[PS]Architecture of Buried Volcanoes as a Factor in Petroleum Systems Analysis: Cases from New Zealand Basins*

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Abstract

Petroleum systems analysis needs to account for coincident volcanism in many diverse situations around the world. New Zealand's mainly offshore sedimentary basins, with extensive publicly available seismic coverage and well data, contain numerous and widespread volcanic edifices and complexes - Miocene and younger arc related in the northwest (including the productive Taranaki Basin), and more widely, a late Cretaceous and younger intraplate basaltic suite. Volcanism introduces complexity to all aspects of petroleum systems analysis. Emplacement of magma beneath and/or within a sedimentary basin frequently causes domal, stratigraphic and paleogeomorphic traps, affects source rock maturation and hydrocarbon migration, and may either degrade or enhance reservoir quality, and give rise to lateral permeability barriers. Seismic interpretation of buried volcanic edifices within Taranaki and Canterbury basins reveals their architecture in terms of pre-, syn- and post-magmatic stages, and an assemblage of elements (geobodies) which can be ascribed petrophysical properties from an extensive analog data set. Where hydrocarbon maturation, expulsion and migration from pre-magmatic source formations results from post-magmatic burial, buried volcanic edifices, which are generally associated with structural doming, are important elements for migration and entrapment modelling. By mapping the fundamental architectural elements of buried volcanoes, the effects of their emplacement on coincident petroleum systems can be predicted. Detailed analog model inputs have been derived from 3D and 2D seismic data sets calibrated by exploration well data and further informed by outcrop analogs.
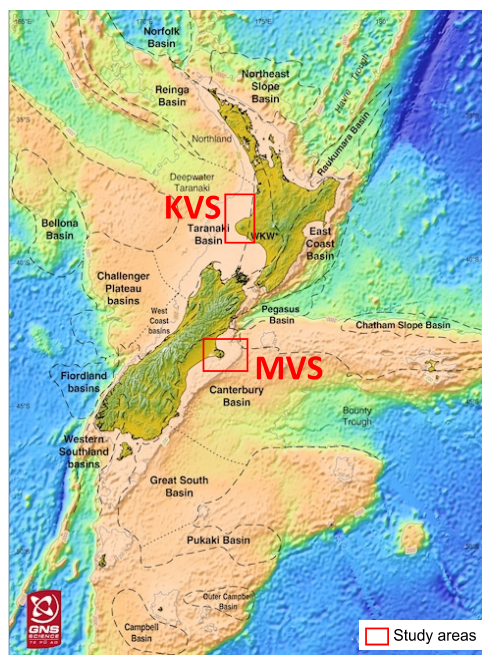
ARCHITECTURE OF BURIED VOLCANOES AS A FACTOR IN PETROLEUM SYSTEMS ANALYSIS: CASES FROM NEW ZEALAND BASINS

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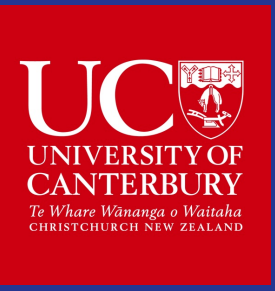
INTRODUCTION

This poster depicts seismic images from a buried arc andesitic volcano (Kora Volcanic System, KVS) and a monogenetic basaltic submarine volcanic field (Maahunui Volcanic System MVS) in Taranaki and Canterbury basins. Proven petroleum systems co-exist with volcanic suites in both basins. In considering potential impacts of intra-basinal volcanism on petroleum systems, several factors are significant:
(1) timing aspects
(2) structural aspects
(3) lithological-petrophysical aspects
(4) thermal and fluid dynamic aspects.

