Fluid Redistribution Coupled to Deformation
Around the NZ Plate Boundary

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Crustal-scale fluid flow is a frontier area in Earth Science, critically relevant to exploration for, and future exploitation of, energy and mineral resources (oil, gas, geothermal power, hydrothermal mineralisation)[1,2]. The New Zealand plate boundary (NZPB) can be viewed as a geochemical processing system where the interplay of tectonic and magmatic processes promotes fluid redistribution between the atmosphere, continental and oceanic rock assemblages, the ocean water mass, and the deep Earth[3,4].

The diverse tectonics of the boundary, comprising opposite-facing subduction zones along the Hikurangi and Fiordland Margins linked by an imperfect transform fault system, gives rise to an array of sites where predominantly aqueous and other (hydrocarbon, CO_2, etc.) fluids are being actively redistributed within the crust. These include: (1) active hydrothermal circulation coupled to magmatism and extensional normal faulting in the Taupo Volcanic Zone (TVZ) (and its northeastward continuation along the Lau-Havre Trough); (ii) fluid loss from sediment compaction and compressional 'squeegee' deformation accompanying thrust/reverse faulting along the Hikurangi and Fiordland subduction interfaces; (iii) areas of ongoing compressional inversion involving steep reverse faulting associated with hydrocarbon migration in the Taranaki Basin and in the northwestern and southern South Island; (iv) fluid redistribution around major strike-slip faults, focused at structural irregularities and coupled to stress and permeability cycling, and (v) topography-driven flow in the uplifted Southern Alps and other mountain ranges flanking the linking transform fault system, and around major volcanic edifices.

Fluid redistribution is variously driven by topographic relief and precipitation, upwelling mantle and magmatic intrusion leading to convective circulation of hydrothermal fluids, compaction, deformation, and metamorphic dehydration of thick sedimentary sequences, changes in the regional stress state, and physicochemical processes (magmatic gas expansion, P-T changes, fluid mixing)[3,4]. While flow in near-surface systems typically occurs under near-hydrostatic fluid pressure (the 'normal state'), fluids at depth may be structurally compartmentalised and overpressured well above hydrostatic values. Flow systems are influenced by structural permeability and modulated by stress cycling which accompanies intermittent rupturing on faults, coupled to changes in fault-fracture permeability. For example, extensive hydrological perturbation accompanied the 2010 M_w7.1 Darfield, Canterbury, earthquake[5]. Though the physical conditions of seismogenesis (differential stress, confining pressure, pore-fluid pressure, temperature, strain-rate) likely vary significantly[6], fluid involvement in earthquake rupturing seems likely across the range of tectonic settings. The degree of fluid-overpressuring above hydrostatic also exerts a first-order control on crustal rheological and strength profiles.

The NZPB thus provides a world-class natural laboratory where dynamic flow systems are accessible to investigation by geological, geochemical and geophysical techniques, both onshore and offshore, and by numerical modelling. Questions to be addressed for each of the tectonic domains include the fluid sources, the rates of flow, the degree of water–rock interaction along flow paths, the influence of structural permeability and fluctuating stress regimes on fluid redistribution and phase separation, and the total fluid budget. Understanding this system will require a combination of geological, geophysical, and geochemical analyses coupled to numerical modelling. Such studies may also contribute significant insights into factors affecting crustal rheology and the physical conditions of seismogenesis in different tectonic settings.

References:

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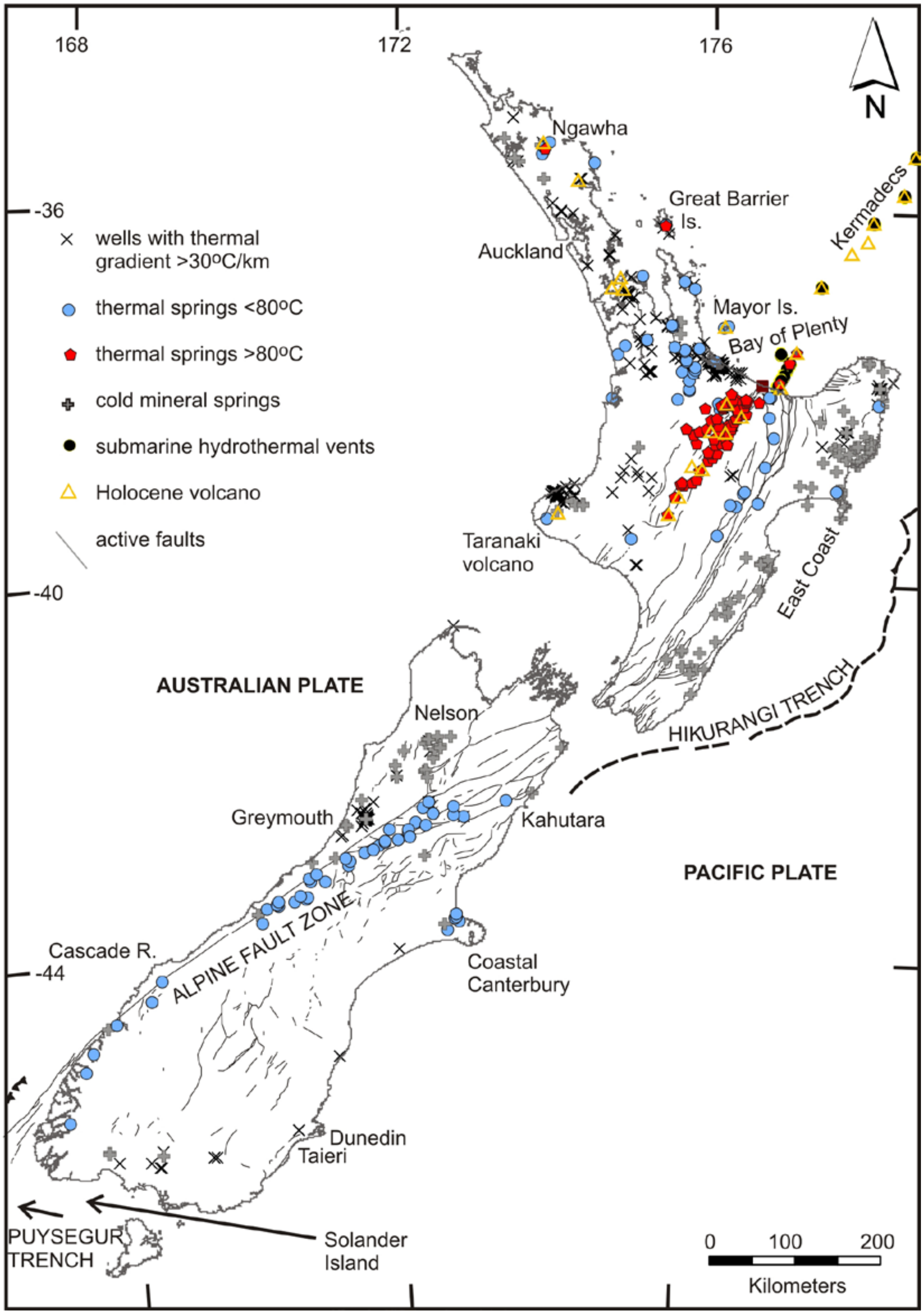

Figure 1. Location map of thermal (> 4 °C above annual ambient air temperatures) and cold mineral springs of New Zealand in relation to principal onshore faults[4].