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Oligo-Miocene peatland ecosystems of the Gippsland Basin and modern analogues

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ABSTRACT

A detailed examination of the brown coal facies preserved in the Latrobe Valley Morwell 1B seam indicates that the type of peat-forming environment and the associated hydrological regime are the main factors influencing the development of lithotypes in brown coal deposits. New palynological data from the Morwell 1B seam suggests that each respective lithotype in the lightening-upwards lithotype cycles was deposited in a particular depositional environment that was characterised by a distinct floral community. The laminated dark lithotype represents a fire-prone emergent marsh that grew on the margins of a coastal lagoon and/or freshwater swamp. This facies grades into the dark lithotype, representing the transition from a meadow marsh to a periodically flooded ombrogenous forested bog. The medium and lighter lithotypes are interpreted as being deposited in an angiosperm-dominated ombrogenous forest bog that was intolerant of fire. These peat-forming environments are interpreted as being largely controlled by moisture and relative depth to water table. Each environment produces distinct lithotypes and lightening-upwards cycles are interpreted as terrestrialization cycles. As the peat grew upwards and above the water table, less moist conditions prevailed and lighter lithotypes were produced. The observed change in colour, from darker to lighter lithotypes, results from the environment evolving from anaerobic/inundated to less anaerobic/less moist settings via terrestrialization. The thin and laterally extensive light and pale lithotypes that top the cycles are interpreted to represent a residual layer of concentrated, oxidation resistant peat-forming elements that result from intense weathering and aerobic degradation of the peats. At a generic level, modern lowland bogs of South Westland in New Zealand have remarkably similar floral/ecological gradients to those of the Oligo-Miocene Morwell 1B brown coal cycles in Australia. This suggests that modern New Zealand bogs can be used as floral/ecological analogues in order to better understand these Oligo-Miocene peatland environments.

1. Introduction

The origin and interpretations of brown coal lithotypes have been controversial. Following the early facies models from the German brown coals (e.g. Teichmüller 1952, 1958), the lighter-coloured lithotypes from the Latrobe Valley were initially interpreted as accumulating in permanently inundated, largely stagnant, laterally extensive and relatively deep (>1 m) lakes (Luly et al., 1980; Kershaw and Sluiter, 1982; Kershaw et al., 1991). This was based on a lack of identifiable plant macro remains and a predominance of pollen derived from supposed dryland plants with good dispersal ability. The slow accumulation of regionally-derived pollen in these lakes was thought to account for the higher pollen concentrations recorded in the lighter lithotypes (Kershaw et al., 1991). In contrast, Anderson and Mackay (1990) argued that the lack of macroscopic plant debris was evidence that conditions at the time of deposition actually led to high degrees of degradation. More recent studies also suggest that the lighter lithotypes represent the final stages of ombrogenous peat growth and reflect relative drying-upwards in ombrogenous peat domes (Holdgate et al., 2014; Korasidis et al., 2016).

This paper presents a detailed study of the lightening-upwards cycles within the Morwell 1B seam of the Latrobe Valley based on new palynological (i.e. spore-pollen abundance data, a study of pollen grain preservation and average pollen concentration), geological and charcoal data, in conjunction with pre-existing geochemical and palaeobotanical data. In particular, the lightest lithotypes were investigated in detail because the controversial interpretation of these lithotypes resulted in contrasting models for the origin of brown coal lithotypes. Comparisons are also drawn from ombrogenous peats in Southeast Asia (i.e. Grady et al., 1993; Esterle and Ferm, 1994; Moore et al., 1996) and modern vegetation zonations in New Zealand (i.e. Mark and Smith, 1975; Robertson et al., 1991; Dickinson and Mark, 1994). We use modern New Zealand environments as floral analogues to better understand the Latrobe Valley Oligo-Miocene peatland environments.

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2. Geological setting

The Latrobe Valley Depression of the Gippsland Basin in Southeastern Australia (Fig. 1) contains thick and widespread Eocene to Miocene brown coals and associated sediments up to 700 m thick (Holdgate et al., 2000). Individual seams are >100 m thick, and the vertical multi-seam levels of the coals are without parallel globally (Holdgate et al., 1995). The main coal-bearing sequences in the Latrobe Valley Group of the onshore Gippsland Basin are, in stratigraphic order, the Traralgon Formation, the Morwell Formation and the Yallourn Formation. Within the Gippsland Basin, the Morwell Formation is further subdivided into the Morwell 1A (M1A), Morwell 1B (M1B), Morwell 2A (M2A), Morwell 2B (M2B) and Morwell 2C (M2C) seams (Holdgate et al., 2009). The M1B seam, the focus of this paper, is the widest in extent and has the overall greatest thickness within the Latrobe Valley Depression, covering some 650 km^2 mostly to the south of the Latrobe River (Holdgate, 2003). The M1B seam is assigned to the Middle and Upper subzones of the *Proteacidites tuberculatus* Zone (Stover and Partridge, 1973; Blackburn and Sluiter 1994; Holdgate et al. (1995) and is suggested to have a Late Oligocene to Early Miocene age (Partridge, 2006). In the Loy Yang Dome area, between the Traralgon Creek and Rosedale Monocline, the M1B seam reaches a maximum thickness of between 100 and 120 m where it is mined at Loy Yang Open Cut (Holdgate, 2003).

