Organic Characterisation of the Tartan Formation, Great South Basin

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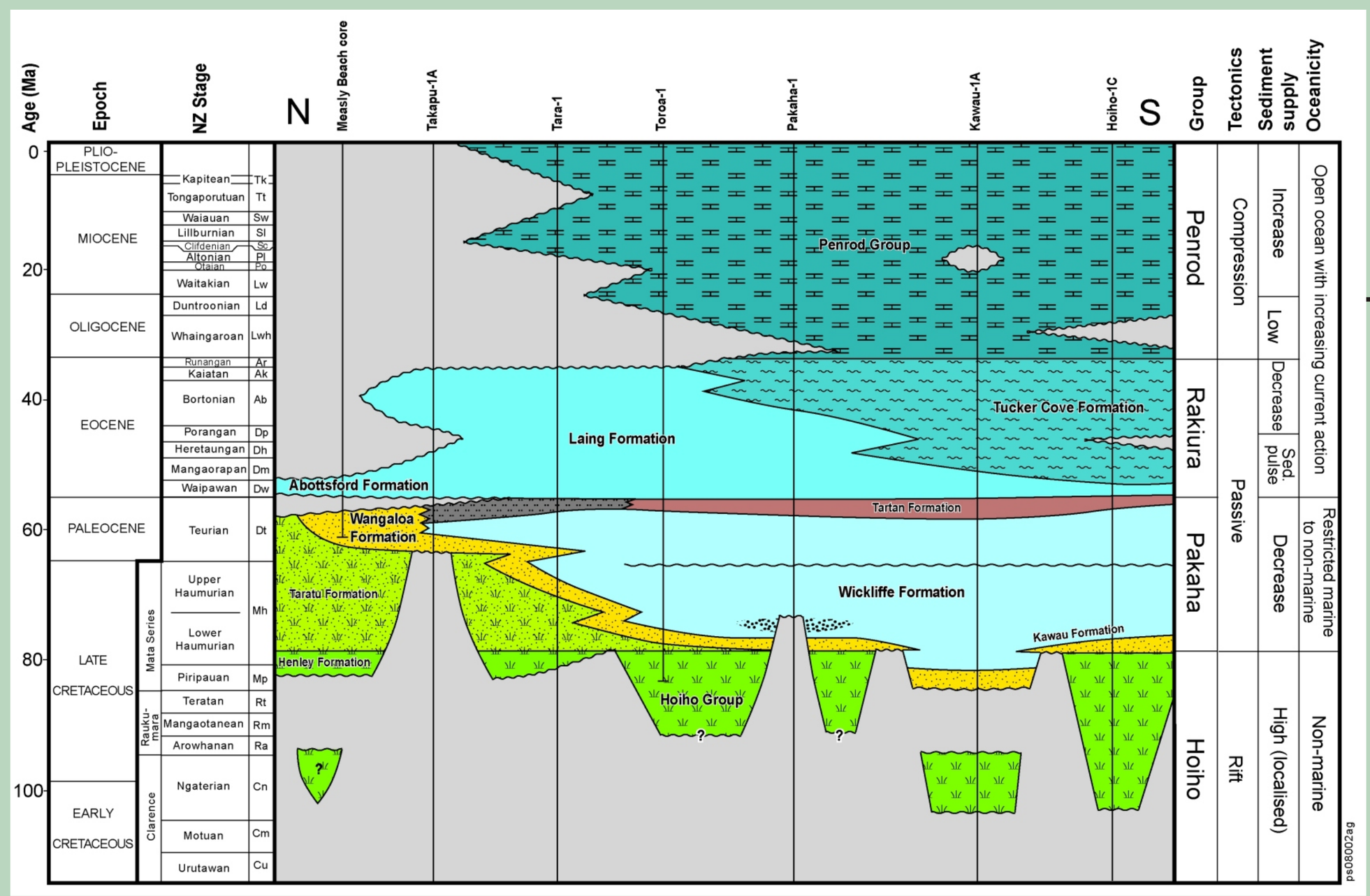
Introduction

- The Paleocene Tartan Formation is an organic-rich, marine mudstone, that is widespread in the Great South Basin.
- It is considered to be a lateral equivalent of the Waipawa Formation, an organic-rich mudstone found in the East Coast Basin and other New Zealand sedimentary basins (Hollis et al., 2006).
- The Tartan Formation is up to c. 57 m thick and is found in five of the eight wells drilled in the basin (Schiøler and Roncaglia, 2008).
- Five wells from the Great South Basin are analyzed for organic richness and bulk organic carbon isotopic composition in order to identify the Tartan Formation (Meadows, 2008).

