International Journal of Coal Geology 152 (2015) 10–18

Contents lists available at ScienceDirect

International Journal of Coal Geology

journal homepage: www.elsevier.com/locate/ijcoalgeo

Electrofacies analysis using high-resolution wireline geophysical data as a proxy for inertinite-rich coal distribution in Late Permian Coal Seams, Bowen Basin

A. Roslin *, J.S. Esterle

The University of Queensland, School of Earth Sciences, St. Lucia, QLD 4072, Australia

A R T I C L E I N F O

Article history:
Received 12 February 2015
Received in revised form 1 August 2015
Accepted 4 August 2015
Available online 7 August 2015

Keywords:
Bowen Basin
Electrofacies analysis
Wireline logs
Coal lithotype
Inertinite-rich coal

A B S T R A C T

This paper examines the stratigraphic and geographic distribution of coal composition in main Late Permian coal measures in the Bowen Basin, using coal electrofacies as a proxy for inertinite maceral group content. Data for this research were derived from some 26 wells in the northern part of the Bowen Basin. A companion paper (Roslin and Esterle, 2015, in review) introduced the methodology, which is based on electrofacies analysis and uses high-resolution wireline data (including microresistivity from Compact Micro-Image (CMI) tool and Photoelectric Factor (PEF) data in addition to conventional gamma ray, density and laterolog resistivity) to obtain coal electrofacies. Validation of the methodology was performed by comparison of the weighted average proportion of coal electrofacies to the weighted average proportion of the corresponding coal lithotypes obtained from millimetre scale logging and to the percentage gathered from maceral content analysis. The weighted average proportion of the interpreted dull inertinite-rich coal electrofacies (independent of rank and heat effects) was then analysed to determine their stratigraphic and geographic distribution.

From the base upward, the main Late Permian coal bearing units are the Moranbah Coal Measure (MCM), Fort Cooper Coal Measure (FCCM), and Rangal Coal Measure (RCM) and their stratigraphic equivalents across the basin. The proportion of inertinite-rich dull coal electrofacies increases upwards in the RCM, with some thick and merged seams showing distinctive electrofacies signatures. Within the study area, the coal measures and individual seams split from north to south, reflecting increased subsidence and sediment influx into basin depocentres. As the seams split, the proportion of inertinite-rich dull coal electrofacies decreases in the tested sample set.

1. Introduction

Many studies (summarised by Diessel, 2010) have noted compositional changes in coal maceral constitution in response to vegetational succession and peat degradation as water tables respond to changing depositional setting and climate. In the Late Permian coals in the Bowen Basin, Australia, the proportion of inertinite group macerals increases up section towards the Triassic boundary, and this is interpreted to respond to increasing aridity resulting in a dropping water table, increased peat degradation and frequency of peat fires (Diessel, 2010). Whether this stratigraphic change occurs everywhere, independent of basin subsidence control on water table, or shows regional changes has not been fully explored for the Bowen Basin. Hunt and Smyth (1989) suggested that basins and/or areas of low accommodation would accumulate relatively thick and non-split coals with abundant inertinite group macerals. Areas of higher subsidence would develop split coals intercalated with thick clastic sediments, and that the increased subsidence would contribute to more anoxic conditions and enhanced preservation resulting in vitrinite-rich coals.

The authors of the present paper have examined the spatial variability in wireline geophysical log characteristics of coal seams (electrofacies, defined below) as a proxy for maceral composition, which is reflected megascopically in the brightness profile. This approach does not rely on the availability of coal samples, and provides an opportunity to exploit currently underutilised borehole data. The geophysical methodology underpinning the research is explained only briefly, and is set out in great detail in a companion paper (Roslin and Esterle, in review).

2. Background

2.1. Geological setting

The Bowen Basin (Fig. 1) is a large, intracontinental coal-bearing basin that developed in eastern Queensland during the Early Permian — Middle Triassic as the northern part of a much larger basin system that also includes the Gunnedah and Sydney Basins in New South Wales (Totterdell et al., 2009). From the Middle to Late Devonian until the

* Corresponding author.
E-mail address: alexandra.roslin@gmail.com (A. Roslin).

