Linking fluid chemistry to mechanics and geophysical structure along the Hikurangi Margin

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GPS studies of elastic strain accumulation in the North Island show that the Hikurangi megathrust has a sharp along-strike depth transition from a shallow (<15 km) to deep (~35 km) downdip termination of interseismic locking from north to south [e.g., *Wallace et al., 2004; 2009*]. This transition accompanies other along-strike changes, including the depth of slow-slip events (SSEs) [see summary in *Wallace et al., 2009*], and a significant change in fluid residence times and mantle input from north to south [*Reyes et al., 2010; Figure 1a*]. The strongly locked southern Hikurangi margin is adjacent to a rapidly growing, gently sloping accretionary wedge, in comparison to the narrow, steep wedge in the north [e.g., *Barker et al., 2009; Figure 1b-c*].

To understand how these changes relate to each other, observations at different timescales from geophysics, geochemistry, and geology need to be integrated into models of subduction dynamics and fluid flow [*Figure 1d*]. There are several projects currently underway that attempt this type of model, including a Marsden that has been studying the effect of high fluid pressures around a seamount on frictional behaviour of the interface [*Williams et al., in prep*.] and a newly-funded 3-year Marsden grant using coupled fluid-mechanical models to investigate the cause of abrupt changes in locking depth along the Hikurangi margin.

A critical input for such models is an estimate of fluid budgets, which requires accurate estimates of fluid sources within subducting sediment and crust [see *Pecher et al., 2010*]. Up to 30 new samples of fluid chemistry from onshore springs and seeps are planned as part of one of the Marsden projects mentioned above. Such samples provide information on fluid residence times in the crust and fluid sources, which can be used to constrain fluid/mechanical models. There are also plans to measure changes in fluid chemistry and fluid pressure on slow-slip timescales as part of the proposed IODP riserless drilling project [*Saffer et al., 2011*]. Finally, plans are underway for the German RV SONNE and the MeBo seafloor drill to install flowmeters and osmo-samplers along the Hikurangi margin, and sample key locations (landslide scars, mud volcanoes and seeps) offshore. This will provide information on in situ flow rates and hence some idea about permeability, as well as a long-term record of fluid geochemical variations with time. When tied to proxies that work as geothermometers (e.g. B and its isotopes, which has been partly incorporated with hydrogeological models of accretionary wedges [e.g. *Saffer & Kopf, 2006*]), we can estimate the depth of fluid source origin and how rapidly these fluids migrate upward.

A key question when linking fluid-flow to mechanical models is: which fluid pressure variations along the Hikurangi margin are compatible with observed changes in fluid chemistry, wedge morphology, and locking depth along-strike? For example, there are two competing hypotheses to explain the along-strike locking depth change, which have clear and opposite predictions for fluid pressure variations: (1) permeability and upper plate tectonic stresses modulate the transition from locked to stable sliding by changing the depth at which brittle give way to viscous processes along the interface; and/or (2) high fluid pressures caused by subduction of fluid-rich sediments (possibly mediated by changes in interface roughness and/or rock properties [e.g., *Bell et al., 2010*]) reduce effective normal stress, promoting stable frictional slip. Hypothesis (1) is consistent with observed along-strike variations in fluid residence times and wedge morphology, but predicts less fluid overpressure to the north, which contradicts other geophysical observations [*e.g., Heise et al., 2012*].

As well as fluid budgets, the present-day geophysical structure [e.g., the recently acquired Sahke transect in the south; *Henrys et al., submitted*], thermal structure [e.g., *Harris et al., this volume*] and the thickness and mechanical properties of subducting sediments provide important constraints to model long-term wedge evolution along the Hikurangi Margin [e.g., *Underwood et al., this volume*]. Models of 2D and 3D wedge evolution in the past few million years can be constrained by decompacting and restoring tied seismic sections to create a time series of geological cross-sections. Key questions include: Which variations in fluid pressure along-strike are consistent with long-term wedge morphology and fluid chemistry? Is fluid pressure an important parameter to control wedge stability through time? Can sufficiently variable fluid pressure within and above the interface be created and sustained over long enough time periods to explain changes in wedge taper along-strike? On shorter time scales, questions to be addressed are: Are the fluid pressure transients or changes in fluid geochemical composition a precursor to seismic events? Does permeability change measurably during seismic events, and how do these changes evolve over time?