Material and Methods

- Wells studied - Kawau-1A, Hoiho-1C, Toroa-1, Pakaha-1, and Takapu-1A (Tartan Formation is absent).
- 75 sidewall core and cutting samples from the Tartan Formation and the under- and overlying Wickliffe and Laing formations.
- Organic richness (Total Carbon, TOC and %Nitrogen) and bulk organic carbon isotopes ($\delta^{13}C$) were performed at the Stable Isotope Laboratory at GNS Science.
- %C (Total Carbon) and TOC were verified independently at Applied Petroleum Technology, Norway and Geological Survey of Canada, Calgary using Rock-Eval 6.
- Errors for TOC, %C and %N are ±0.3%, and $\delta^{13}C$ are ± 0.2‰

Stratigraphy

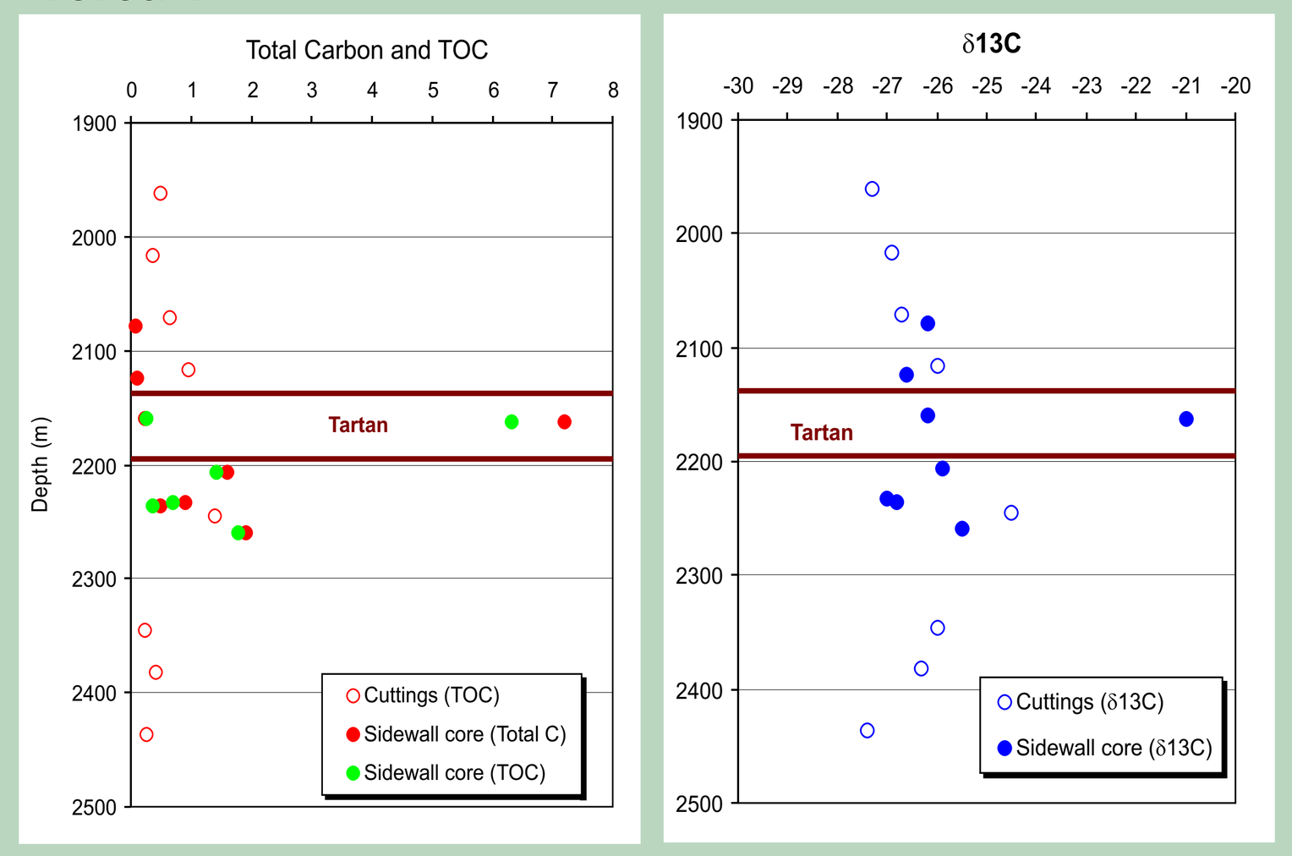


Generalised stratigraphy of the Great South Basin (Schiøler and Roncaglia, 2008).

- The Great South Basin formed during a mid-Cretaceous extension of the Campbell Plateau associated with the rift phase which separated New Zealand from Australia.
- The basin was extensively faulted, forming horst and graben structures, subsequently infilled and overlain with mid–Late Cretaceous and Cenozoic sediments (Cook et al., 1999).
- The Tartan Formation overlies the Wickliffe Formation and is considered to have been deposited in a nearshore, marine setting with reduced oxygen (Cook et al., 1999).