METHODS
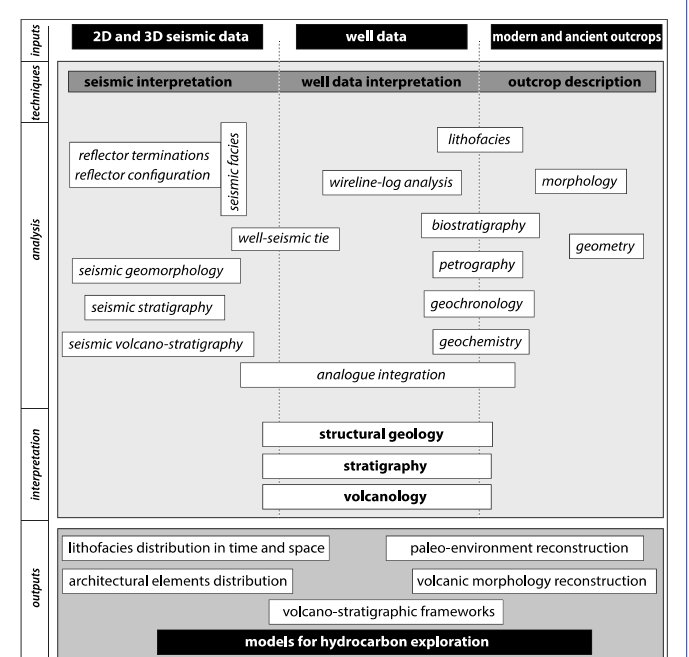
CONCLUSIONS
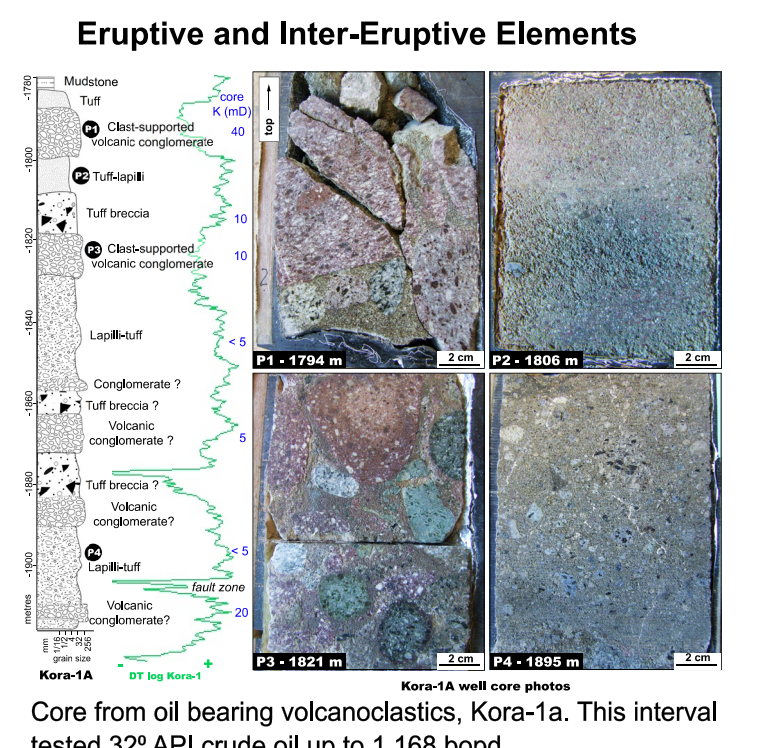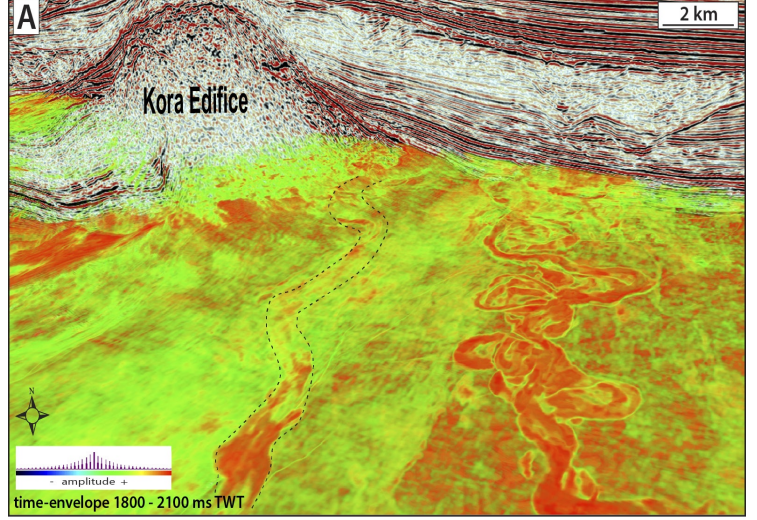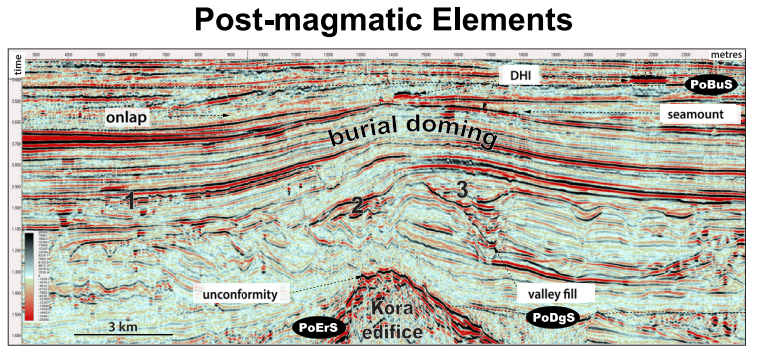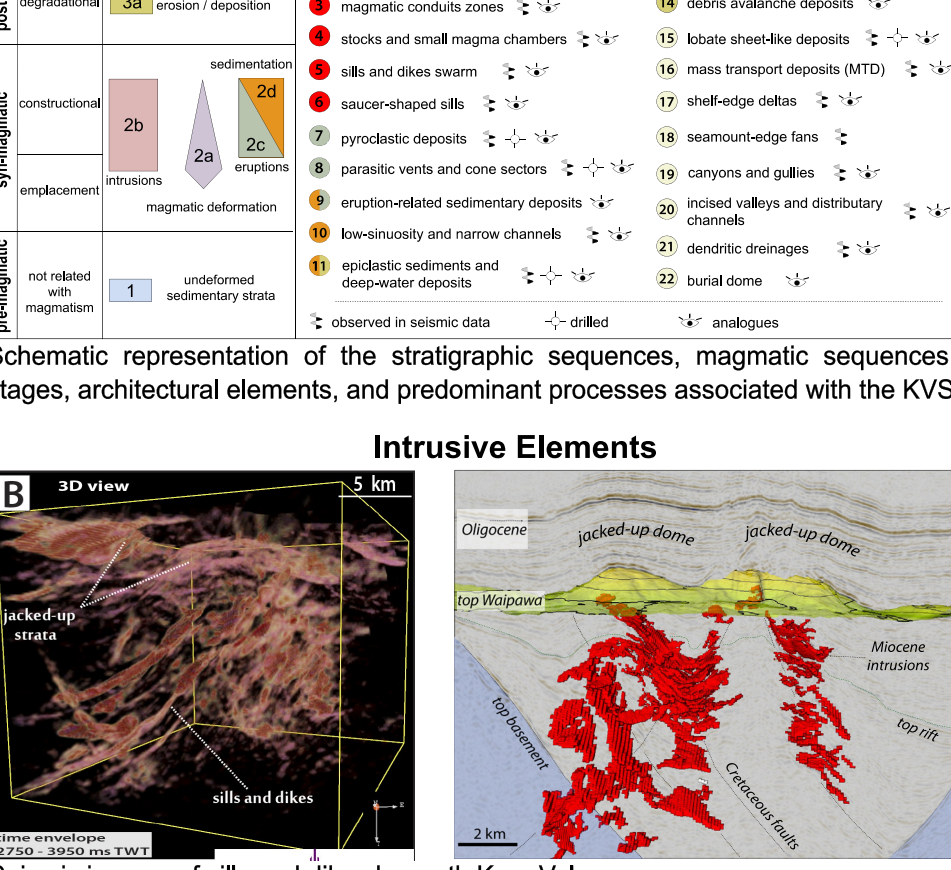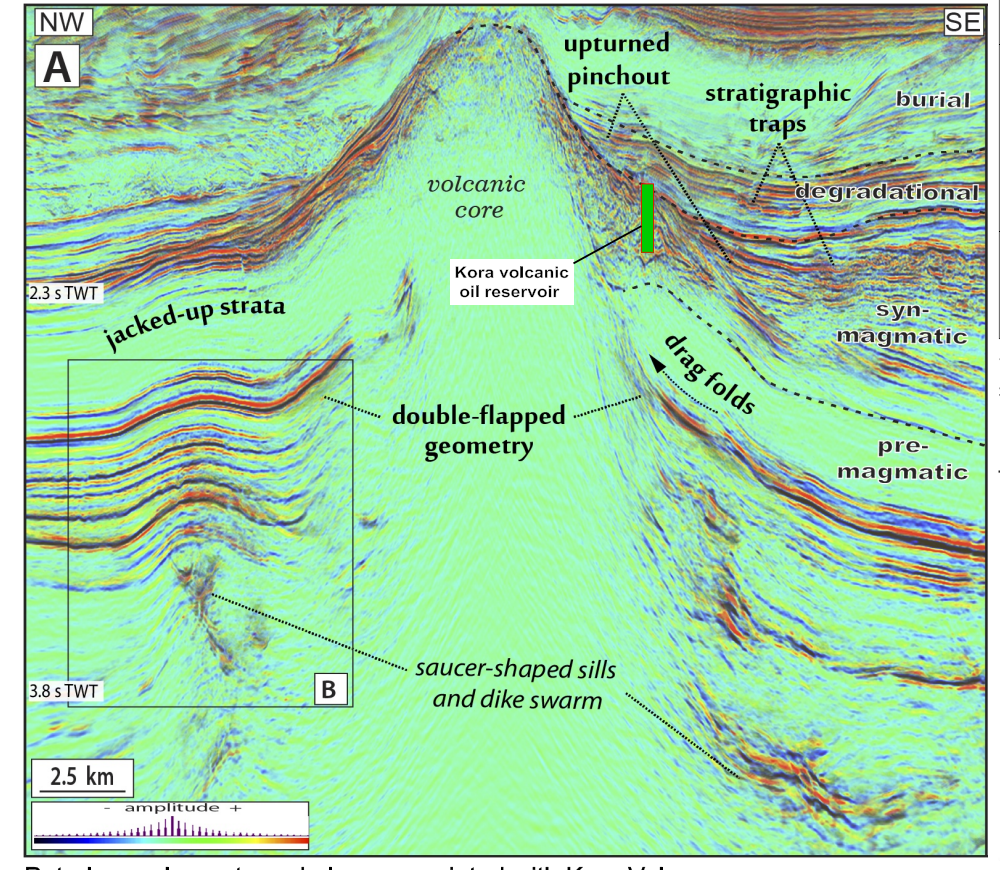