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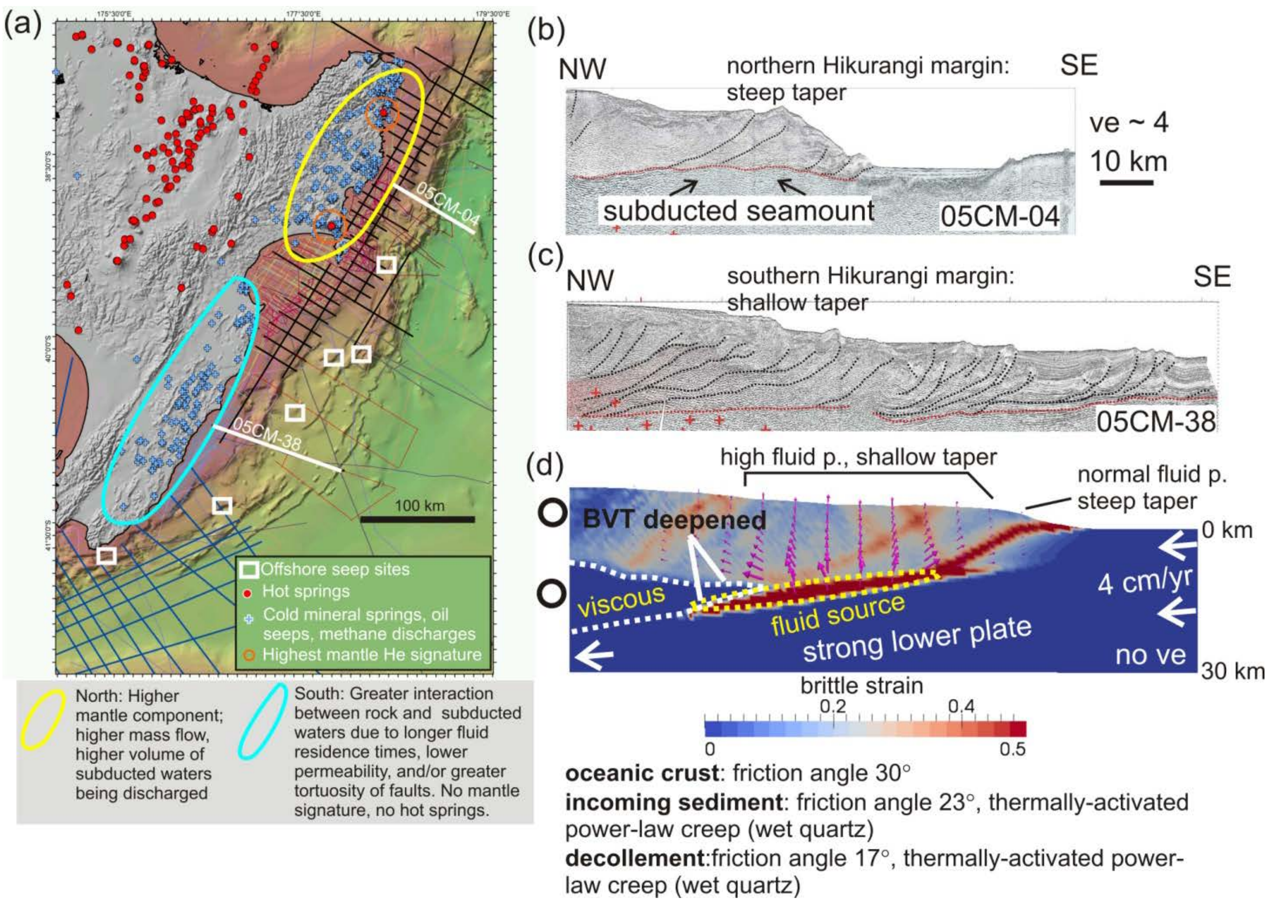

Figure 1.