing of hot geothermal fluid flowing from the west through ignimbrite units and cold groundwater moving through the shallower layers.

1. INTRODUCTION

The physical model of Wairakei Geothermal Field, built out of wood (Figure 1) is one of New Zealand's first three physical models of the subsurface, and the only one that is known to survive. Other models included the 'walk-through' geological model of the Wairakei Geothermal Field that represented well logs on coloured dowels suspended from a ceiling, above a large-scale Wairakei map, in one room of the current Grange Building at GNS Science Wairakei; and a 'see-through' model of the Christchurch groundwater system that plotted well logs on multiple glass panels (Weeber, pers. comm.).

The Wairakei Geothermal Field model, completed in the late 1950s, or early 1960s, by Dawson, Banwell and Zander, is an important historical record as it describes geology and temperatures in the Field that were measured in the 'testing' phase of development (1950 – 1958), prior to current 'production' phase (White and Hunt, 2005). The model consists of a base layer, six horizontal layers, and a wooden carry-case, with dimensions approximately 750 mm by 330 mm by 200 mm. Data from 24 deep drill holes was used to build the model; locations of these holes are plotted on the base. The holes, completed by 13th August 1958, were drilled in the Waiora Stream Valley, and environs (Figure 2). Each of the six layers represents a one-hundred metre thickness of the field. The horizontal datum is feet relative to Maketu 1949 and the vertical datum is metres, and feet, relative to sea level. Parts of the model were painted black sometime after construction, possibly to indicate where temperatures were less than approximately 230°C. The model is complete, apart from one vertical set of blocks that is now missing; these blocks, of horizontal dimensions approximately 9 cm by 1.5 cm, were located on the western edge of the model.

Figure 1: The Wairakei Geothermal Field physical model, showing the top surface, six layers and the base with carry handles. The model is viewed from the south.

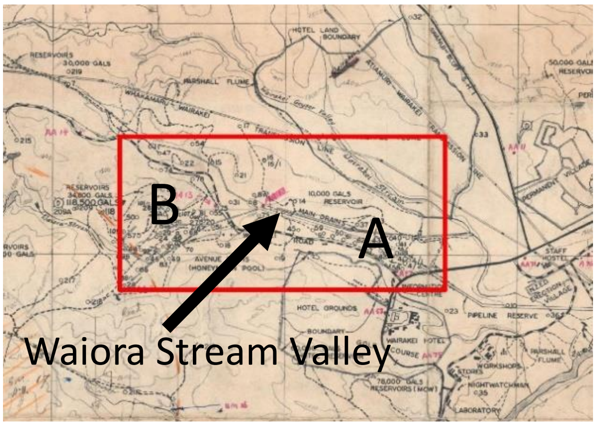

Figure 2: Extents of the Wairakei Geothermal Field physical model, on a 1963 map of Wairakei Field. 'A' and 'B' indicate the general locations of the eastern and western borefields, respectively.

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This paper will describe construction of the physical model and demonstrate some model features including Wairakei Geothermal Field temperature contours, which are summarised with a digital 3D model.

The Discussion then considers the current relevance of the physical model, largely through a digital 3D temperature model of temperature contours. Particularly, the temperature model is used to consider the schematic of groundwater flow (hot and cold fluids) in the groundwater catchment of Wairakei Geothermal Field (White et al., 2015; White and Reeves, 2017) and address the hypothesis that geothermal springs are sourced from two deep geothermal sources in the Wairakei Thermal Valley (White and Hunt, 2005). The discussion will conclude with a summary of present developments in physical modelling of geology using 3D printers.

2. PHYSICAL MODEL CONSTRUCTION

Each horizontal layer Wairakei Geothermal Field physical model is made up of 22 irregularly-shaped wooden blocks. The blocks were designed from section lines drawn between the mapped drill hole locations. Features (i.e., well lithology, geological layers, faults and temperature contours) were represented on all sides of the blocks (e.g., Figure 3).

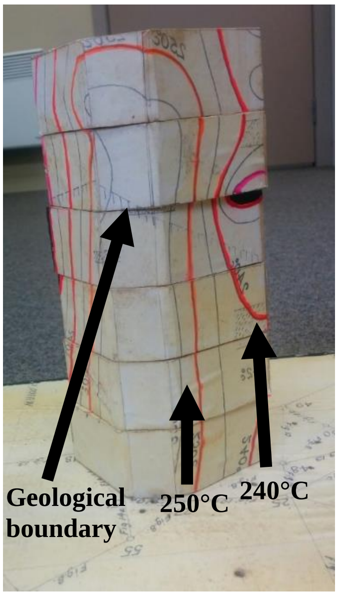

Figure 3: A vertical set of model blocks showing a geological boundary and temperature contours in six model layers above the model base.

3. 3D DIGITAL TEMPERATURE MODEL

Temperature contours recorded by the physical model are in the range 230°C to 255°C. These contours were digitized on the top horizontal surface of each slice, i.e., at elevations relative to sea level (RL) of: 0 ft (Figure 1), - 328 ft, -656 ft, -984 ft, -1312 ft and -1640 ft. These data were then modelled as a 3D grid, and rendered as iso-temperature surfaces, using EarthVision software (Figure 4). The temperature model calculated that approximately 31 Billion cubic feet (or approximately 1 km^3) of ground has a temperature in the range recorded by the physical model.

