# Sill Emplacement and Forced Fold Growth in Sedimentary Basins

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## ABSTRACT

Magma plumbing systems in petroliferous sedimentary basins worldwide are typically dominated by interconnected sills and inclined sheets (i.e. a sill-complex) that facilitate significant vertical (up to 12 km) and lateral (10s–1000s km) magma transport (Magee et al., 2016). Seismic reflection data, particularly 3D surveys, have revolutionized our understanding of these sill-complexes. For example, sill-complex emplacement has been shown to be strongly influenced by pre-existing basin structure and host rock lithology (e.g., Jackson et al., 2013; Schofield et al., 2015). Deciphering how the host rock deforms and accommodates the intruded magma volume is particularly important from a hydrocarbon exploration perspective because: (1) elastic folding of the overburden and free surface above intruding shallow-level (< 2 km depth) sills can produce forced folds that may result in the formation of structural (i.e. four-way dip closures) and stratigraphic (i.e. pinchout) traps (Smallwood and Maresh, 2002); (2) intrusion-induced faulting and fracturing increases local permeability, potentially breaching forced fold traps; and (3) inelastic deformation processes involving porosity reduction (e.g., compaction and fluidization) can inhibit hydrocarbon migration and reduce reservoir quality (Schofield et al., 2015). Igneous intrusions can also impact source rock maturity, and may act as impermeable barriers or permeable reservoirs/conduits to fluid or gas flow (e.g. Rodriguez Monreal et al., 2009). To assess whether magmatic products have a positive or detrimental effect on petroleum systems it is critical to not only elucidate magma emplacement mechanics, but also to determine the timing of magmatism relative to hydrocarbon generation and migration. Many sedimentary basins offshore New Zealand represent frontier exploration areas containing poorly documented igneous systems. The potential impact of magma plumbing systems and ancient volcanic activity on subsequent petroleum system development thus remains unknown, increasing exploration risk. Here, we analyse a magma plumbing system imaged in borehole-constrained 3D seismic reflection data from the Canterbury Basin, offshore SE New Zealand. Basin formation occurred in response to rifting between New Zealand, Antarctica, and Australia in the Late Albian-to-Early Campanian (Fulthorpe et al., 1996). The basement corresponds to the Torlesse Supergroup, a series of Permian-to- Early Cretaceous greywacke and argillite meta-sedimentary rocks (Uruski, 2010). Graben and half-graben formed during this phase of rifting were infilled by fluvial and paralic sediments, including the coals that form the main source rock in the region (e.g., the Matakea Group; Killops et al., 1997; Uruski, 2010). The onset of passive subsidence and marine transgression in the Late Cretaceous resulted in the post-rift deposition of marine mudstones, siltstones, and limestones belonging to the Onekakara Group (Carter, 1988); some Paleogene shales represent potential source rocks (Killops et al., 1997). Maximum transgression at ~29 Ma is marked in the Canterbury Basin by a regional unconformity, which has previously been described as the Marshall Paraconformity (Carter, 1988; Fulthorpe et al., 1996). The Kekenodon Group overlies this unconformity and consists of shallow-marine sandstones and limestones deposited following a marine regression induced by uplift along the Alpine Fault (Carter, 1988; Lu et al., 2005). Continued uplift and an increase in the supply of terrigenous silt and sand resulted in the eastward progradation of continental shelf and slope deposits belonging to the Early Miocene to Recent Otakou Group (Lu et al., 2005). Hydrocarbon generation, migration, and accumulation in the Canterbury Basin likely began in the ~Mid-Miocene when Mid- to LateCretaceous coals were buried to sufficient depths (Haskell and

Wylie, 1998). Most plays rely on stratigraphic traps within Upper Cretaceous sandstone reservoirs. Eocene sandstone reservoirs within Miocene fault- and fold-related structural traps also form viable prospects.