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# Developing a Rock Physics Template for Improved Seismic Mapping of New Zealand Coaly Source Rocks

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## Introduction

Coal and coaly mudstones are considered the main source rocks of the petroleum systems in New Zealand. Our ability to predict their nature in the subsurface from seismic mapping is constrained by a lack of calibration of geophysical attributes (e.g. acoustic impedance and seismic amplitudes) to the physical properties of these rocks. Few studies have evaluated the relationships between geophysical properties (e.g., P- and S- wave velocities) and coaly source rock properties (e.g., TOC, rank, and organic constituents). New Zealand presents a unique opportunity to refine this link and apply the results towards future exploration.

*Figure 1. Map of the key coal producing regions of New Zealand. Coal ranks range from lignites (low rank) to anthracites (high rank) across the country.*

The New Zealand Coal Band spans both the North and South Islands and hosts a continuum of coal ranks from low-grade lignites to higher ranking anthracites (Figure 1). We plan to analyse a suite of coaly rock samples from boreholes and outcrops throughout the country and prepare a rock physics template. The trends established with the template will aid future interpretations of both the presence and quality of coaly source rocks both on and offshore New Zealand. This will be accomplished by extending the laboratory study and coal source rock characterization to predict geophysical signatures (forward seismic modeling) by combining experimental data and well logs.

## Methods

A range of samples are collected, including coals of different ranks (lignite through anthracite) and adjacent shaly coal and coaly mudstone lithologies. Samples are characterized with field descriptions and each is measured for density and porosity using the principles of Archimedes. Compositional and textural variability are incorporated into the rock physics template by analysing samples for TOC content, ash content, calorific value, volatile matter, source rock potential, vitrinite reflectance, and organic maceral constituents.

Elastic property data is collected by transducers and laser-based ultrasonics. Transducer measurements calculate P- and S- wave velocities along longitudinal and transverse axes. These measurements are taken under both atmospheric conditions and confining pressures ranging from 0-60 Mpa. The benchtop laser measures similar wave velocities along a 360 degree rotational scan of cylindrical plugs. Wave velocities are then used to calculate various elastic moduli and incorporated into the rock physics template.

Vertical and horizontal anisotropy are further investigated by Computed Tomography (CT) scans of plugs. This non-destructive technique builds a 3D image of samples by combining individual slices at a maximum resolution of 8µm per pixel. CT scans may elucidate whether tectonic stress regimes have overprinted upon the internal fabric of New Zealand’s coal seams. Such a fabric would influence both P- and S- wave velocities through anisotropy.

## Results

The first phase of sampling was performed at three mines in the Waikato Coal Region on the North Island. Proper coal samples were all of bituminous rank and their measured densities ranged between 1.27 and 1.37 g/cm$^3$ (Figure 2). Across the Renown Coal Seam at the Rotowaro Mine, density increases as the seam transitions from coal to shaly coal to coaly mudstone. These changes are a response to increasing amounts of sediment (“ash”) input and will influence both P- and S- wave velocities.

Initial scans from the benchtop laser reveal variations in first arrival, P-waves, among samples cored parallel and normal to bedding (Figure 3). CT scans of these samples reveal internal density contrasts, which may reflect a variety of organic maceral groups, coal lithotypes, or fluctuations in ash content (Figure 4).

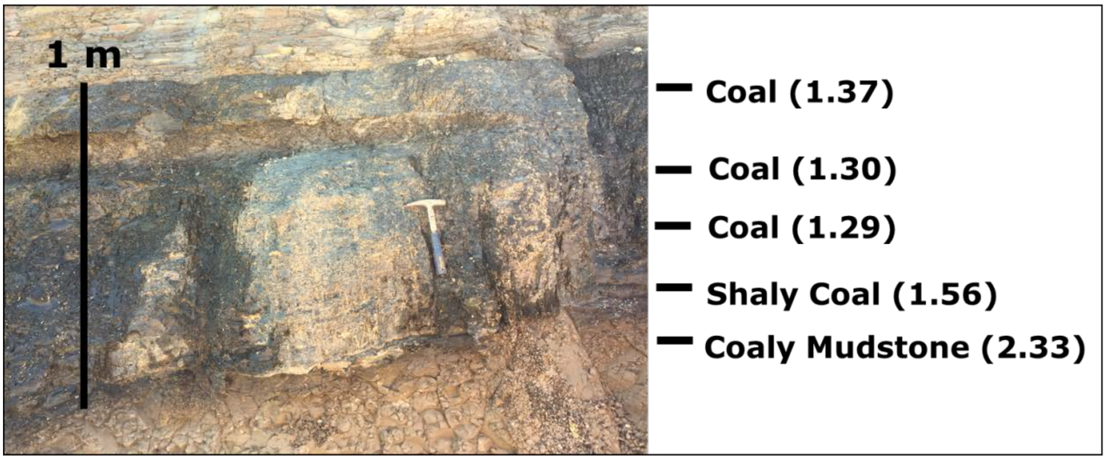

*Figure 2. Measured densities (in g/cm$^3$) across the Renown Coal Seam (Rotowaro Mine, Waikato, NZ). Values increase with increasing sediment input (coal to shaly coal to coaly mudstone).*