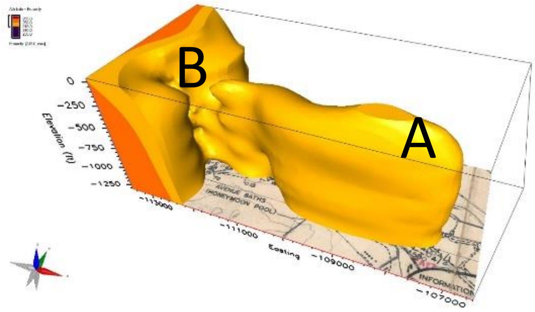

Figure 4: The 3D digital temperature model of the Wairakei Geothermal Field physical model temperature contours in the ranges 245°C to 250°C (yellow) and 250°C to 255°C (orange), viewed from the south. 'A' and 'B' indicate the general locations of the eastern and western borefields, respectively.

4. DISCUSSION

Near-isothermal conditions below the eastern borefield are consistent with the vertical upflow of geothermal fluid (i.e., 'A', Figures 4 and 5) and discharge of geothermal fluid to surface features such as geysers and springs (White and Hunt, 2005). Vertical temperature gradients are larger in western borefield area. Here, hot geothermal fluid is probably mixing with cold groundwater, consistent with White et al. (2015), Figure 5. However, White et al. (2015) incorrectly identified cold groundwater flows in the modelled Whakamaru Ignimbrite west of 'B', and in the elevation range 0 m RL to -500 m, i.e., the physical model identified high temperatures in this area and elevation range.

Two geothermal sources for geothermal features in the Geyser Valley were suggested by the behavior of spring flow in the period 1954 to 1963 (White and Hunt, 2005). The elevation ranges of the shallow source (-90 m RL to -130 m RL) and the deep source (-350 m RL to - 500 m RL) are within the domain of the Wairakei physical model. However, the model provides no insights to the pre-production pressure distribution within the reservoir.

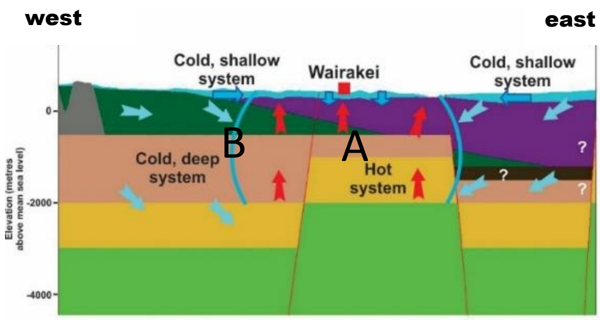

Figure 5: Section of the Wairakei geothermal field groundwater catchment showing: schematic of cold flow (blue arrows) and hot flow (red arrows); and geological model units including basement (green), pre-Whakamaru volcanics (ochre), Whakamaru Group (pink) and shallow units (after White et al., 2015). 'A' and 'B' indicate the general locations of the eastern and western borefields, respectively.

Today, physical models still have their place in the representation of geology and geological properties, at least because they provide a stable storage medium which is the antithesis, somewhat, of modern computer-based 3D model datasets.

Currently, 3D printing, which takes layers from 3D digital models and reproduces them in plastic, may prove to be a revolution in the physical modelling of geological systems. For example, a printer was used to represent eight geological layers in the Wairau Plain, Marlborough District (Figure 6). In this case, GNS Science used an Ultimaker 3 Extended 3D printer, with a print-layer height of 0.2 mm. The dimensions of the final model, printed in four blocks, was approximately 40 cm by 23 cm by 14 cm. Print time was approximately 200 hours for all layers.

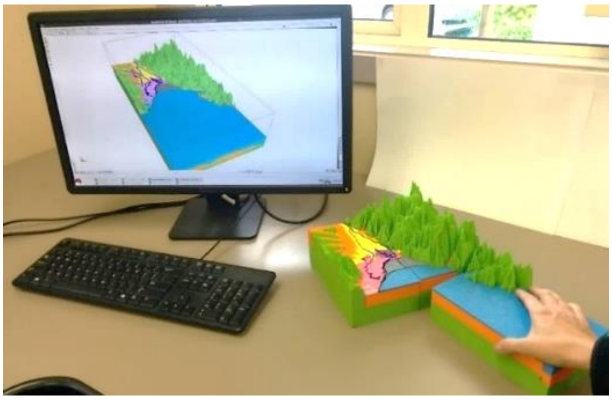

Figure 6. The 3D printed geological model of the Wairau Plain (right-hand side) and the companion 3D computer model (left-hand side). Note that printed-model unit colours were chosen to match the computer-model colours.

5. CONCLUSIONS

The Wairakei Geothermal Field physical model, built in the late 1950s or early 1960s, is unique because it is one of New Zealand's first, and the only extant, such model. Today, the physical model, constructed in wood, is an important historical record as it shows features of the Wairakei Geothermal Field before the commencement of geothermal power production. These features included geology, well logs, faults and temperature contours measured in drillholes located in the eastern and western borefields.

This paper summarised some characteristics of temperature contours (i.e., in the range 230°C to 255°C) recorded by the physical model. The eastern borefield area was typified by nearly-isothermal conditions which was consistent with vertically-upwards flow of hot geothermal fluid to surface geothermal features. Physical-model temperature contours in the western borefield area were probably impacted by two groundwater inflows to the Field, i.e., relatively hot geothermal fluid flowing in ignimbrite units and cold groundwater flowing in shallower layers.

The Wairakei Geothermal Field physical model demonstrates that timber is a stable storage medium for geological information. Physical models are now produced with 3D printers; we hope that the longevity of these plastic depictions of geology will prove to be the equal of their long-lived ancestor!

6. REFERENCES

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