Location of Tartan Formation in wells

Toroa-1



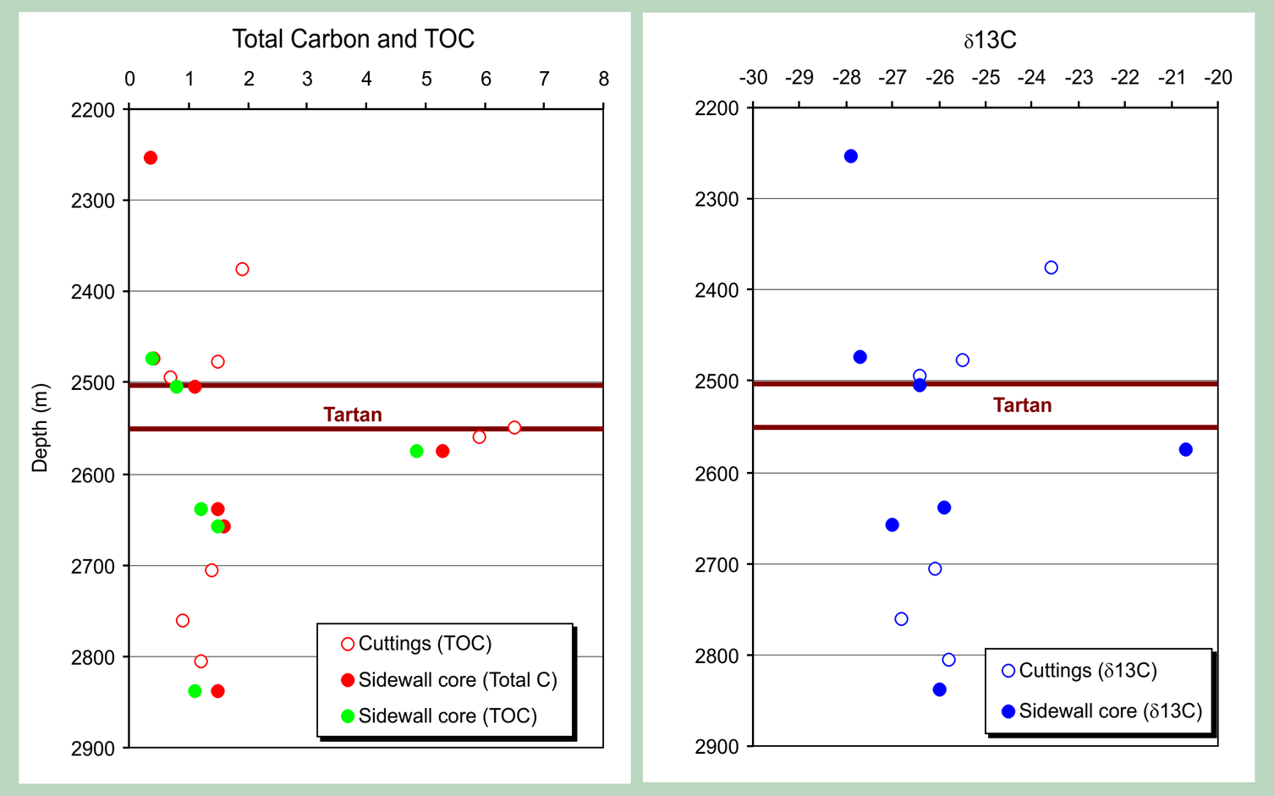
→ TOC_{max} of sidewall cores is 6.3% and $\delta^{13}C_{max}$=-21.0‰.

→ Based on lithostratigraphy, the top and base of the Tartan Formation are suggested to be at 2138 m and 2195 m respectively (Schiøler and Roncaglia, 2008).

→ However, sidewall cores and cuttings from 2160 m have lower TOC and $\delta^{13}C$ values, typical of the overlying Laing Formation.

→ TOC and $\delta^{13}C$ results suggest that if the petrophysical boundaries are correct, there is variation in organic content within the Tartan Formation.

Pakaha-1



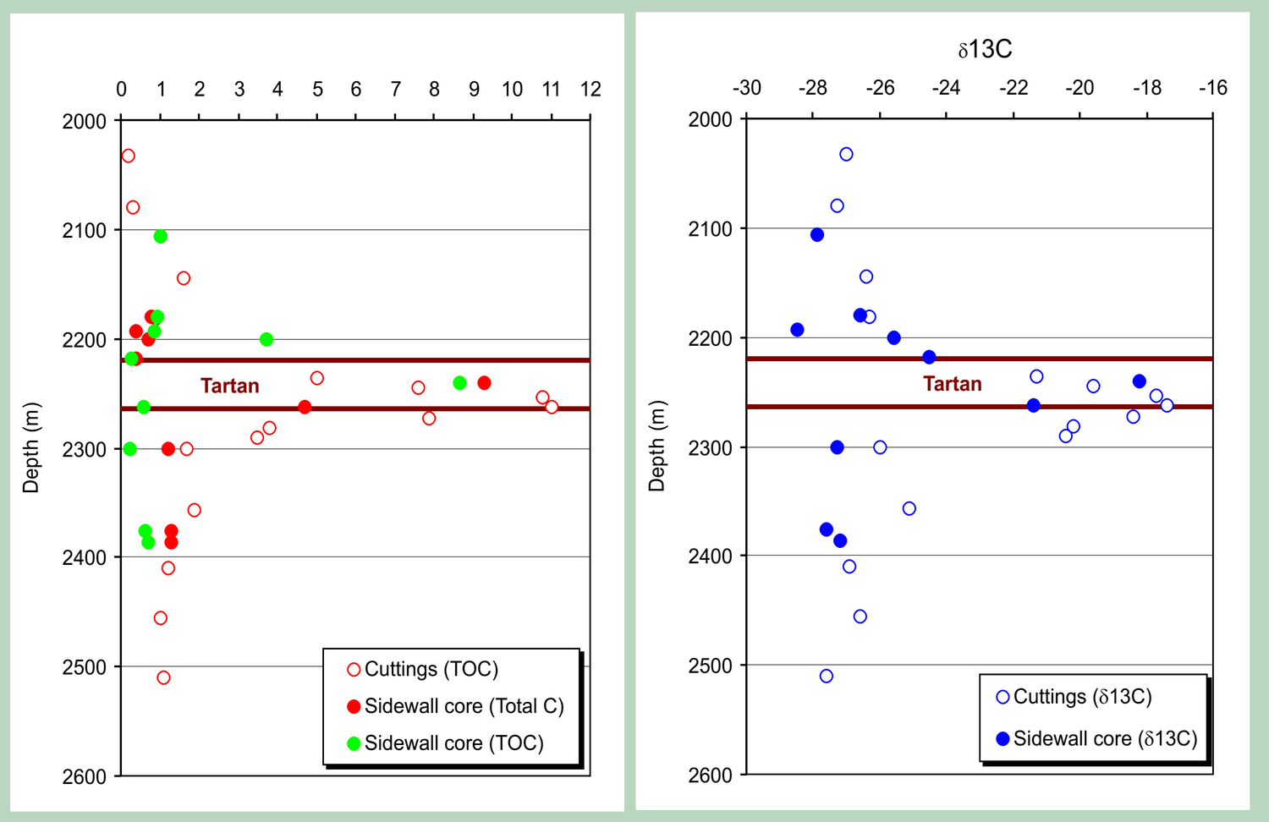
→ TOC_{max} is 4.9% and $\delta^{13}C_{max}$=-20.7‰.

