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PGEOLA 600 No. of Pages 23

ARTICLE IN PRESS

Proceedings of the Geologists' Association xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Proceedings of the Geologists' Association

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

Context article

The Carboniferous coal swamp floras of England: a window on an ancient tropical ecosystem

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ARTICLE INFO

Article history:
Received 7 December 2016
Received in revised form 18 April 2017
Accepted 4 May 2017
Available online xxx

Keywords:
Carboniferous
Palaeobotany

ABSTRACT

England has an exceptional range of Westphalian–Stephanian (late Bashkirian–Moscovian) fossil floras spanning some 10 million years. They represent vegetation growing in part of a swamp that covered large areas of tropical Euramerica and which was responsible for the removal of vast quantities of carbon from the atmosphere. This coincided with significant global climatic cooling—the Late Palaeozoic Ice Age. The cratonic Pennine Basin in central and northern England has some of the best preserved fossil floras of this age anywhere in the world, especially notable being those of the Barnsley Thick Seam in Yorkshire and Derbyshire, the Bensham Seam in Northumberland and Durham, and the Coseley Ten Foot Ironstone in the West Midlands. The floras in southern England are mostly not as well preserved but include the historically important Radstock flora of Somerset. The taxonomic diversity dynamics of the fossil floras of the Pennine Basin are rather different from those seen in South Wales, probably due to differences in landscape and habitat, which in turn probably reflect the different tectonic settings. However, evidence of a significant change from lycophyte- to fern-dominated vegetation in latest Westphalian times, recognisable across Euramerica, can be seen in the English floras.

1. Introduction

In Pennsylvanian (late Carboniferous) times England was located within a belt of swamp forests that at its maximum extent covered some 1.2×10^6 km^2 of lowland tropical Euramerica (Fig. 1; Cleal and Thomas, 2005; Opluštil and Cleal, 2007; Cleal et al., 2010, 2011). Partly because of the rather bizarre biology of one of the dominant groups of plants, the arborescent lycophytes or club mosses (Thomas, 1978; DiMichele and Phillips, 1985; Phillips and DiMichele, 1992), these swamps generated vast quantities of peat. Overall it has been estimated that at their peak the swamps were responsible for the sequestration of 13–47 $\times 10^9$ t of carbon per annum (Cleal and Thomas, 2005), substantially reducing levels of CO_2 in the atmosphere (Berner, 2005) and coinciding with a time of global climatic cooling and polar glaciation—the Late Palaeozoic Ice Age (Cleal and Thomas, 2005). The peat largely remained in the ground as coal until the 19th century, when Europeans and then Americans started large-scale exploitation of it to fuel the Industrial Revolution. Evidence now strongly suggests that returning this long-buried carbon back into the atmosphere is having a reverse effect on the climate, coinciding with a period of marked global warming (e.g. Stocker, 2014).

Associated with these coals are abundant fossil plants, which have told us a great deal about how these swamps (often referred to as coal swamps) developed and changed with time. The geoheritage of these fossils in England is remarkably good, especially for the Westphalian Stage, and this paper will explore some aspects of what they tell us about this important time of Earth history. Since coal mining has declined dramatically in England in recent years, making it difficult to collect these plant fossils, now is therefore a good time for such a review.

The main focus will be on the adpression floras (adpression is a term introduced by Shute and Cleal (1986) to replace the more cumbersome compression–impression), these being the commonest type of plant fossil found in these clastic deposits. Reference is also made to the plant fossils preserved as authigenic mineralisations (*sensu* Schopf, 1975) in siderite nodules and anatomically preserved, allochthonous plant fossils found in the clastic deposits (Falcon-Lang et al., 2011a, 2012). The coal ball floras will only be discussed briefly (they have been reviewed elsewhere—Galtier, 1997).

2. Historical context

The plant fossils associated with the Pennsylvanian coals in England (sometimes referred to as coal floras or Coal Measures floras) have attracted collectors in England since the 18th century

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http://dx.doi.org/10.1016/j.pgeola.2017.05.005
0016-7878/

Please cite this article in press as: C.J. Cleal, The Carboniferous coal swamp floras of England: a window on an ancient tropical ecosystem, Proc. Geol. Assoc. (2017), http://dx.doi.org/10.1016/j.pgeola.2017.05.005

