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The use of stable carbon isotope trends as a correlation tool: an example from the Surat Basin, Australia

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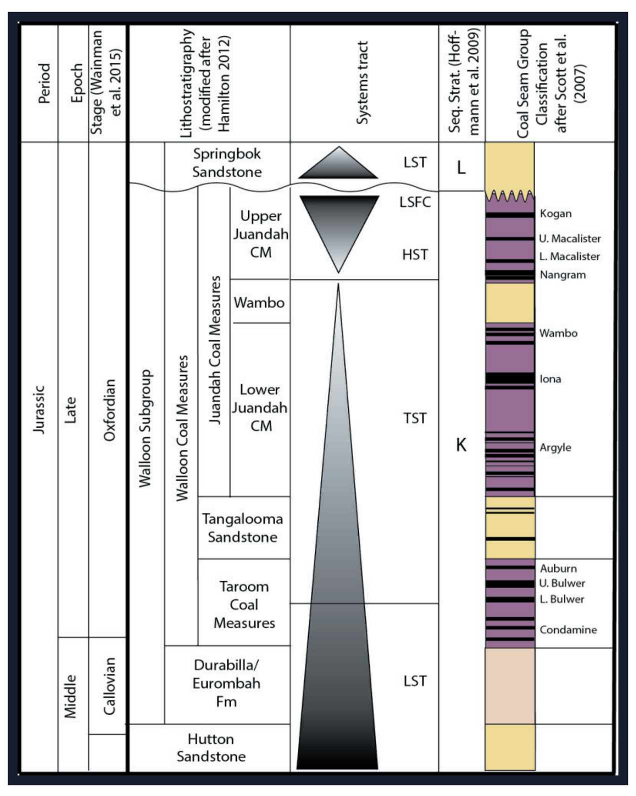
ABSTRACT

This study uses organic stable carbon isotope trends and organic petrology data as a correlation tool within the Surat Basin's Walloon Subgroup and its overlying Springbok Sandstone. The Jurassic Walloon Subgroup, a productive coal seam gas source, is commonly divided into sub-units based on different proportions and thicknesses of coal and sandstone. However, correlation across the basin is challenging due to high lateral variability and a lack of extensive stratigraphic markers. The Walloon Subgroup is also, in places, incised by the overlying Springbok Sandstone, sometimes interpreted as far down as the Tangalooma Sandstone. New age dates suggest that the Walloon Subgroup is Oxfordian in age and marks a period of high rates of organic carbon production and burial, and an intermittent decrease of atmospheric pCO2. The un- or disconformable base of the Springbok Sandstone coincides with a turning point of this supposedly global phenomenon. Analysis of a stratigraphic suite of coal samples from several wells across the Surat Basin shows a gradual enrichment in ^{13}C up section from the Taroom to Lower Juandah Coal measures, with the most positive $\delta^{13}C$ values within the Upper Juandah Coal Measures. Thereafter there is a rapid reversal to more negative $\delta^{13}C$ values for coal samples from the Springbok Sandstone. The upward enrichment occurs well before a shift in maceral composition to increased inertinite content in the coals, suggesting more global allogenic processes are controlling the carbon isotope trend as opposed to local, environmental factors.

1. BACKGROUND



The Walloon Subgroup

- Stratigraphic variability in coal and interburden character allows subdivision into different sub-units (Fig. 1)
- Maximum thickness of approximately 400-450 m
- Walloon Subgroup underlies erosively based unit called Springbok Sst, which also contains thin coal seams
- The unconformable base is thought to represent a major global event
- Oxfordian (158-162 Ma) in age

Recent Correlations

- Thickness and distribution of the upper coal measures controlled by erosive base of the overlying Springbok Sst and is a function of differential erosion due to regional uplift
- Fluvial incision at the base of the Springbok Sst has been recognized from well-log correlation
- However, correlation errors due to a lack of stratigraphic marker horizons, the nature of the depositional system, as well as uncertainty regarding the extent of the incision of the Juandah CM

Fig. 1. Surat Basin stratigraphy (after Hamilton et al. (2012), Hoffmann et al. (2009), Scott et al. (2007) and Wainman et al. (2015)). Triangles represent base level sequences. Direction of narrowing represents increasing base level. LST=low stand systems tract, TST=transgressive systems tract, HST=high stand systems tract, LSFC=late stage falling cycle.

2. AIMS

The aim of this study is to assist with a more confident correlation of sub-units of the Walloon Subgroup and to test existing basin-wide correlations. In order to achieve this aim, robust stratigraphic marker horizons are required. These could come from a systematic petrographic and stable isotopic characterisation of the Walloon coals; an approach that has not been applied before to these Jurassic coals.

