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Low-temperature geothermal reserves in New Zealand

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ABSTRACT

Low temperature geothermal resources are ubiquitous throughout onshore New Zealand where heat energy can be harnessed directly from the rock or transported by aqueous solutions in thermal springs and abandoned underground mines and hydrocarbon wells. Inferred subsurface temperatures in low temperature thermal springs are up to 250 °C. However, even in regions deemed geothermally cold outside thermal spring areas, the solute geothermometry of aqueous solutions from abandoned mines and wells indicate the circulation at depth of fluids with median temperatures of 30–155 °C (range: 15–195 °C). An initial estimate of recoverable heat energy from aqueous solutions in low temperature geothermal resources is at least 870×10^3 MW h/a (3.1 PJ/a) with 94% derived from temperatures >20 °C. However this value is but a small fraction of heat energy that can be harnessed conductively from the rock.

1. Introduction

The earth is a massive generator of heat with an estimated global surface heat flux of 47 ± 2 TW (Davies and Davies, 2010). However, not all heat from the earth is a geothermal resource. By their very definition, a geothermal system can only occur where heat from the earth is technologically recoverable and extraction economically feasible. Physically, a geothermal system is a volume of rock where heat can be extracted by conduction or from fluids circulating in the rock or introduced into the system by way of drill holes. In the case of geothermal ground source heat pumps, heat is extracted directly from the ground or circulating ground water. As new methods and technology for heat extraction become available to geothermal field developers and consumers the temperature range for heat extraction from the rock or aqueous solutions has extended from <10 °C (Lund et al., 2010) to as high as >350 °C and from depths of about 6 to >3500 m. Because of ground source heat pumps any heat energy stored below about 6 m, or the depth at which ground temperatures remain constant through the seasons, is considered geothermal energy (Rybach and Sanner, 2000).

Geothermal development in New Zealand has been focussed mainly on power generation in two regions of Recent volcanism, the Taupo Volcanic Zone (TVZ; Region 3 in Fig. 1) and Ngawha in Northland (Region 9A in Fig. 1), where temperatures >300 °C were intersected by drilling. The two volcanic regions, together, have an installed capacity of 775 MWe (www.nzgeothermal.org.nz) as of 2014, with the TVZ producing only 15% of its potential (Harvey and White, 2012). Although comprising only 3% of the total area of onshore New Zealand, the TVZ provides nearly 99% of the total surface heat energy output from thermal springs (Reyes et al., 2010), producing at least $3.7 (\pm 0.4) \times 10^7$ MW h/a (133.2 PJ/a; Bibby et al., 1995). Ngawha, located about 550 km northwest of the TVZ, covers an area of 30–40 km^2 with surface thermal manifestations discharging mostly wet gas and contributing <0.05% to the total surface heat output. The remaining 1% heat output from thermal water surface discharges, at 3.1×10^5 MW h/a (1.1 PJ/a), are derived from more than 100 thermal spring systems (Reyes et al., 2010) outside the TVZ and Ngawha, in the North and South Islands, distributed in 17 tectono-geographic regions (Figs. 1 and 2).

Direct heat use in New Zealand is currently focussed in the TVZ, in terms of the total energy consumed at nearly 10 PJ/a (2.8×10^6 MW h/a; Harvey and White, 2012) and the wide variety of applications including space-conditioning using ground source heat pumps, domestic uses, bathing complexes, horticulture, beekeeping and prawn farming for the lower end temperature ranges (<50 °C) and involving industrial processes such as timber drying and paper production (Harvey and White, 2012) for higher temperatures. Cascade applications include prawn farming in Wairakei and horticulture in Mokai (Harvey and White, 2012). Outside the TVZ, thermal springs are mostly used for bathing, space-heating and domestic hot water use (Fig. 3). Installations of ground source heat pumps have spread beyond the TVZ e.g. in Christchurch, Wanaka, Alexandra, Invercargill and Canterbury including high country in the Rakaia Ranges (nextenergy.co.nz) in the South