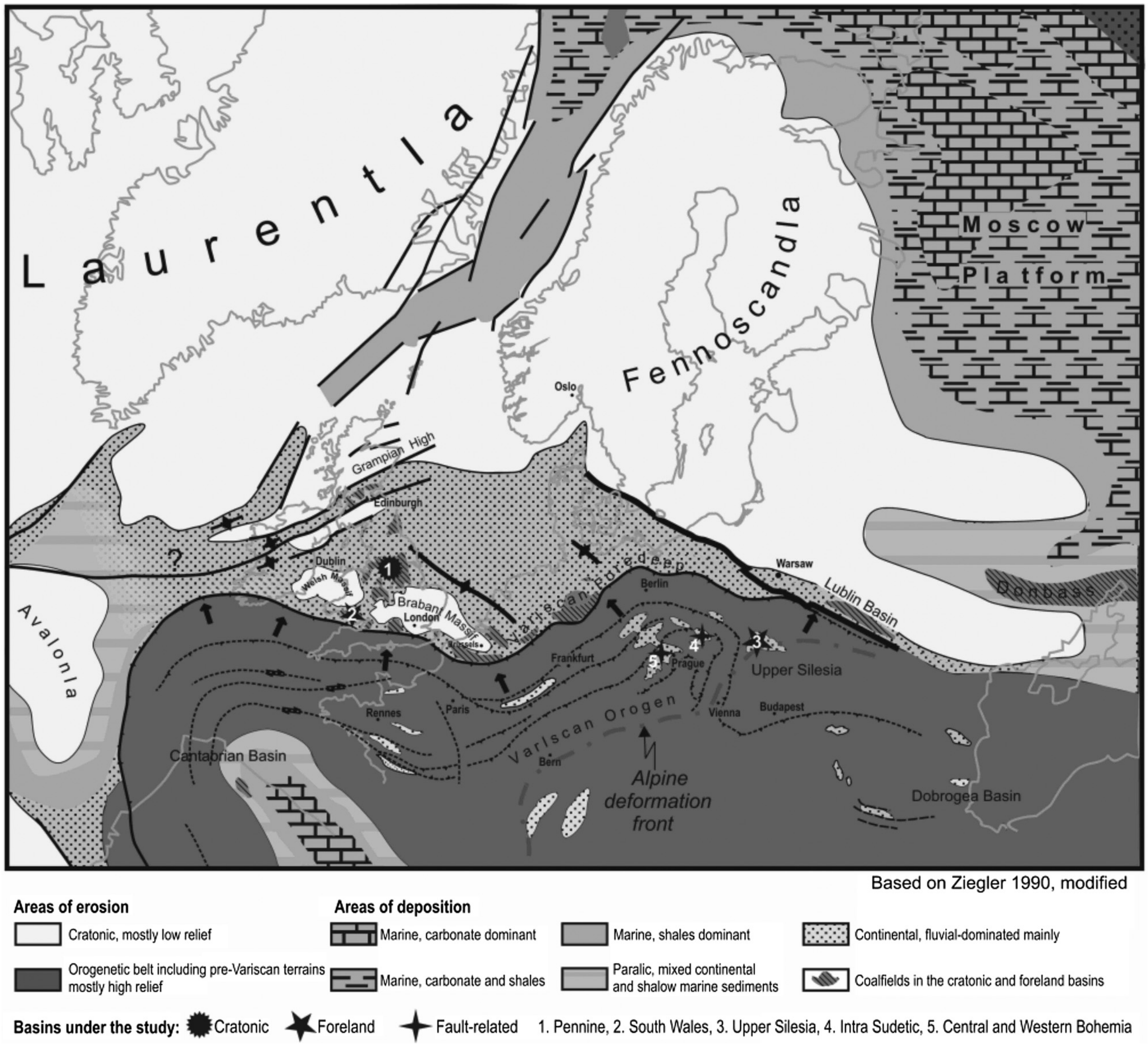

Fig. 1. Palaeogeographical map of the Variscan Foreland area in Europe (from Opluštil and Cleal, 2007).

(for historical reviews, see Arber, 1921; Crookall, 1938; Walton, 1959; Andrews, 1980; Edwards, 1984; Cleal et al., 2005, 2009a, 2012a; Chaloner and Pearson, 2005). Importantly, these fossils came to be regarded as major biostratigraphical tools for helping correlate these coal deposits (Kidston, 1894, 1905; Hickling, 1907; Crookall, 1931a,b; Crookall, 1932a,b,c,d, 1934) and as a result large collections were built up, which are now housed in many national and local museums. The work culminated in the classic publications on the British Carboniferous floras by Kidston (1923–1925) and Crookall (1929a, 19551976).

In the mid-20th century, however, interest in these fossil floras in England waned as non-marine bivalves, marine bands and later palynology took over as the main stratigraphical tools (Ramsbottom et al., 1978); it is notable that the only review of the upper Carboniferous floras of Britain during this time was written in German by the Dutch palaeobotanist Wilhelmius Jongmans (1940). In continental Europe, palaeobotany nevertheless continued to be extensively used as a biostratigraphical tool (e.g. Wagner, 1966, 1984; Germer et al., 1968; Germer and Kneuper, 1970; Josten, 1971; Josten and Laveine, 1983; Doubinger and Vetter, 1985; Laveine, 1987). In recent years, there has been a resurgence of palaeobotanical interest in some of the English coalfields (e.g. Chaloner and Collinson, 1975; Scott, 1977, 1978, 1979, 1984; Cleal, 1986, 1987, 1991a, 1997, 2005, 2008a; Thomas and Cleal, 1994; Cleal and Thomas, 1988, 2004; Pendleton et al., 2012), partly for biostratigraphical correlation, especially in the younger strata where there are no marine bands and the non-marine bivalves are less useful stratigraphically (e.g. see comments by Cleal (1984)). There is also now a raised awareness of the importance of the dynamics of vegetation change recorded in these rocks and its relationship to late Carboniferous climate and landscape change (Cleal et al., 2007, 2010, 2011, 2012b).

3. Palaeogeographical context

During late Carboniferous times, England lay to the north of the rising Variscan Orogen (Fig. 1). Clastic deposits derived from this orogen, as well as from sources to the north and east (Cope et al., 1992; Hallsworth and Chisholm, 2000) formed the substrate for the eventual development of the coal swamps during Westphalian times. The resulting coal-bearing deposits are now segmented into a series of separate coalfields, reflecting a combination of original