http://dx.doi.org/10.1016/j.coal.2015.08.003
0166-5162/

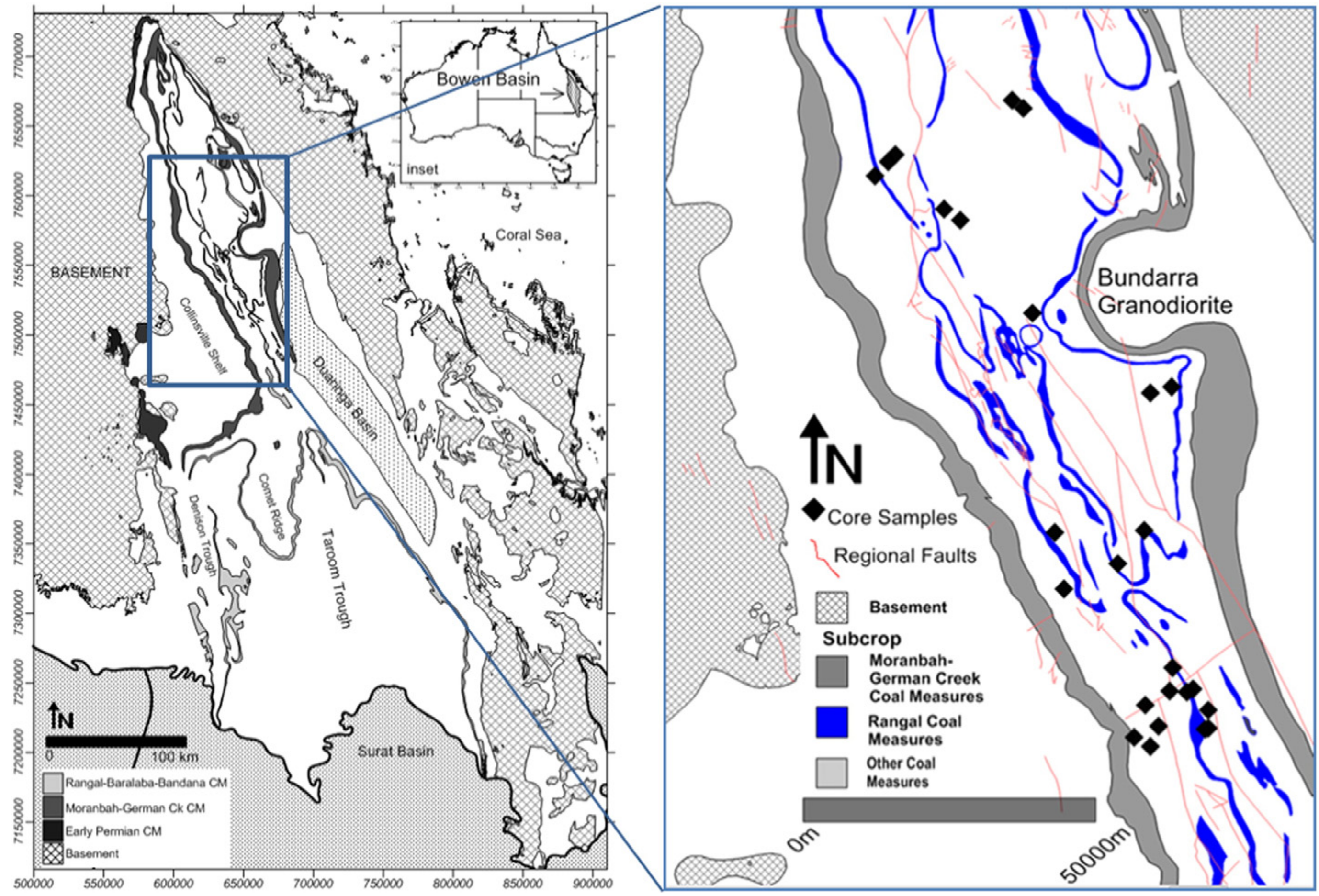

Fig. 1. Location map of the study area: a) simplified geological map of the economic coal measure units in the Bowen Basin, with inset showing location within Australia; and b) detail showing location of core samples with wireline logs. Note that the Fort Cooper Coal Measures are not shown. Compiled from IRTM shape files www.irtm.qld.gov.au.

Cretaceous, eastern Australia was a part of eastern Gondwana. A west-dipping subduction zone influenced the active, convergent plate margin, which was located to the east of the basin system. This resulted in the development of the Early Permian to Middle Triassic Bowen-Gunnedah–Sydney Basin complex in response to a series of tectonically driven subsidence events (Korsch and Totterdell, 2009; Korsch et al., 2009). The event, which initially formed the Bowen and Gunnedah Basins in the Early Permian, is referred to as the Denison Event. During the Late Permian the extension phase changed to a contraction phase followed by west-oriented thrusting from the early Late Permian to Middle Triassic at the New England Orogen at the eastside of the basin system. This caused foreland loading and subsidence in the system, along with deposition of the basin fill (Holcombe et al., 1997; Korsch et al., 1998, 2009).

The sedimentary sequence in the northern Bowen Basin comprises three coal measure units of the Blackwater Group, which are termed (from bottom to top) the Moranbah Coal Measures (MCM), the Fort Cooper Coal Measures (FCCM) and the Rangal Coal Measures (RCM) (Figs. 1 and 2). These coal measure sequences are interpreted to have formed in generally prograding alluvial to coastal environments during the Late Permian, in response to foreland crustal loading and propagation of thrust sheets associated with the Hunter-Bowen orogenic event (Fielding et al., 1993; Holcombe et al., 1997). Base level fluctuations occurred periodically, resulting in marine incursions and/or lacustrine conditions that punctuated fluvial progradation. Within this setting, coal seams developed during periods of relative stability, where peat accumulation kept pace with subsidence. The Late Permian peat mires, accumulating at high latitudes, also experienced the global climatic shift to a drier Triassic climate (Hunt, 1989). These factors influenced the architecture, composition and rank of the coals. Within the RCM are two main coal seams — the Vermont Upper and the Leichhardt, and their associated splits.

3. Methodology

The study described in this paper has used a novel method for coal characterisation (Roslin and Esterle, in review), based on electrofacies analysis of wireline geophysical logs. An electrofacies is an interval defined from wireline logs, through which there are consistent or consistently changing log responses and characteristics, sufficiently distinctive to separate it from other electrofacies (Rider and Kennedy, 2013). Electrofacies analysis implies dividing the whole geological profile into a finite number of electrofacies and geologically classifying them.

Electrofacies partitioning is performed by a clustering procedure, and classification is conducted by the interpreter based on knowledge of the relationship between wireline log responses and coal properties (Roslin and Esterle, in review). The clustering method that was used for the research is MRGC (Multi-Resolution Graph-based Clustering; Ye and Rabiller, 2001). This automatic clustering method is based on the analysis of log data distribution and does not require any predefined cut-offs or assumptions about number of electrofacies. Classification was performed by analysing the distribution trends of wireline log values against trends in physical coal properties such as ash yield, maceral composition or lithotype composition where such data were available.

For this study, 26 wells were selected for electrofacies analysis. The following wireline measurements were used: gamma ray, density,