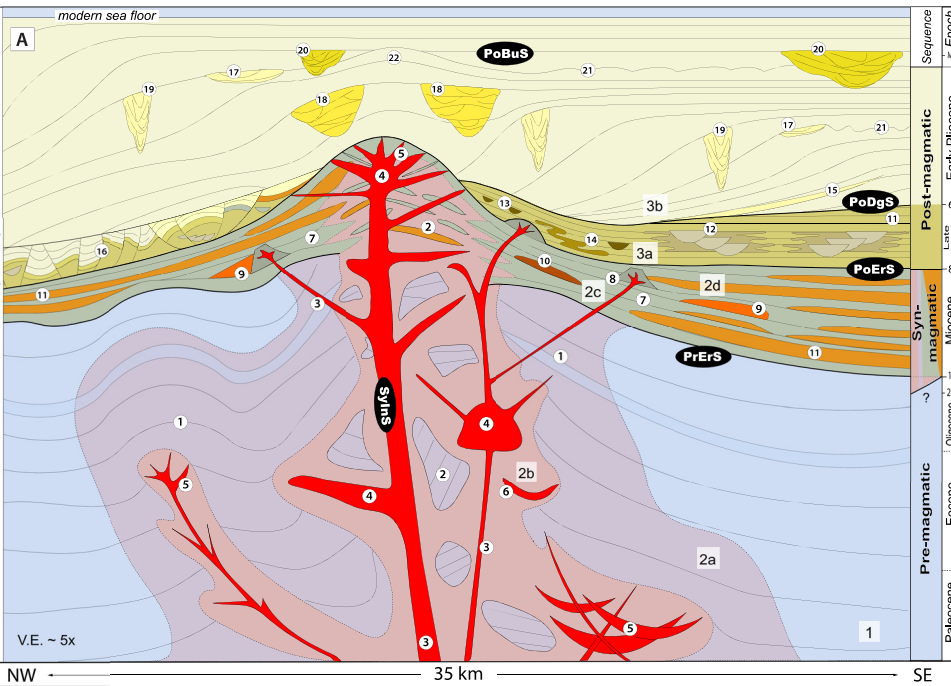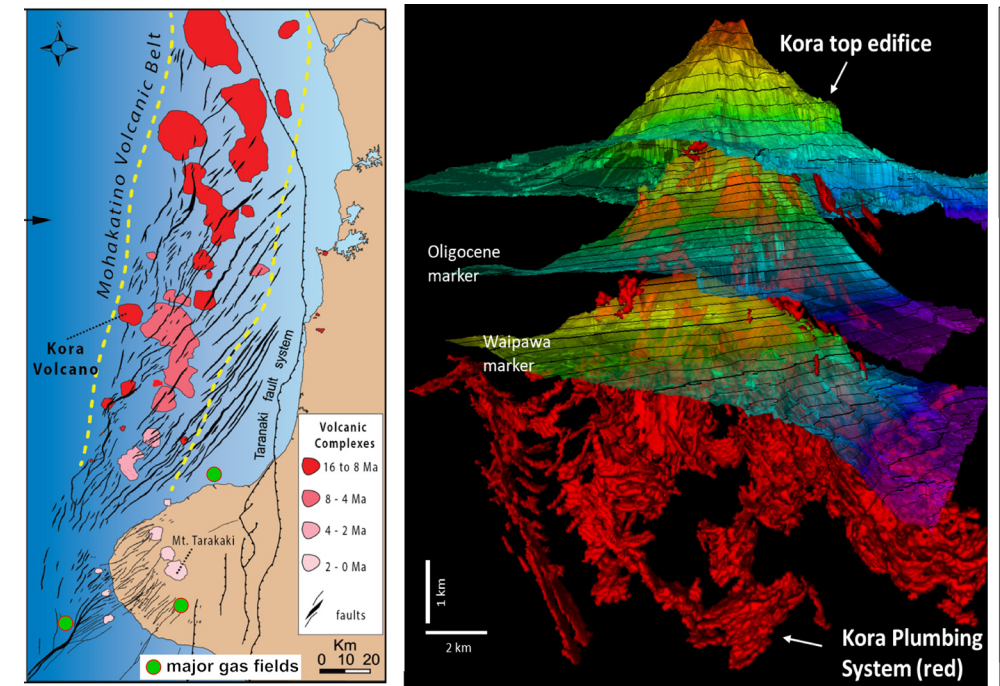
Timing aspects: In each of our cases, the intra-basinal volcanic episode is late Miocene – younger than the major source and reservoir bearing formations in the host basins. In Taranaki, hydrocarbon maturation, expulsion and migration results from post-eruptive burial. In Canterbury, the MVS is on the basin flank, somewhat remote from mature source rocks in late Cretaceous rift fill.

