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The origin of lithotype cycles in Oligo-Miocene brown coals from Australia and Germany

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ABSTRACT

Brown coal colour lithotype cycles range from 10 to 30 m thick in Oligo-Miocene coals of the Latrobe Valley, Gippsland Basin, Australia. Similar colour lithotype cycles occur in the Lusatia German Miocene brown coals. In both the Latrobe Valley and Germany, the cycles often display well-developed colour-lightening-upward trends as defined by new colourimetry measurement. The typical lithotype cycle boundary is abrupt between light below and dark lithotype above. Geological, geochemical, palynological and macrofossil evidence is consistent with a relative drying (terrestrialisation) upward depositional model for each cycle, and the overlying dark lithotype represents renewed peat accretion. The dark lithotype may include charcoal near the cycle base, explained by the fire-prone and highly flammable nature of the herbaceous/reed wetlands. In both the German and Australian coals, wetter (darker) lithotypes are characterized by a gymnosperm paleoflora, while drier (lighter) lithotypes are characterized by angiosperms.

In the German (Rhenish) Miocene brown coal exposed in large open cut mines at Garzweiler and Hambach, a 1.0 m spaced sampling and colourimetry measurement program shows lightening-upwards cycles for the Morken seam, Frimmersdorf-A seam, Frimmersdorf-B seam and for the Garzweiler-II seam. At Hambach where the 60 m thick 'Main Seam' includes amalgamations of Frimmersdorf-A, Frimmersdorf-B and Garzweiler-I, II & III seams, the lightening-upwards trends, provides a means of stratigraphic subdivision.

The palaeogeographic setting for Latrobe Valley and German brown coals is similar – in Latrobe Valley the seams split and thin to the east into marine facies. In the Rhenish and Lusatia brown coals they also split and thin to the north into marine facies. The two Rhenish mines at Hambach and Garzweiler respectively typify end members of this palaeogeography – the Hambach mine is located in a distal location where sulphur content is negligible; the Garzweiler mine is located in a proximal location to the marine boundary where sulphur content is higher. The colourimetry and facies succession suggest German brown coal deposition followed a similar cyclic depositional succession to the Latrobe Valley, and that this succession may be fundamental in all thick coal seams.

1. Introduction and background to brown coal lithotypes

Brown coals are complex biologically-derived materials that have undergone numerous diagenetic transformations. Knowledge of brown coal formation involves research in the fields of paleobotany, palynology, ecology, geology, organic chemistry and hydrology. Even in very similar depositional settings, different coals may be produced in different geographic regions. This complexity has meant that relative to other sedimentary rocks, disagreements exist as to their exact depositional model. This has a bearing on all coal successions, because brown coals form a vital link between modern peatland depositional settings and black coals.

Lithotype analysis of brown coals is essentially a method of subdividing thick coal seams into several depositional facies. Lithotypes in the Australian Gippsland Basin's Latrobe Valley brown coals (Fig. 1) refer to coal banding in the air dried state, usually seen where moisture losses of 10–15% occur in the top few centimeters of the open cut faces. It is a characteristic to Latrobe Valley coals that has important implications for briquetting applications. First Edwards (1947) then George (1975) proposed a 5 fold colour subdivision consisting of pale (P), light and medium light (L; ML), lignitic or medium dark (MD) and dark (Dk) lithotypes. A sixth category of Very Dark (laminated) (vDk) was first introduced by Holdgate et al. (1995).

In Germany (Figs. 2 & 3), different brown coal classification systems have evolved between different open cut areas, including schemes similar to Latrobe Valley or even to black coal (i.e. bright and dull). In the Rhenish brown coals in Germany, lithotype colour is generally regarded as being less important, and the relative degree of banding, diffuse