→ Top and base of the Tartan Formation are suggested to be at 2503 and 2551 m respectively (Schiøler and Roncaglia, 2008).

→ Sidewall cores and cuttings from 2576 m have both elevated TOC and $\delta^{13}C$ values, typical of Tartan Formation.

→ TOC and $\delta^{13}C$ results suggest the base of the Tartan Formation is somewhat deeper than is indicated by petrophysical properties in Pakaha-1.

Kawau-1A

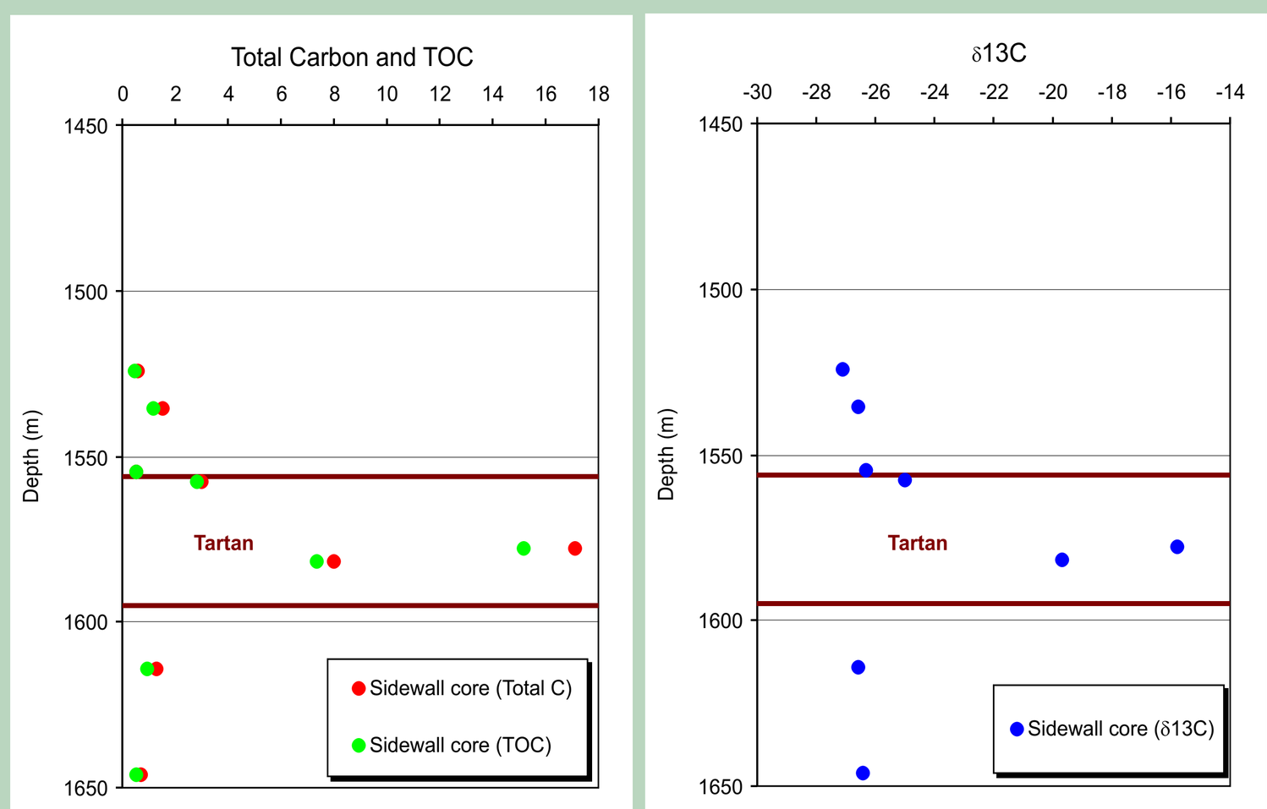


→ TOC_{max} is 8.7% and $\delta^{13}C_{max}$=-18.2‰.