3. Lithotypes in the Latrobe Valley and lithotype models

Six lithotypes, defined on dry and weathered coal surfaces by colour, texture, gelification and weathering, are recognized in the Latrobe Valley brown coals: laminated dark, dark, medium dark, medium light, light and pale (George and Mackay, 1991; Holdgate et al., 1995). The lithotypes occur as a series of 10–30 m cycles and are characterised by lightening-upward trends with prominent banding on a 1–3 m scale (Mackay et al., 1985; Holdgate et al., 2014). Various models have been proposed, based on different disciplines, to explain the formation of lithotype cycles in brown coals. Teichmüller (1958) first suggested a series of palaeoenvironments ranging from open water to dry forest, in a regular hydroseral series. Luly et al. (1980) and later Kershaw et al. (1991) modified this German model for the Latrobe Valley and proposed that the palaeoenvironment ranged from open water (represented by the lighter lithotypes), to increasingly drier swamp substrates (represented by the darker lithotypes). In contrast, Anderson and Mackay (1990) proposed that the dark lithotypes represented the wettest facies while the light lithotypes represented the driest. More recently, Korasidis et al. (2016) and Holdgate et al. (2014) proposed that the Latrobe Valley lightening-upwards lithotype cycles were caused by relative drying-upwards in ombrogenous peats, in agreement with Anderson and Mackay (1990). The lighter lithotypes were suggested to form in the less moist, less anoxic and upper portions of the peat dome, while darker lithotypes formed in the lower, more anoxic, wetter facies (Anderson and Mackay, 1990; Korasidis et al., 2016).

4. Methodology

Stratigraphic sections from the M1B seam were measured on the southeastern and eastern face of the Loy Yang Open Cut Mine (Fig. 2). Coal samples were repeatedly collected at 25 cm intervals based on the stratigraphic heights measured using a Jacob's staff. These samples were dried at 40 degrees for 3 days and crushed to a grain size of 0.5–1 mm because the lithotype colour range is dependent on the grainsize of the crushed coal (Attwood et al., 1984). Quantitative colourimetry was subsequently performed using a Konica Minolta Chromameter CR-410 with the Hunter L, a, b colour scale. The three colour outputs - L(lightness), a(red) and b(yellow) were combined to produce a colour index using the formula as stated in Holdgate et al. (2014):

Colour index = 10(L' + a' + b') + 100, where L = (L-16.966)/2.050, a' = (a-2.534)/0.604 and b' = (b-4.421)/1.304. This is the standard colour index system used for colourimetry in the Latrobe Valley (e.g. Attwood et al., 1984; HunterLab, 2007). At the beginning of each session the colourimeter was calibrated using a white calibration standard and an internal standard coal sample was repeatedly measured every 24 samples to determine precision. The typical colour range of each lithotype as outlined in Korasidis et al. (2016) at Loy Yang has been followed in this study.

A detailed palynology study of selected intervals throughout the M1B seam has been undertaken to investigate the lightening upwards cycles and in particular, the formation of the light and pale lithotypes (Fig. 3). The selected intervals include two relatively complete lightening-upwards cycles and select samples from more restricted

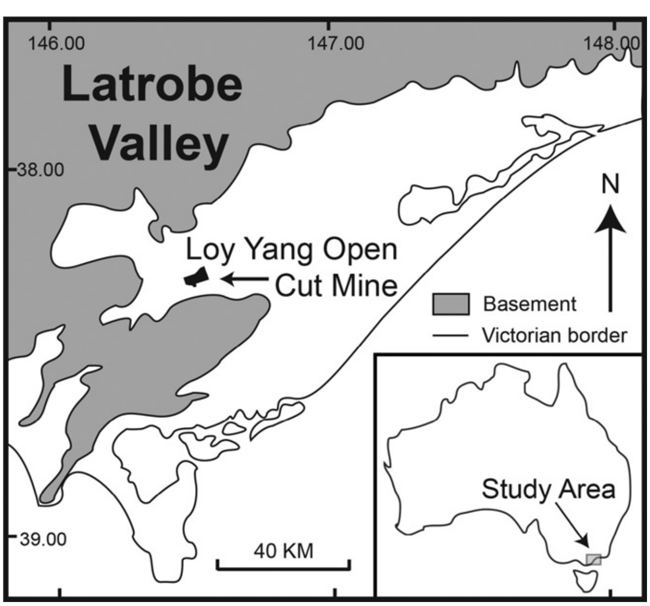

Fig. 1. Location of the Latrobe Valley in the Gippsland Basin. Modified from Holdgate et al. (2014).

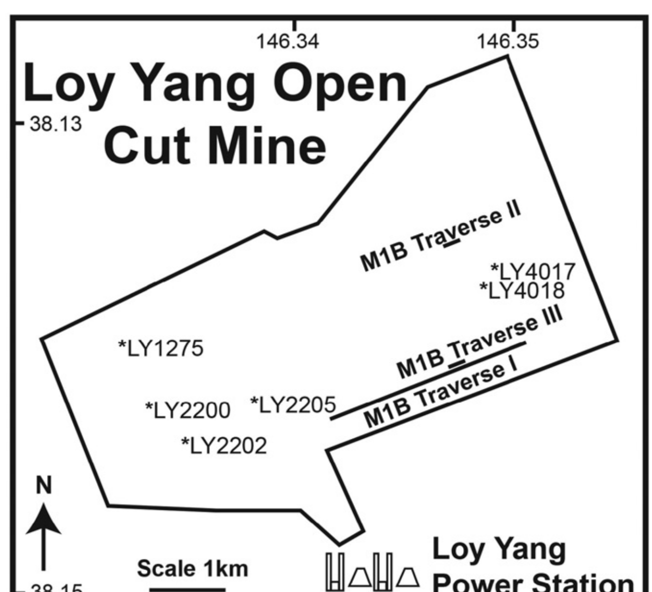

Fig. 2. Map of Loy Yang Open Cut Mine illustrating the location of the M1B Traverse Sections I–III and bores (prefix LY). Modified from Holdgate et al. (2014).