3. METHODOLOGY

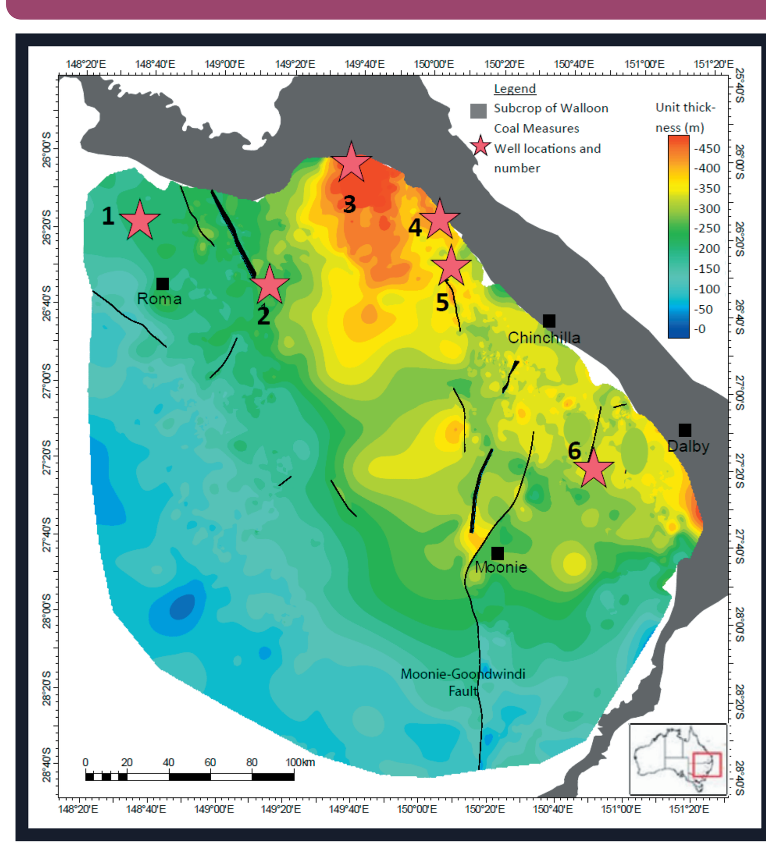


Table 1. Analyses conducted and sources of data. Pacey (2011)[1], Hentschel (2013)[2] and this study[3].

Well	Analyses conducted: Petrographic analysis	Analyses conducted: Organic stable carbon isotope analysis
1	27 block samples[3]	27 samples[3]
2	27 block samples[2]	17 samples[2]
3	19 grain mounts[3]	20 samples[3]
4	25 block samples[3]	25 samples[3]
5	42 grain mounts[1]	38 samples[1]
6	41 grain mounts[1]	40 samples[1]

Fig 2. Thickness map of the Walloon Coal Measures interval (Juandah Coal Measures, Tangalooma Sandstone and Taroom Coal Measures) including locations of study wells.

4. RESULTS

Petrographic analysis

- All samples dominated by vitrinite group macerals (purple triangles; Fig. 3)
- Abundant liptinite group macerals (blue diamonds); however, no significant trend with depth
- Jump to increased inertinite group macerals recorded in U. Juandah CM and coals of the Springbok Sst (yellow circles) suggests change to lower base level conditions in the mire

Organic stable carbon isotope analysis

- Taroom CM and the Tangalooma Sst coal samples show relatively negative $\delta^{13}C$ values across all study wells
- Shift to less negative compositions within samples from the U. Juandah CM, followed by shift back to more negative $\delta^{13}C$ values for samples from the Springbok Sst (Fig. 3)
- In well 1 this shift to more negative $\delta^{13}C$ values occurs in U. Juandah CM (as correlated by exploration company; Fig. 3), as opposed to the Springbok Sst