→ Top and base of the Tartan Formation are suggested to be at 2220 and 2264 m respectively (Schiøler and Roncaglia, 2008).

→ TOC and $\delta^{13}C$ values are consistent with the top and bottom picks. Cutting samples just below the base of the Tartan Formation show elevated TOC and $\delta^{13}C$ values, suggesting cavings.

Hoiho-1C

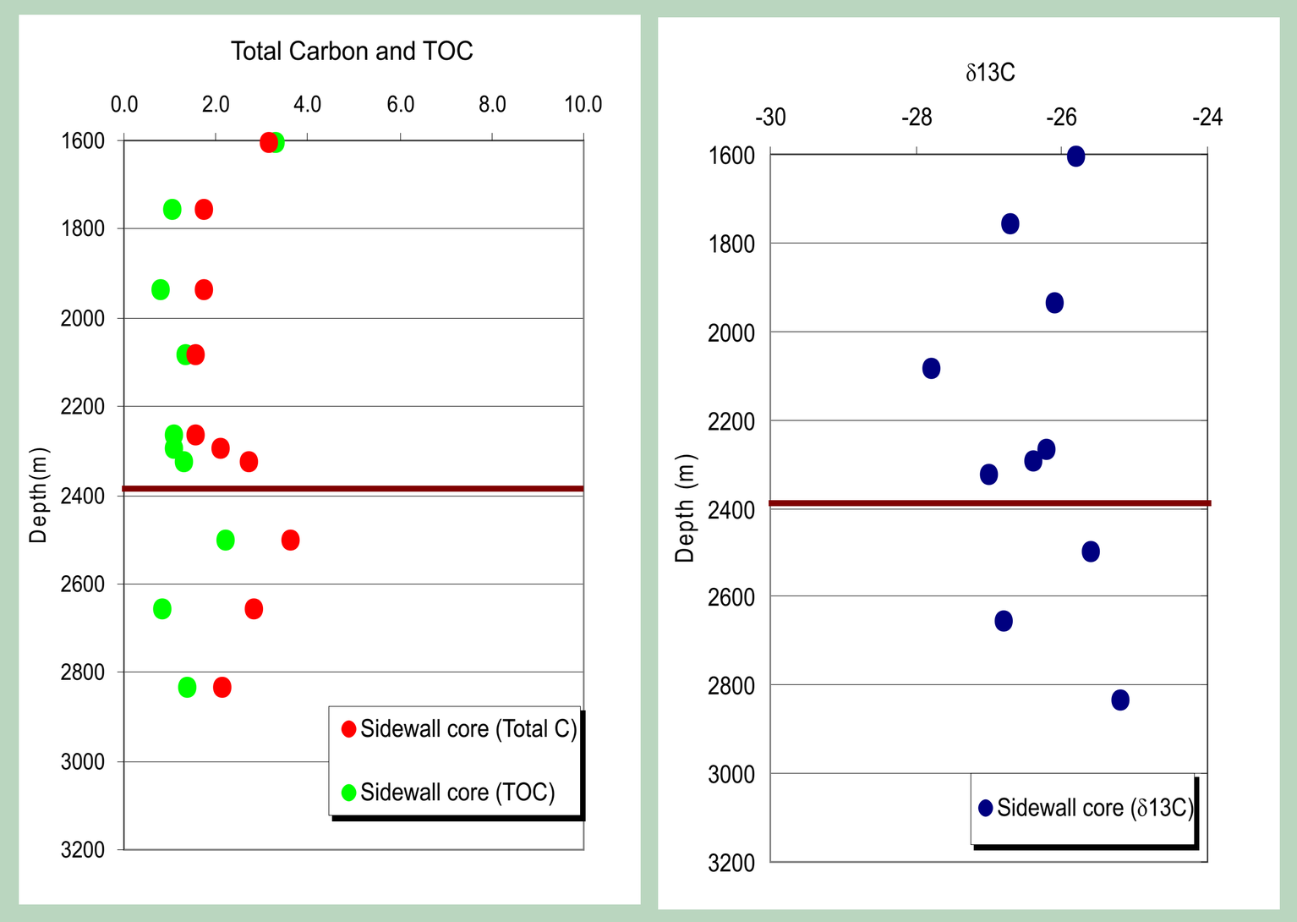


→ TOC_{max} is 15.2% and $\delta^{13}C_{max}$=-15.8‰.

→ Top and base of formation are suggested to be at 1556 and 1595 m respectively (Schiøler and Roncaglia, 2008).

→ TOC and $\delta^{13}C$ values are consistent with the top and bottom picks.