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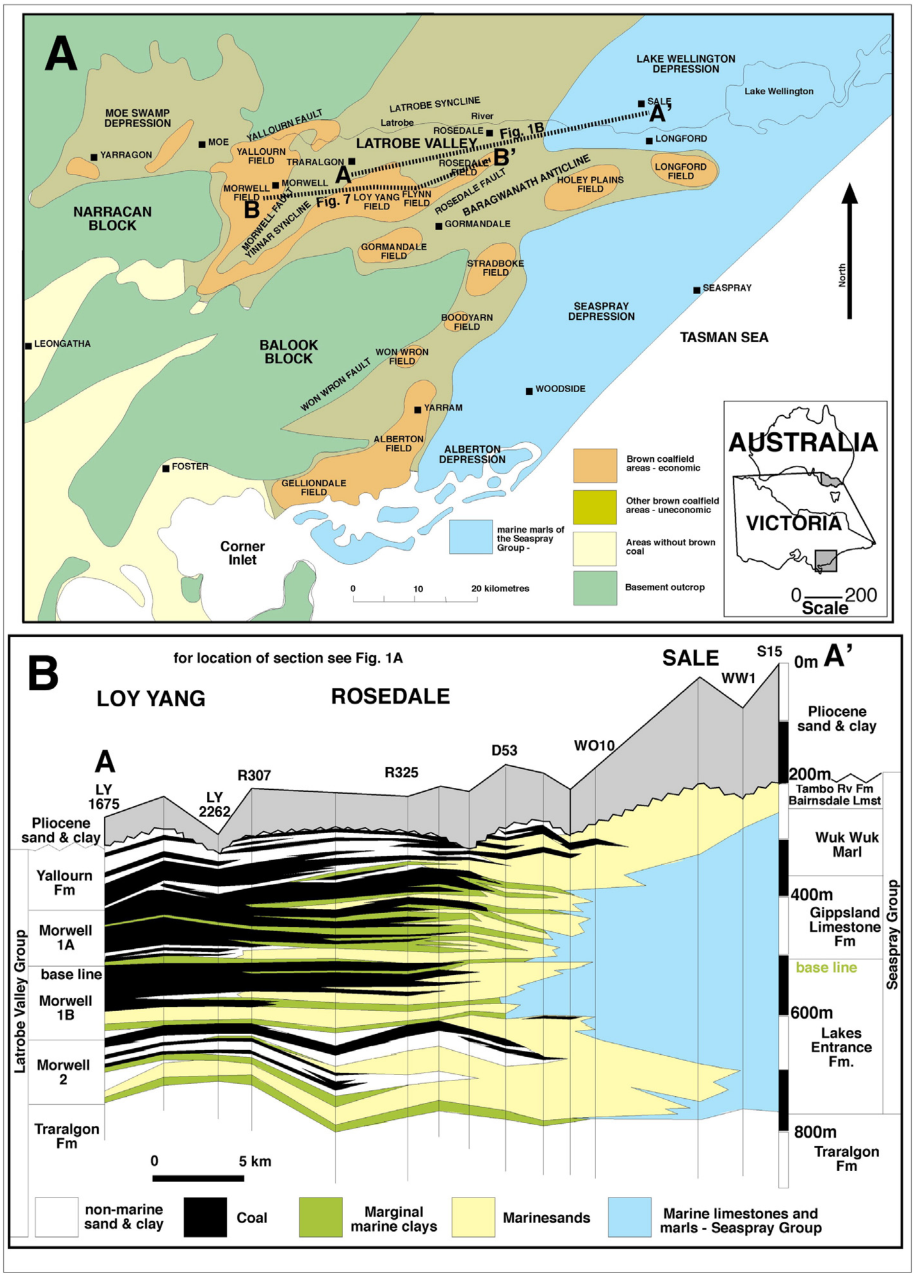

Fig. 1. Fig. A Above: location map of Gippsland Basin, Latrobe Valley and section lines Figs. 1B & 6. Fig. B. Below: West to east borehole stratigraphic cross-section along the Latrobe Valley, showing main coal seams and equivalent marine carbonate units for Yallourn and Morwell Formations.

reflectance, together with floral facies (Hagemann and Hollerbach, 1980; Schneider, 1992; Naeth et al., 2004) are considered more important than colour. Other coal aspects related to lithotype include the occurrence of charcoal, degree of gelification and abundance of larger woody pieces.

Lithotype analysis led to the recognition of cyclicity in Latrobe Valley brown coals (Mackay et al., 1985; Holdgate et al., 1995), but there remains some disagreement in interpretation of the causes. Each coal seam was found to comprise a number of colour cycles mostly with lightening-upwards trends (Fig. 4). The principle lithotypes (P, L, ML, MD, Dk, vDk) contain characteristic patterns of colour but also texture, gelification and weathering which are more fully documented by George and Mackay (1991). Brown coal cyclicity is also not universally agreed upon, and is contingent on interpretation of lithotypes. The two dominant models for lithotype cycles are the dry-dark model and the dry-light (Holdgate et al., 2014). In the dry-dark model, darker lithotypes are interpreted as the driest lithotypes and light lithotypes are deposited in open water. In the dry-light model, the reverse is true. These two opposing models were first developed for the German brown coals (Teichmüller, 1950; Teichmüller, 1958, 1989; Hagemann and Hollerbach, 1980; Hagemann and Wolf, 1987). Research on the Latrobe Valley lithotypes initially followed the dry-dark model (e.g. Luly et al., 1980; Kershaw and Sluiter, 1982; Sluiter and Kershaw, 1982; Finotella and Johns, 1986; Sluiter et al., 1995; Blackburn and Sluiter, 1994) after the early work on German coals.

However, some researchers more recently have found evidence to support the dry-light model for the Latrobe Valley Coals. The dry-light model as used here refers to the development of a peat dome and increasingly ombrogenous conditions during the development of the cycle (Anderson and Mackay, 1990; Holdgate et al., 1995, 2014). As the peat dome develops, the peat in the upper part of the cycle is deposited in increasingly better drained (slightly drier) conditions, leading to