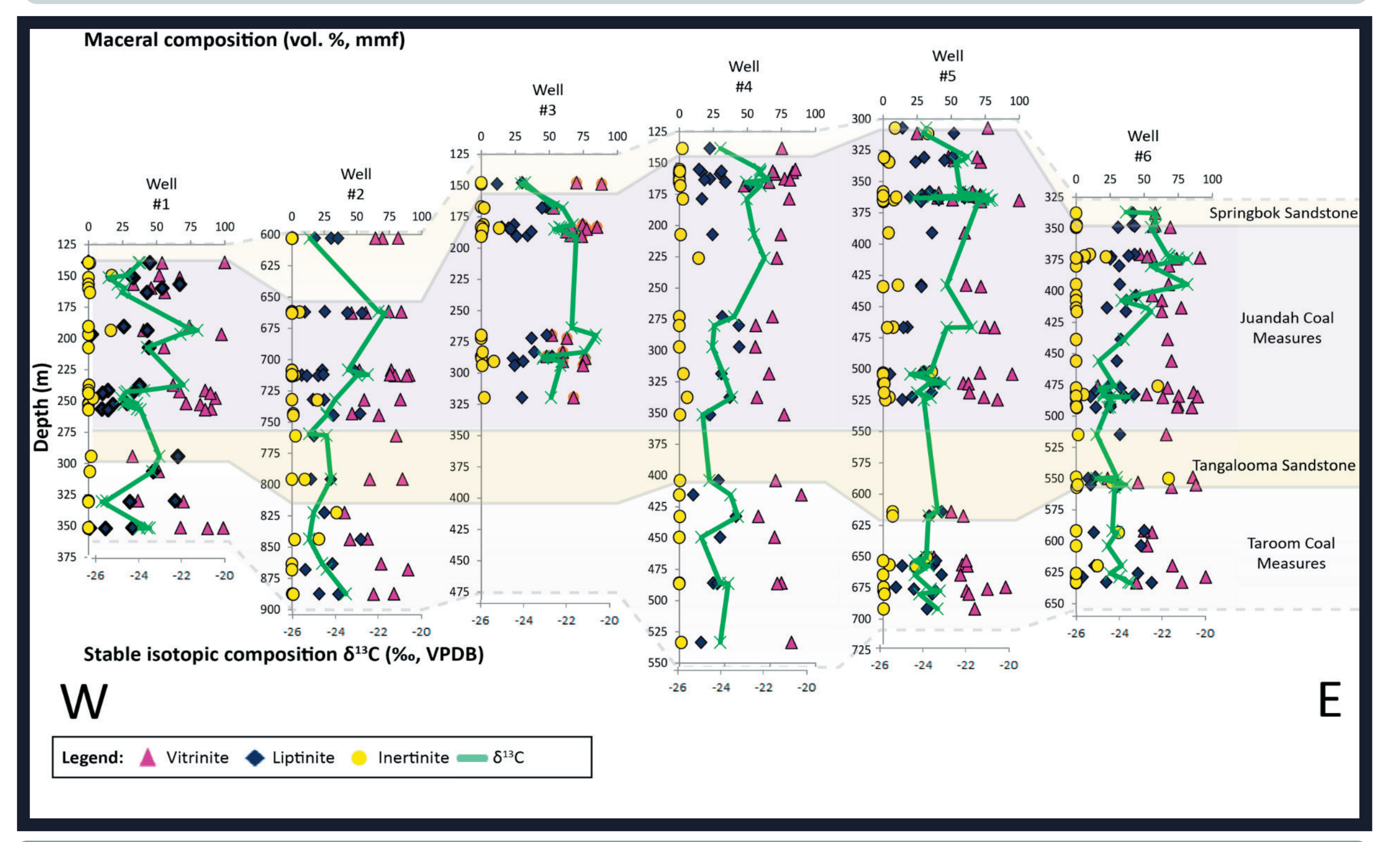


Fig 3. Maceral composition (vol. %, mmf) and stable isotopic composition ($\delta^{13}C$ in ‰, reported against VPDB standard) for coal samples from wells 1 to 6 (west to north to the east of the Surat Basin). Correlation of sub-units according to company picks.

5. CONCLUSIONS AND IMPLICATIONS

Conclusions

- Maceral composition of U. Juandah CM and coals of the Springbok Sst suggest environmental change (Fig. 3)
- Positive excursion in $\delta^{13}C$ does not respond to change in maceral composition, as it sets in earlier
- Shift to less negative $\delta^{13}C$ values in U. Juandah CM is consistent for wells 2 to 6
- Follows global climate trend, as recorded in Mid-Oxfordian marine carbonates
- In well 1, the stratigraphic boundaries had to be adjusted based on positive excursion in $\delta^{13}C$
- More negative $\delta^{13}C$ values of samples from depth interval of 139–163m implies that these are Springbok coals
- Samples from a depth of 190–257m have inertinite group macerals only in trace amounts, whereas samples from U. Juandah CM showed increased inertinite contents in all other wells
- U. Juandah CM in well 1 were eroded in their entirety (Fig. 4)

Implications

- Trends in isotope record of the Walloon coals are substantial and fairly consistent, and have potential to serve as stratigraphic markers, as they represent changes in global ocean-atmosphere carbon reservoir
- Isotope trends can be applied as a tool to test existing correlations and especially the extent of Springbok incision