Takapu-1

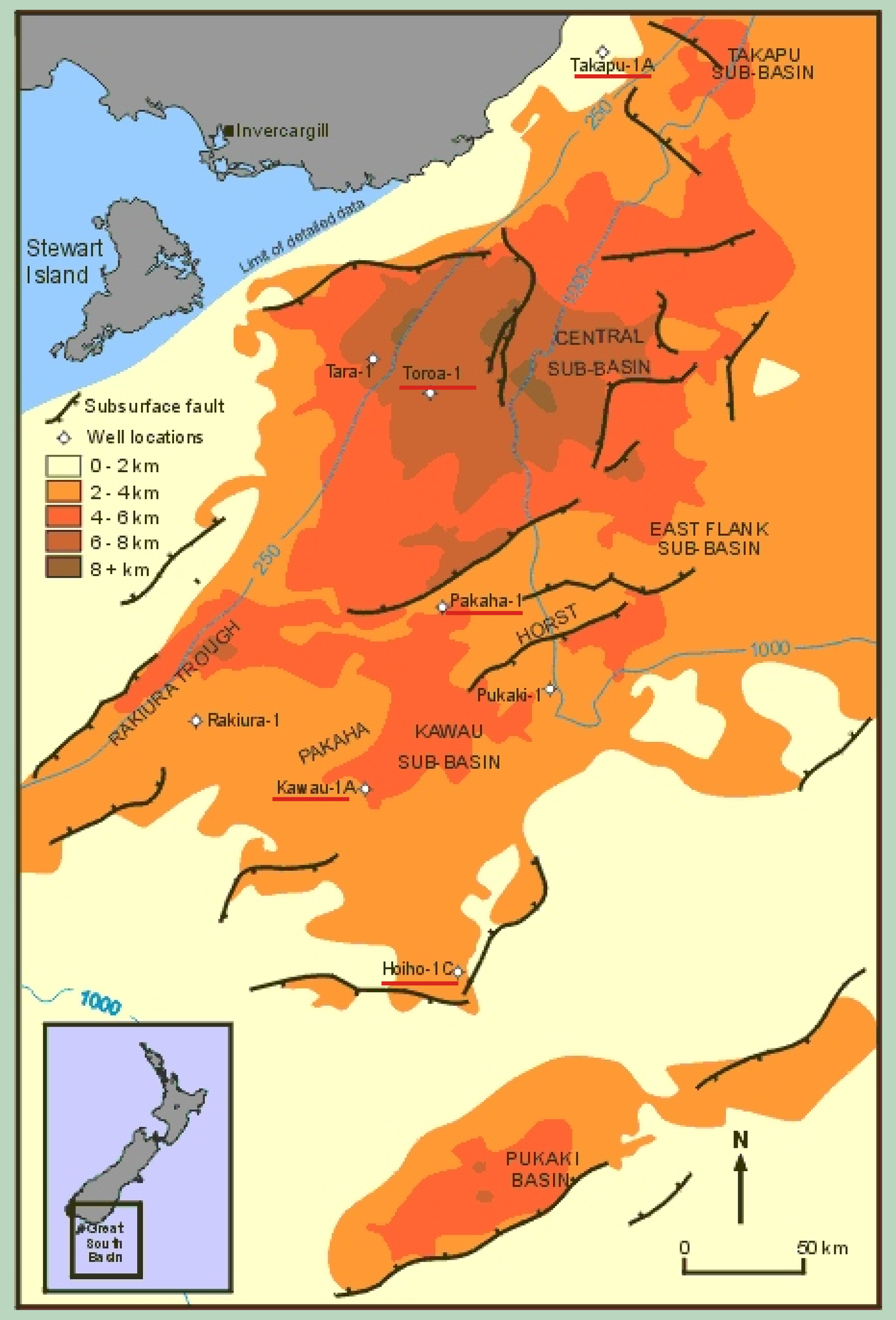


→ TOC_{max} is 2.0% and $\delta^{13}C_{max}$=-25.5‰.

→ TOC and $\delta^{13}C$ values support petrophysical evidence that the Tartan Formation is absent in this well.

→ An unconformity is suggested between 2340 and 2490 m.

Great South Basin location map



The Great South Basin is approximately 100,000 km2 in size and eight wells have been drilled. Wells in this study are underlined in red.

Discussion

The Tartan Formation is characterized by a combination of moderate to high TOC's, and relatively heavy $\delta^{13}C$ values compared to the enclosing marine formations above and below.