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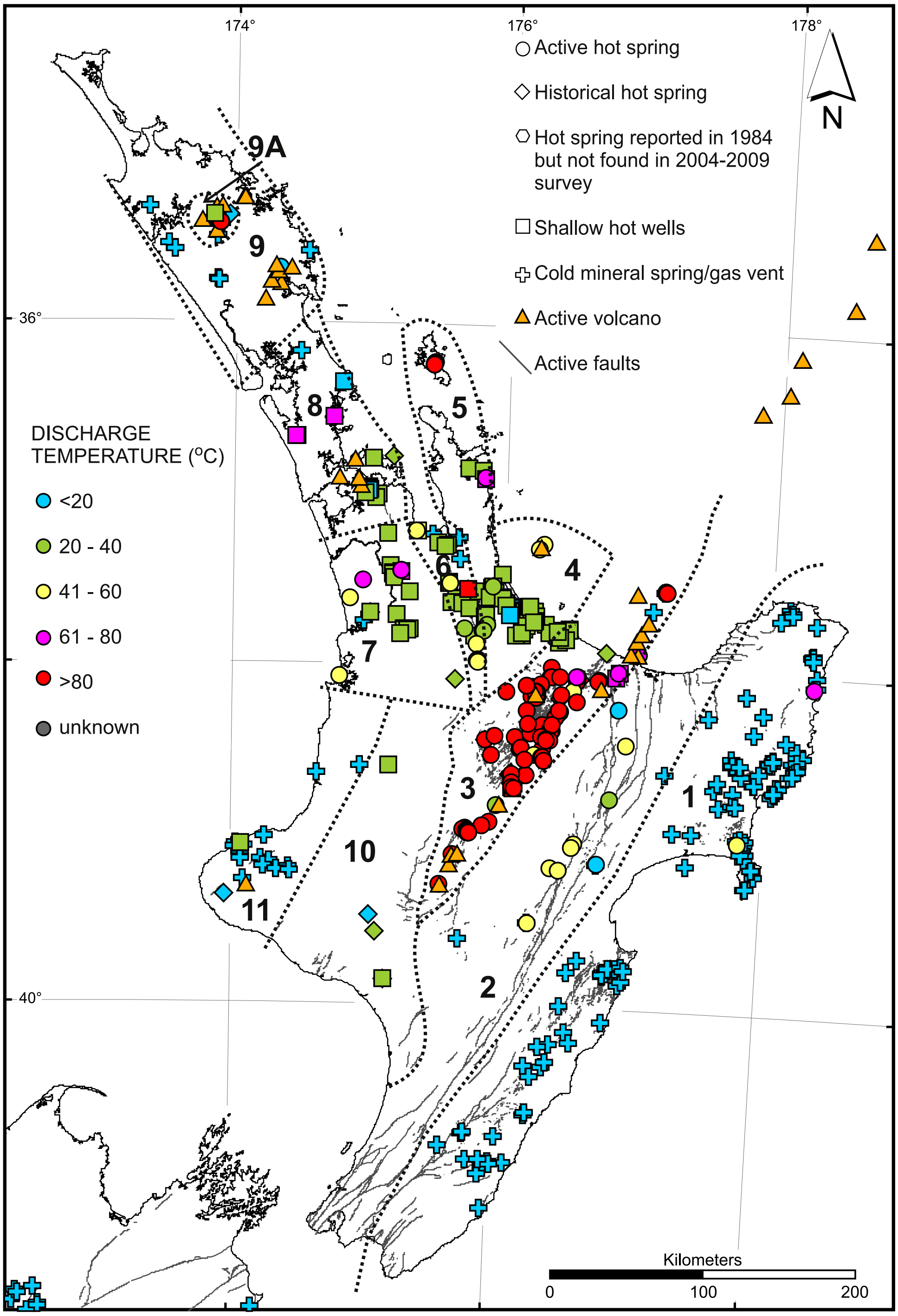

Fig. 1. Location map of thermal springs, shallow wells discharging warm aqueous solutions, cold mineral springs and gas vents in the North Island tectono-geographic regions including (1) Hikurangi Accretionary Prism (HAP), (2) North Island Axial Ranges (NIAR), (3) Taupo Volcanic Zone (TVZ), (4) Bay of Plenty (BOP), (5) Coromandel region including Great Barrier Island, (6) Hauraki Rift Zone (HRZ), (7) Western Waikato (WW), (8) Auckland (AKL), (9) Northland (NLD), (9A) Ngawha in Northland, (10) Whanganui-Taumarunui (WH) and (11) Taranaki (adapted from Reyes et al., 2010). Thermal springs are divided into active, historical (reported before 1984 but has since disappeared) and recently extinct (reported by Mongillo and Clelland (1984) but not found during the 2004–2009 survey (Reyes, unpublished notes). Discharge water temperatures from springs and shallow wells, range from <20 °C to >80 °C (up to 100 °C), as indicated by colours.

Island (Fig. 3). However, the use of ground source heat pumps in New Zealand is limited compared to Europe and the USA (www.nzgeothermal.org.nz).

The main focus of this study are low-temperature regions in New Zealand outside the TVZ and Ngawha, and seeks to (1) define the types and heat sources of geothermal resources, (2) evaluate geothermal resources outside known thermal spring systems using solute chemistry and estimated bottom hole well and mine temperatures, (3) estimate stored, accessible and recoverable heat energy and (4) compare the geothermal prospectivity within and outside thermal spring systems, based on accessible aqueous solutions.