Structural aspects: Pre-eruptive strata in both of our cases were folded into large domal structures as a precursor to the volcanic episodes. The syn-eruptive geometry is highly complex but can be interpreted readily in 3D seismic with reference to volcanological knowledge and analogues. For example, large saucer sills and intrusion swarms can form additional 4-way closures.

Lithological and Petrophysical aspects: Intrusions and deformation associated with magma emplacement can modify rock properties, for example fracturing reservoirs or lateral seals. High-quality carbonate reservoirs may often be localised over shoals arising from differential compaction around buried volcanic edifices. Limited well data can be complemented with analogue data (including from outcropping volcanic edifices) to populate detailed static models for volcanoes buried within sedimentary basins as a robust basis for dynamic basin modelling. This is the current and future research direction.

Thermal and fluid dynamic aspects: By interpreting volcanic-related systems within the pre-, syn- and post-eruptive framework, impacts of the volcanism on the associated petroleum system can be evaluated objectively. A vast range of plays, including potentially large and prolific accumulations, can form in association with buried volcanic systems. When the architecture of the whole system has been established through the integration of available data and insights from analogues, the scope for potential traps, reservoirs, seals and hydrocarbon charge can be evaluated.

Kora Volcanic System - Taranaki Basin

Geobody mapping of the Kora volcano plumbing system from a 3D seismic reflection dataset.

Petroleum elements and plays associated with Kora Volcano.

Schematic representation of the stratigraphic sequences, magmatic sequences, stages, architectural elements, and predominant processes associated with the KVS.

Post-magmatic Elements

Seismic image of post eruptive deep-water channels and fans onlapping Kora edifice.

Eruptive and Inter-Eruptive Elements

Core from oil bearing volcaniclastics, Kora-1a. This interval tested 32º API crude oil up to 1,168 bopd.

Intrusive Elements

Seismic images of sills and dikes beneath Kora Volcano.

Maahunui Volcanic System - Canterbury Basin

Schematic representation of the stratigraphic sequences, magmatic sequences, stages, architectural elements, and predominant processes associated with the MVS.

BURIED VOLCANIC FIELD PETROLEUM PLAYS

Schematic representation of the possible petroleum plays associated with buried monogenetic volcanic systems, based on the observation of the MVS architectural elements. Distinctive sets of architectural elements can create prospective plays according to the magmatic stages of emplacement, construction, degradation, and burial of the volcanoes.

References
Bischoff, A. P., A. Nicol, M. Beggs., 2017, Stratigraphy of Architectural Elements in a Buried Volcanic System and Implications for Hydrocarbon Exploration: Interpretation, https://doi.org/10.1190/INT-2016-0201.1
Bischoff, A. P., A. Nicol, J. Cole, D. Gravley, 2019, Stratigraphy of Architectural Elements of a Buried Monogenetic Volcanic System and Implications for Geoenergy Exploration: Eartharxiv preprint, doi.org/10.31223/osf.io/h9zuq