STABLE ISOTOPES AS SIGNPOSTS OF FLUID THROUGHPUT IN ROTOKAWA AND OTHER GEOTHERMAL FIELDS, AND THE DIFFICULTY OF IDENTIFYING MAGMATIC FINGERPRINTS

P. BLATTNER[1], S. WOLDEMICHAEL[2] AND P.R.L. BROWNE[2]

[1]Institute of Geological and Nuclear Sciences Limited, Lower Hutt, NZ

[2]Geology Department and Geothermal Institute, The University of Auckland, NZ

SUMMARY - We present a background for wafer-rock interaction generally, and new data on the Rotokawa geothermal field. The oxygen isotope shifts of total rock samples allow the deduction of past flowpaths and total fluid throughput. Estimates of any input of true exsolved magmatic water am difficult as the lithosphere *can* act as an effective isotopic screen.

REAL FLOW PATHS

In fluid-rock interaction, zero dimensional "box", or test tube, models require caution. Test tube chemistry, supported by equilibrium thermodynamics is an idealised, a-historical, and *intensive* (therefore space-less) point of view of almost scholastic presumption. In contrast, when a real fluid moves through a variety of porous rock types, it clocks up a history of innumerable consecutive interactions, which cause its own and the solid rocks' compositions to mutually adapt, creating spatial *patterns* of composition. For stable isotopes the systematics of these patterns has been outlined by Blather and Lassey (1989). For chemical components they are far more difficult to determine.

The oxygen and hydrogen isotope shifts of geothermal fluids (Craig, 1963) *can* be interpreted in different ways, as an effect of (1) boiling, and/or (2) the mixing of different fluids, and/or (3) of fluid-rock interaction. For boiling, the relative magnitudes of the hydrogen and oxygen isotope shifts depend on temperature and temperature history, for mixing on the proportions. In fluid-rock interaction, alone of the three choices, shifts in

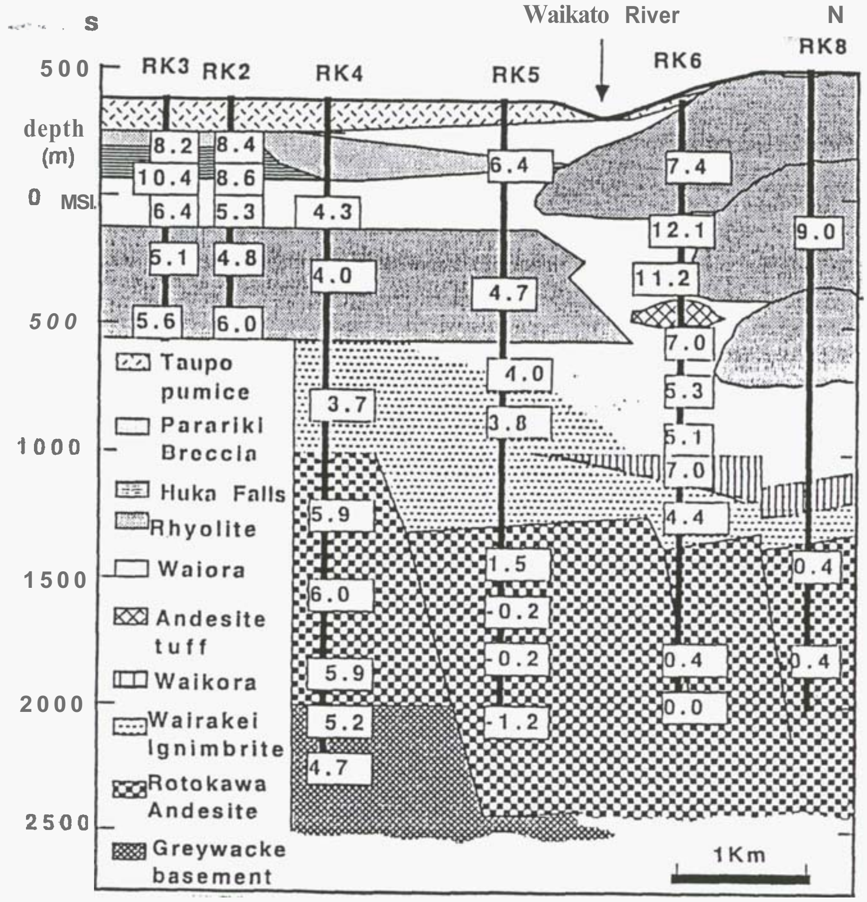

Fig.1. $\delta^{18}O$ values, in permille, of Rotokawa reservoir rocks as distributed in the reservoir space. Numbers less than c. 7 permille $\delta^{18}O$ (c.10‰ in the case of greywacke basement) *can* be assumed to have been shifted down by interacting meteoric waters. Maximum recorded throughput clearly occurred near the bottom of wells RK 5 and RK 6. From there upflow was and is mainly in the direction of wells RK 2 and RK 3 (Woldemichael 1993).

the fluids will be accompanied by quantitatively equivalent shifts of opposite sign in the rock. General analytic (rather than numerical) models are possible in the case of isotopes, and show in detail what can happen when the requirements of mass balance are thus spread out along one-dimensional trajectories, or flow lines, in the crust. Both fluids and the solid minerals of the rock *carry memories* - not necessarily of their original sources, if the isotopic capacity has run out, but of flow patterns and interaction histories.

APPLICATION

Of the three mechanisms above, we are looking at the importance of fluid-rock interaction from the point of view of new data on the Rotokawa and some other geothermal fields. In Rotokawa, as generally in the North Island of New Zealand, original rocks have $\delta^{18}O$ values higher than c 7 permille (8-12 permille in the case of greywackes). As seen in Fig.1, the negative oxygen isotope shifts have therefore exceeded about 7 permille. The uneven distribution of these shifts maps precisely the uneven permeability of the rock reservoir at Rotokawa, parts of which resemble fissured blocks.

The isotope shifts provide a quantitative measure of the total throughputs of geothermal water for a given geothermal field. The potential admixture of *magmatic water* to a geothermal output (Craig 1963, Giggenbach 1992) has to be gauged against a backdrop of variable and probably increasing meteoric throughput. In incipient geothermal systems, which may include many of those in rapidly evolving volcanic belts, output waters will always tend to isotopically resemble "magmatic" waters - because they have equilibrated with magmatic or magmatic-derived, rocks (Blattner 1993) rather than being magmatic fluids in the sense of having *ascended from depth* with a magma. Only if a true magmatic fluid has travelled along the same flow path sufficiently long term to impose and retain its isotopic identity (picked up below or within a mantle wedge?), may its contribution to total geothermal output be assessed in terms of mixing with meteoric water, of equally well established flow lines and isotopic identity.

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