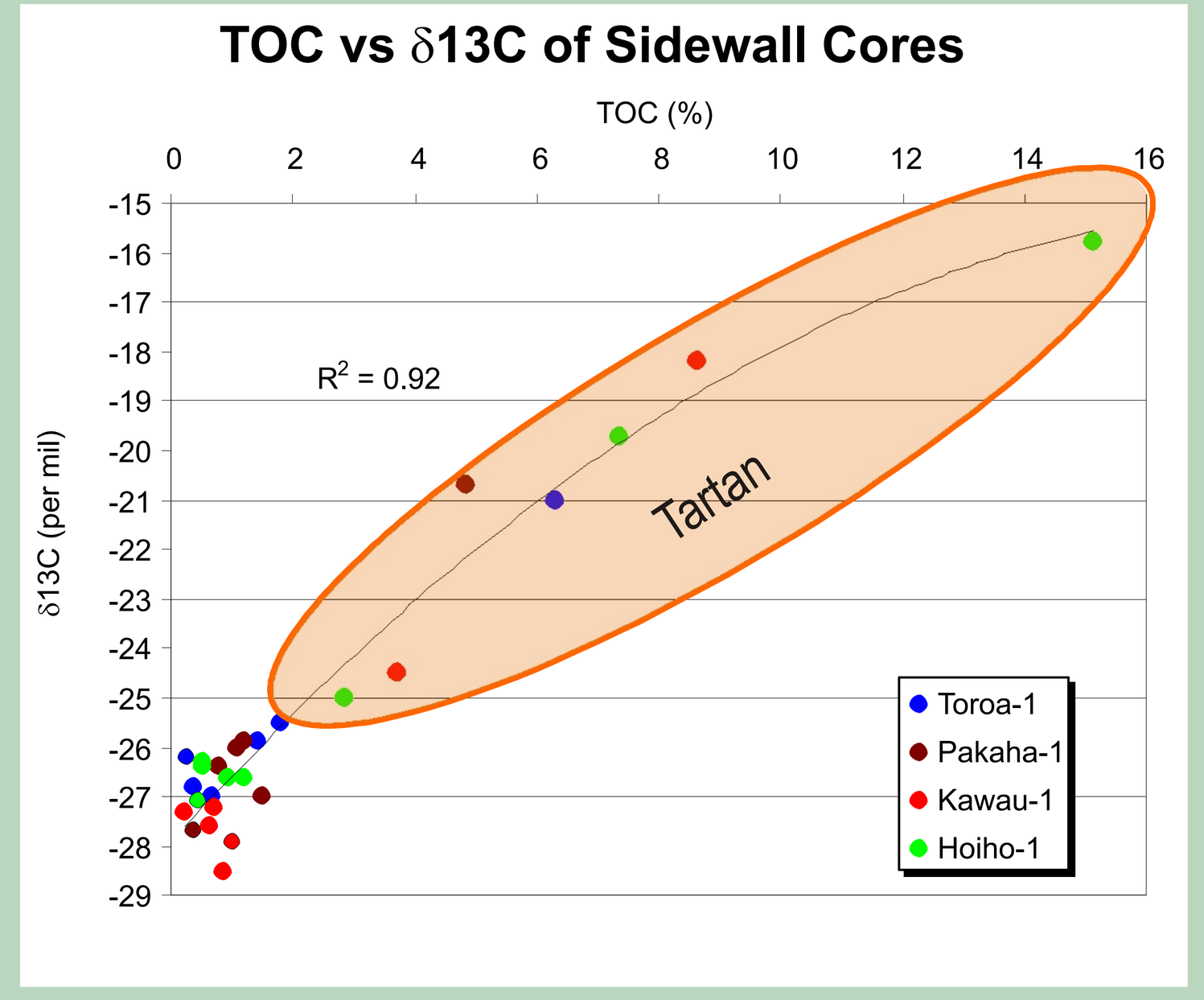
The Tartan Formation sidewall cores have TOC's of typically 2 to 15%, %N of 0.2 to 0.5%, and δ13C values of c. -21.0 to -15.8‰, compared to TOC, %N and δ13C values of typically <2%, <0.1% and -28 to -25‰, respectively, for the enclosing marine formations.

C/N ratios are >20 for all Tartan Formation samples indicating a terrestrial influence. However, the Wickliffe and Laing formations have comparable C/N ratios to the Tartan Formation, especially in Kawau-1 and Hoiho-1. This suggests that the isotopic excursion found in the Tartan Formation is due to a different organic source than is found in the Wickliffe and Laing formations.

Heavy $\delta^{13}C$ values within the Tartan Formation are similar to those of the Waipawa Formation found elsewhere in New Zealand, but in the more distal Hoiho-1C ($\delta^{13}C$ to -15.8‰) and Kawau-1A ($\delta^{13}C$ to -18.2‰) wells, the enrichment exceeds those previously reported for the Waipawa Formation (Hollis et al. 2006 and references therein).

Hydrocarbon discoveries from the Great South Basin have $\delta^{13}C$ values of c. -28 to -26‰ (Killops et al. 1997, Cook et al. 1999) consistent with generation from source rocks older than the Tartan Formation.

