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Investigation of tritium and noble gas isotopes in New Zealand geothermal fluids

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Improved geochemical techniques for monitoring and characterisation of subsurface geothermal reservoirs will support the sustainable development of low-carbon geothermal energy. Tritium (^{3}H) is a well-established tracer of groundwater residence time [1], yet our understanding of its behaviour in geothermal systems is limited to a handful of case studies [e.g. 2,3]. Similarly, whilst noble gases are used for conventional techniques such as $^{3}He/^{4}He$ ratios for identification of mantle gas, the use of their elemental ratios to investigate subsurface phase partitioning is underexplored [4].

We present measurements of noble gas isotopes and high-sensitivity tritium analyses in a suite of 27 geothermal fluid samples taken from three New Zealand geothermal fields: Ngā Tamariki, Kawerau and Rotokawa. Samples include production well brines, reinjection streams and hot springs. Tritium results differ markedly between the three fields. At Rotokawa, all sampled production wells are tritium-free (<0.02 TU), whilst at Kawerau all production wells contain measurable tritium (0.031 – 0.085 TU). At Ngā Tamariki, a subset of the production wells contain measurable tritium, whilst others are tritium-free. Reinjection streams of steam condensate from the flash plants at Kawerau and Rotokawa contain measurable tritium, likely derived from direct-contact condensers.

These data demonstrate that live tritium can be introduced into geothermal reservoirs both through brine reinjection, and by ingression of young groundwater. As such, tritium has significant potential as a monitoring tool, but interpretations must be made in the context of reservoir-specific geological and structural controls. Helium isotopes ($^{3}He/^{4}He$) range from 3.94 to 7.50 R_A, with Kawerau samples consistently lower than Ngā Tamariki or Rotokawa. Neon and argon isotope ratios are predominantly atmospheric, with a maximum observed $^{40}Ar/^{36}Ar$ of 306.1 ± 2.7. Distinct atmospheric noble gas ratios ($^{20}Ne/^{36}Ar$, $^{84}Kr/^{36}Ar$) between the three fields are attributed to solubility-dependent partitioning between steam and water in the subsurface.

[1] Morgenstern, U. *et al. Hydrology and Earth System Sciences* **14**, 2289–2301 (2010).

[2] Shevenell, L. & Goff, F. *Journal of Volcanology and Geothermal Research* **67**, 187–205 (1995).

[3] Pinti, D. L. *et al. Chemical Geology* **584**, 120539 (2021).

[4] Byrne, D. J. *et al. Earth and Planetary Science Letters* **560**, 116805 (2021).