Review of Palaeobotany and Palynology 190 (2013) 1–14

Contents lists available at SciVerse ScienceDirect

Review of Palaeobotany and Palynology

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

Research paper

Pennsylvanian (Namurian and Westphalian) miospore assemblages from the west coast of Scotland

Duncan McLean [a,*], Bernard Owens [b], Janine L. Pendleton [b], David Bodman [a]

[a] MB Stratigraphy Ltd., 11 Clement Street, Sheffield, S9 5EA, UK
[b] Palynology Research Facility, Department of Animal and Plant Sciences, University of Sheffield, Sheffield, S10 2TN, UK

ARTICLE INFO

Article history:
Received 16 March 2012
Received in revised form 7 November 2012
Accepted 18 November 2012
Available online 5 December 2012

Keywords:
miospores
Carboniferous
Pennsylvanian
palynostratigraphy
Scotland

ABSTRACT

Examination of cored borehole sections of Pennsylvanian sediments in the Machrihanish Coalfield on Kintyre and samples from coastal exposures at Inninmore Bay on the Sound of Mull, demonstrate the existence of Westphalian (Langsettian to Bolsovian) sediments in both close proximity to the Highland Boundary Fault zone and in isolated outliers within the western parts of the Scottish Highlands. Earlier studies suggested a Duckmantian to Bolsovian age for the Inninmore Bay sections and the investigation of material from new sections in the area confirms this stratigraphical range. The borehole sections in the Machrihanish Coalfield demonstrate the unconformable relationship between the probable Namurian to Westphalian sediments of the Scottish Coal Measures Group and the underlying early Namurian Limestone Coal Formation. In addition to rich assemblages of western European miospore taxa, the Machrihanish populations contain examples of species such as *Columinisporites ovalis*, *Paleospora fragila*, *Spackmanites irregularis* and *Vestispora colchesterensis* which are characteristic of North American assemblages. The distinctive species *Playfordiaspora cancellosa* is reported from the British Carboniferous.

1. Introduction

Carboniferous (Pennsylvanian) deposits have been extensively reported throughout the Midland Valley of Scotland from Fife in the east to the Machrihanish Coalfield in Kintyre in the west (Fig. 1), with much of the sedimentation taking place during a period of syndepositional rift development (Fyfe et al., 1993). In the central part of the Midland Valley basin up to 3000 m. of sediments accumulated but in the west, towards the Malin Sea, that total is significantly reduced (Waters et al., 2011). The exploitation of the mineral wealth, particularly coal, in these deposits was important not only in the development of Scottish industry but also, from the early 1940s, in the foundations of Carboniferous palynostratigraphy.

As early as 1938, Elizabeth Knox at the University of Edinburgh carried out pioneering studies on the miospores recovered from the Westphalian Scottish Coal Measures Group of Fife in which she documented the stratigraphical ranges of species from a number of sections (Knox, 1938, 1939, 1941–1942). Subsequent studies in the Central Coalfield (Knox, 1945–1946) generated analogous results and in 1948 she recognised the consistent relationship between the stratigraphical distribution patterns for the miospores with those from the non-marine bivalves that provided the standard for Coal Measures correlation (Knox, 1947–1948). Miospores in all of Knox's early publications were identified using a numerical classification following the practice of Raistrick (1934–1935) but in 1950 she became the first worker to apply standard binomial nomenclature to British dispersed miospores (Knox, 1950). Studies in other British coalfields by Balme (1951), Balme and Butterworth (1952), Butterworth and Millott (1960) and Butterworth (1964) led to the development of the first formal miospore biozonation scheme to deal with the correlation of Westphalian coal-bearing deposits.

Attention was also turned to documenting the palynostratigraphic characteristics of other, older, Scottish Carboniferous coal-bearing deposits in the Midland Valley. Butterworth and Williams (1958) described Mississippian, early Namurian miospore assemblages from coals in the Limestone Coal Formation and Upper Limestone Formation whilst Love (1960) and Sullivan and Marshall (1966) documented late Viséan microfloras from the Lower Oil Shale Group of the Lothians (now the Hopetoun Member of the West Lothian Oil Shale Formation, Chisholm and Brand, 1994) and the Upper Sedimentary Group (now the Lawmuir Formation, Browne et al., 1999) and Lower Limestone Formation of Renfrewshire and Ayrshire respectively. These latter studies involving examination of a wider spectrum of sample lithologies were significant in demonstrating close comparison in distribution patterns across a range of sedimentary environments. Coal seams are poorly developed in the Namurian Passage Formation and paucity of biostratigraphical evidence led to the belief that much of the stage was probably absent. Examination of miospore assemblages from thin coal seams from a borehole in the Clackmannan Coalfield by Neves et al. (1965) suggested correlations with the thick, well-dated successions in the Central Pennine Basin.

* Corresponding author. Tel.: +44 114 2663786.
E-mail address: d.mclean@mbstratigraphy.co.uk (D. McLean).

