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Crustal-scale heat-flow evolution and heterogeneity at a young convergent margin: Taranaki Basin, New Zealand

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The Taranaki Basin lies in the west of New Zealand's North Island, only 400 km away from the convergent Australian-Pacific plate margin. It is an exceptional example of a basin that documents the evolution from a passive to a convergent margin. In it's less than 100 million year history, the basin has developed from a rift margin to a hybrid intra-arc/back-arc basin/fold-thrust belt in response to propagation of Pacific plate subduction beneath the Australian plate in the region, starting 25 Myrs ago. Yet, the Taranaki Basin is surprisingly cold, given it's proximity to the subduction front: the surface heat-flow in Central North Island decreases from a staggering 800 mW/m2 at the volcanic arc to an average of 60 mW/m2 in the Taranaki Basin. These heat flow values are extreme if compared to established margins, which raises the question of how crustal temperature patterns evolve during the transition from a passive to an active margin. To answer this question, a 3D crustal scale forward model was developed, using the industry-standard basin-modelling software Petromod.

The Taranaki Basin has been well studied during decades of petroleum exploration and therefore offers unique possibilities to investigate the thermal evolution of the crust and sedimentary cover in the proximity of an evolving subduction zone. The composition of mid and lower crustal rocks of the Taranaki Basin can be correlated with exhumed equivalents elsewhere in New Zealand. On average, 40% of the heat is generated within the crust, and so, the crustal composition is an important control, not only on thermal properties, but also on content of heat producing radioactive elements. In the case of the Taranaki Basin, the heat generation potential between granitic basement, related to the Mesozoic Gondwana margin in the west, and mafic and metasedimentary rocks in the east varies by a factor of up to three. The challenge of this study therefore was to differentiate between the effects of variability in heat generation due to crustal heterogeneity, and changes in heat advection and effects of tectono-sedimentary processes related to the formation of a subduction zone. The results of the model indicate that surface heat flow in the Taranaki Basin varies by as much as 20 mW/m2 due to the variability in crustal heat generation. Other individual factors such as change in mantle heat advection, tectonic subsidence, uplift and crustal thickening, and related sedimentary processes, only result in a variability of up to 10 mW/m2. The model further suggests that increased heating of the upper crust due to additional mantle heat advection related to the onset of subduction is still an ongoing process. Combined with low heat generation potential of parts of the crust and a cooling effect of crustal thickening, the lag in the additional heat transfer from the mantle explains why the surface heat-flow in the Taranaki Basin is 10-20 mW/m2 lower than in more typical back-arc areas around other Pacific plate margins.