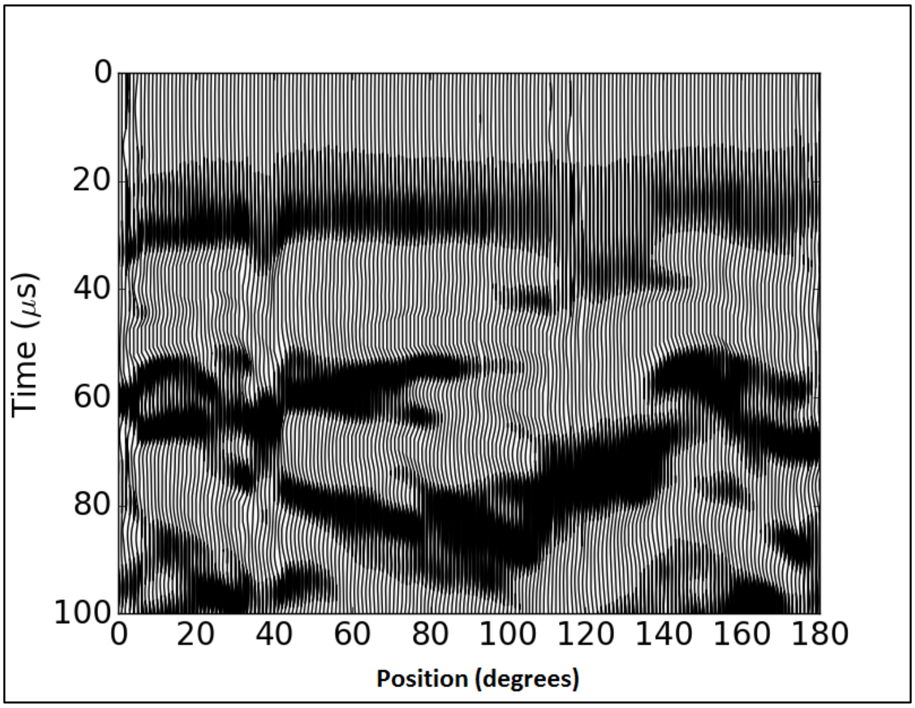

*Figure 3. Wiggle trace plot of wave arrival times versus the rotational scan position (in degrees from 1 to 180). Preliminary benchtop velocity (P-wave) varies between 1,270 and 1,814 m/s.*

## Discussion

Previous works by Morcote et al. (2010) on the dynamic elastic properties of coals demonstrated their properties depend upon both coal rank and the applied effective pressure. They identified increasing P- and S- wave velocities with increasing density and coal rank. This corresponded with increases in both dry bulk and dry shear moduli, as well as, decreases in the Vp-Vs ratio. The relationship between the variability of ash content (i.e., sediment input) and organic macerals in coals and the resultant geophysical properties is less understood. The transitional lithologies surrounding coal seams (e.g., shaly coals and coaly mudstones) contribute to the source rock potential of New Zealand's petroleum systems, and previous works have not evaluated their influence on geophysical measurements.

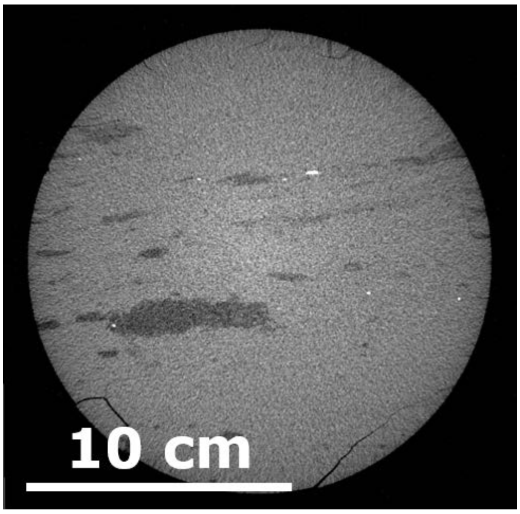

*Figure 4. CT scan slice reveals density contrasts within coal samples. These variations may reflect individual organic macerals, maceral groups, coal lithotypes, or fluctuations in ash content.*

This study is unique in that it combines measurements of dynamic elastic properties of coals over a range of rank and ash content with a comprehensive coal quality and petrophysical analysis. This robust dataset will be used to construct a rock physics template that may assist further exploration initiatives in New Zealand.

## Acknowledgements

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