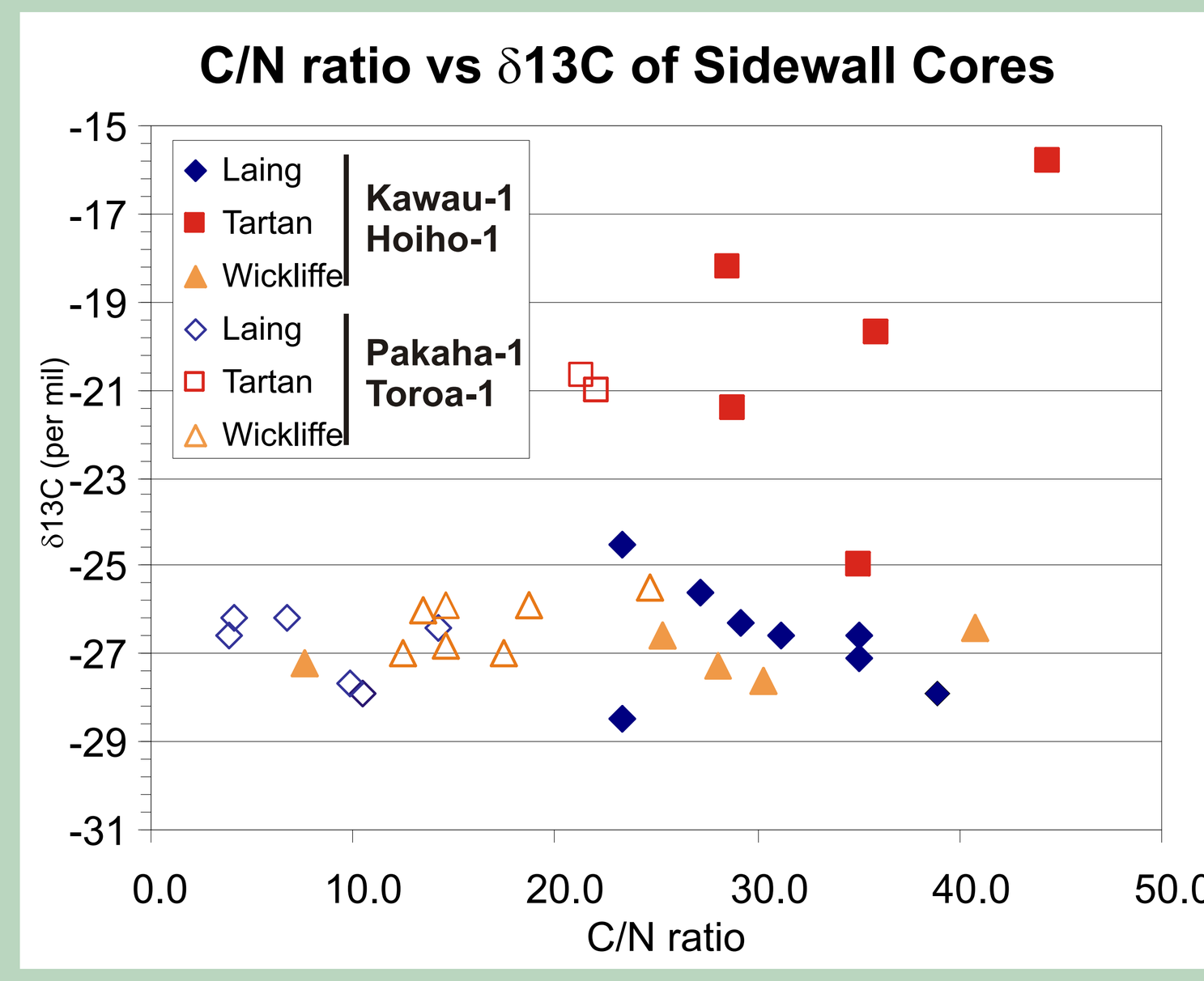
Source characterisation of the Tartan Formation



TOC and $\delta^{13}C$

→ As TOC increases, the $\delta^{13}C$ values become less negative. The Tartan Formation stands out from the Wickliffe and Laing formations, by its characteristically high TOC and heavy (less negative) $\delta^{13}C$ values.

→ Heavy $\delta^{13}C$ values suggest that the Tartan contains dominant marine algal/bacterial sources. Yet higher C/N ratios (see below) and kerogen observations (Schiøler and Roncaglia, 2008) suggests a strong terrestrial influence, which is usually associated with lighter (more negative) $\delta^{13}C$ values.



C/N Ratio and $\delta^{13}C$

→ C/N ratios indicate organic source where:

C/N<10 indicates an algal/marine source

C/N = 10–13 indicates a mixed marine/terrestrial source

C/N> 13 indicates a terrestrial source

→ The Tartan, Wickliffe and Laing formations from Kawau-1 and Hoiho-1 wells have C/N ratios >20 suggesting that the organic material preserved in these formations contains a high terrestrial component.

→ The Wickliffe and Laing formations from Pakaha-1 and Toroa-1 wells have variable C/N ratios from 4 to 23 suggesting a more marine/mixed source contribution to these formations. The Tartan Formation, has C/N ratios around 20-22.

Conclusions

The Tartan Formation can be characterized organically by three main features:

1. Relatively high TOC contents of typically 2–15%, indicating very good to excellent source potential.
2. High C/N ratios of 20–30, suggesting some considerable terrestrial input to the contributing organic matter, especially in Kawau-1 and Hoiho-1.
3. Heavy $\delta^{13}C$ signature of up to -15.8‰, which is usually associated with a significant algal and/or bacterial contribution.

The burial and thermal histories of the Tartan Formation are still poorly constrained in deeper parts of the basin. Any hydrocarbons generated and expelled from this formation would have a similarly heavy $\delta^{13}C$ signature. Future geochemical work on the Tartan Formation (and Waipawa Formation) will focus on:

→ The nature and origins of organic matter composition and its stratigraphic variability

→ Compound-specific isotope analysis to help identify the origin(s) of the heavy $\delta^{13}C$ signature

→ Geochemical investigation of Waipawa Formation in other basins

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Acknowledgments

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