CONCLUSIONS AND IMPLICATIONS (continued)

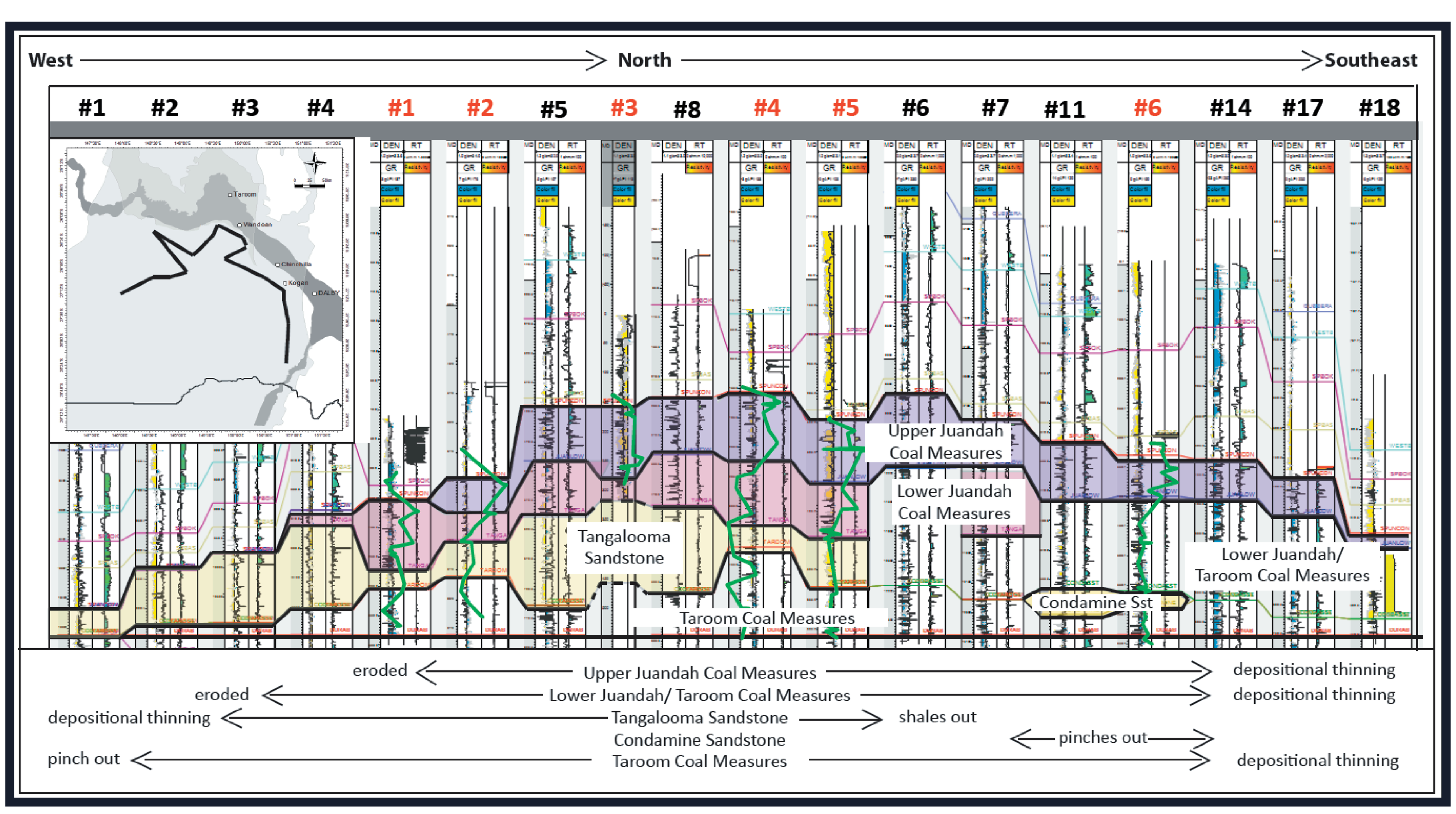


Fig 4. West to north to southeast trending cross-section through the Surat Basin including wireline logs for a number of wells throughout the Surat (black labels) and wireline logs for wells 1 to 6 as shown in this study (red labels). Correlation of sub-units in study wells 1 to 6 is based on the use of organic stable isotopes (note: boundary between Springbok Sandstone and Juandah Coal Measures was shifted to a depth of 171 m in well 1). The stable isotope trends for wells 1 to 6 are schematically shown in green.

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