0034-6667/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.revpalbo.2012.11.005

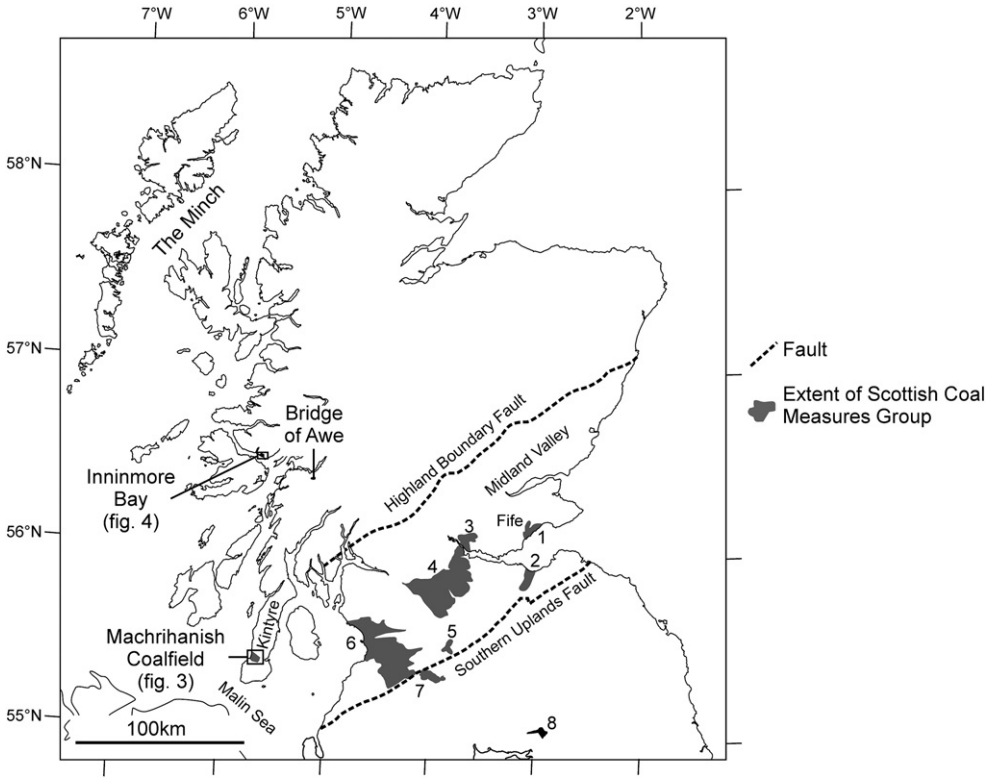

Fig. 1. Extent of the Scottish Coal Measures Group in Scotland, and location of study areas. Identified coalfields are: 1. Fife; 2. Lothians; 3. Clackmannan; 4. Central; 5. Douglas; 6. Ayrshire; and 7. Sanquhar.

Detailed investigations of each of the main Scottish coalfields were published by Smith and Butterworth (1967) and the results consolidated with those from other British coalfields used to formulate a comprehensive scheme of eleven miospore biozones extending from the Viséan to Stephanian. The framework of this scheme was later integrated with only minor modifications into a more comprehensive proposal applicable throughout Western Europe by Clayton et al. (1977).

1.1. Stratigraphic framework

Pennsylvanian (Namurian–Westphalian) sediments display a high level of overall uniformity throughout the Midland Valley Basin. Local variations, particularly in terms of thickness and facies development are recorded in particular sub-basins in response to local tectonic and subsidence variations (Browne and Munro, 1989).

Unlike their counterparts in other parts of the United Kingdom, the Scottish sections lack the widespread occurrence of diagnostic macrofauna, particularly goniatites, necessitating the establishment of local criteria to subdivide the successions.

Browne et al. (1999) in a major review of Scottish Carboniferous stratigraphical nomenclature (Fig. 2) assigned all of the Namurian deposits of the Midland Valley to the Clackmannan Group. The base of the group is placed at the late Viséan (late Brigantian) Hurlet Limestone. The lower, Brigantian to Chokierian part of the group is characterised by cyclic deposits, dominated by limestones in the Lower Limestone Formation and the Upper Limestone Formation and by limestones and coals in the Limestone Coal Formation. The Passage Formation overlies the Upper Limestone Formation and constitutes the upper part of the Clackmannan Group. The lower boundary of the Passage Formation is placed at the top of the Castlecary Limestone which goniatite evidence indicates to be of Arnsbergian age (Currie, 1954). The formation consists predominantly of coarse-grained sandstones, structureless, grey and purple clayrocks, less common siltstones and mudstones and only rarely, thin coals. The upper boundary of the formation is placed at the Lowstone Marine Band in the basal Westphalian (early Langsettian). The goniatite *Gastrioceras subcrenatum* which is used to define the Namurian–Westphalian boundary has not been recorded in Scotland.

The overlying Westphalian deposits in the Midland Valley are assigned to the Scottish Coal Measures Group (Waters et al., 2007), a unit accorded group status in the revised classification of Browne et al. (1999). The unit consists of repeated cycles of sandstone, siltstone and mudstone with frequent coals and seatearths representing a wide range of fluvial, deltaic and lacustrine depositional environments. Marine faunas are rare but those developed are important in providing the basis for subdivision of the group into its component formations. The repeated cycles of the deposits of the Scottish Lower Coal Measures Formation typically consist of grey–white, coarse sandstones, siltstones and grey to black mudstones which frequently contain abundant non-marine bivalves. Coals and seatearths are developed at the top of most of the cycles. The upper boundary of the Scottish Lower Coal Measures Formation is placed at the Vanderbeckei Marine Band, locally known as the Queenslie Marine Band, at the Langsettian–Duckmantian substage boundary. Sediments assigned to the Scottish Middle Coal Measures Formation comprise similar lithologies with coals continuing to be developed at the top of many of the cycles. The upper boundary of this unit is placed at the base of the Aegiranum Marine Band, known locally as the Skipsey's Marine Band, which defines the Duckmantian–Bolsovian substage boundary. Reddish brown and purple sandstones dominate the sequences of the Scottish Upper Coal Measures Formation and are accompanied in these cyclic deposits by siltstones and structureless mudstones. Coals occur but are rare and frequently are replaced by red, haematitic limestones. The upper limit of the formation is marked by a regional unconformity beneath the overlying Permian.

Whilst these formations are extensively recorded and supported by detailed biostratigraphy in the Ayrshire, Douglas and the Central