U-Pb dating of zircon as an aid in interpretation of geothermal systems: a case study from the Kawerau Geothermal Field, New Zealand

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Exploration and development of geothermal resources for electrical power generation and direct heat use requires an understanding of the geology that hosts the geothermal system. Key to this understanding is being able to date and correlate marker horizons to link permeable formations, constrain displacement history of faults and time the presence of local heat sources.

The Kawerau Geothermal Field is the most northeasterly of high-temperature geothermal systems in the Taupo Volcanic Zone (TVZ, New Zealand), an active Quaternary arc locus of rhyolitic volcanism and thermal output. The reservoir rocks are a 1 km thick pile of lava, pyroclastic rocks and sediments, supplied with fluid circulating through faulted Mesozoic basement greywacke. Here, where correlation solely by petrographic and textural observations was ambiguous due to hydrothermal alteration, we show the value of U-Pb age information on interpreting geothermal systems. U-Pb age determinations on zircons from extensively altered lithologies provide estimates of crystallisation and eruption ages that allow depositional and faulting histories of rocks hosting the geothermal system to be reconstructed. These histories may be linked to evidence for episodic local magmatism beneath the field and to changes in regional tectonic stress patterns.

Prior to the 0.32 Ma Matahina ignimbrite (a regional marker plane), deposition of ignimbrites occurred in short-lived episodes around 1.45, 1.0, and 0.55-0.6 Ma, separated by thin sediment-dominated intervals which accumulated at average rates of 0.06 mm/yr. The ignimbrites represent marker horizons from other volcanic centres and do not reflect the presence of local magmatic heat sources. Net subsidence rates inferred from depths to these marker planes do not reflect the present-day situation. Modern rates of subsidence (2+/-1 mm/yr) associated with TVZ rifting processes can have been active for no more than 50,000 years in the area of the field, based on elevation differences of the Matahina ignimbrite top surface.

Bodies of coherent rhyolite (i.e., lava or intrusive material) occur at multiple intervals in the volcanic/sedimentary cover and basement greywacke. Age dating resolves these multiple bodies as either domes or intrusions: two petrographically contrasting magma types with associated tuffs were emplaced as domes and sills at 0.36+/-0.03 Ma, and a third type at 0.138+/-0.007 Ma as dikes, and domes exposed at surface. Heat sources beneath the field resulted from these local magma intrusions, together with that feeding the Holocene eruptive activity of Putauaki andesite/dacite volcano. Of these, the last is responsible for the thermal and alteration characteristics of the modern field. We infer that only at long-spaced intervals is there evidence of magma at shallow enough crustal levels beneath the field to generate vigorous hydrothermal activity (as at the present day); at other times no Kawerau geothermal system' existed.