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CORRELATION OF THE UPPER COAL MEASURES OF CENTRAL ENGLAND AND ADJOINING AREAS AND THEIR RELATIONSHIP TO THE STEPHANIAN OF THE CONTINENT

by E.G. POOLE, B. Sc. (*)

SUMMARY. — Recent deep fully cored boreholes sunk by the Institute of Geological Sciences in Oxfordshire have provided the key to the correlation between the Upper Coal Measures of the British South-West and Pennine provinces. Great variations in sedimentation occur among thick suites of primary red beds, coal-bearing sequences and thick sandstones. Good palaeontological collections made from various horizons have facilitated local correlation. These and other fossils from equivalent measures elsewhere are reviewed in terms of their stratigraphical significance. It is concluded that they are not sufficiently diagnostic to solve the controversial problem of the recognition of the Stephanian in Central England on a purely palaeontological basis It is therefore necessary to seek a stratigraphical solution to this problem and it is suggested that the base of the Stephanian in England be taken at the base of the Symon Unconformity, i.e., at or about the present boundary of the *Anthraconauta phillipsii* and *A. tenuis* zones. This boundary represents the time of a widespread enlargement of Upper Coal Measures deposition which overlapped on to earlier formations after a period of late-Westphalian earth-movements and is the only horizon in the English Upper Coal Measures which parallels the behaviour of the Holzer Konglomerat at the base of the Stephanian in N.W Germany.

PALEOGEOGRAPHICAL SYNTHESIS

In Westphalian times, large areas of North-West Europe and the British Isles were occupied by a gently subsiding swampy deltaic region which was bounded to the north by the land mass of the Scandinavian Shield and to the south by the main Hercynian Continent (Fig. 1).

Within the main deltaic region, a smaller land mass projected between south-eastern Eire and Belgium. This area, the Wales-Brabant Massif (Fig. 1), almost certainly formed an island from time to time during the Westphalian (WILLS, 1951, plate IX) when the deltaic region sank more rapidly and the connecting link to the main Hercynian Continent was overwhelmed by the marine incursions which now enable correlation between the present South Wales and Kent coalfields. Smaller islands also probably occurred at various other places within the delta such as the present-day Southern Uplands. Some parts of the delta had a greater rate of subsidence than others within which thick sequences of coal-bearing sediment accumulated. These basinal areas form the main productive coalfields of North-West Europe. At various times and in various places along the margin of the delta, subsidence did not keep pace with sedimentation and primary red beds (KRYNINE, 1949) of continental type (with only thin poor coal seams) were formed. Thus on the northern margin of the Wales-Brabant Massif in the Wyre Forest Coalfield and the southern part of the South Staffordshire Coalfield thick red beds form most of the Coal Measures sequence below the Halesowen Group (WHITEHEAD and EASTWOOD, 1927, pp. 83-95; WHITEHEAD and POCOCK, 1947; POOLE, 1966,

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pp. 132-139), and a similar situation occurs along its southern margin in the Forest of Dean and North Bristol coalfields (KELLAWAY & WELCH, 1948, p. 26).

In the main basinal areas the rhythmic sedimentation of mudstone, sandstone, seatearth, coal, continued normally throughout Westphalian times being only occasionally interrupted by short periods of greater subsidence when the sea flooded the whole deltaic region so producing the marine bands which are of

pp. 140-141) and faulting and folding in the Coalbrookdale Coalfield of the South Midlands of England with uplift and erosion. In this latter locality, secondary reddening (TROTTER, 1953) of uplifted, originally grey Coal Measures occurred at this time with hematitisation of the seams in the zone of oxidation (HOARE, 1960). The general uplift even extended into the central parts of the Pennine Province with the formation of primary red beds such as the Etruria Marl Group (GIBSON,

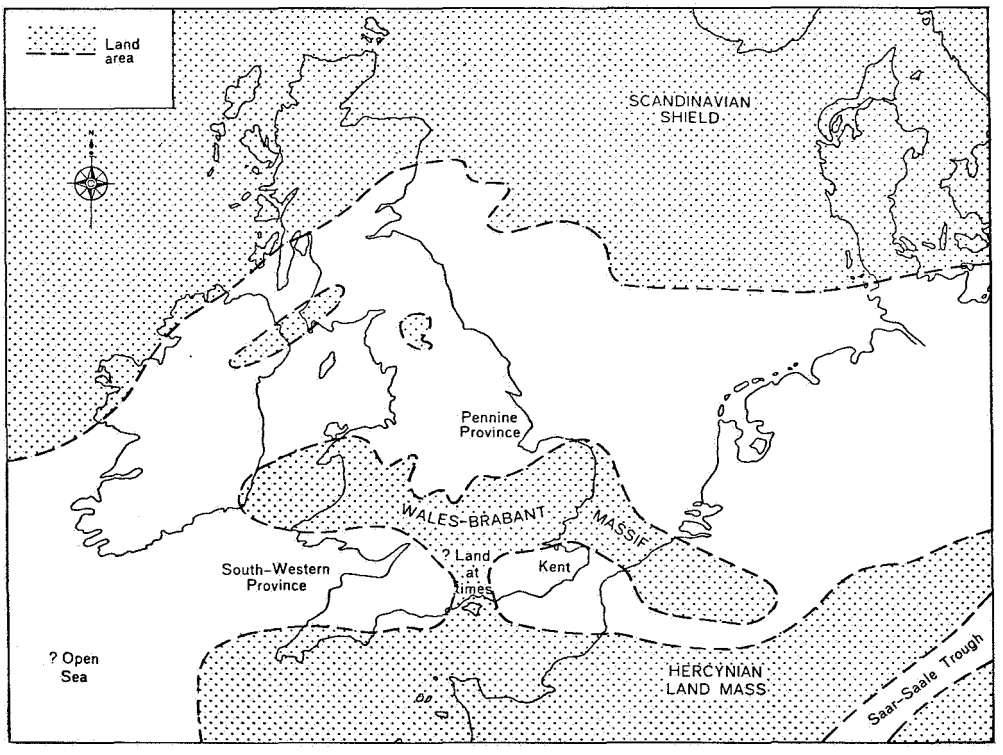

Fig. 1. — The paleogeography of North-West Europe in late Westphalian times (after Wills, 1951, plate IX).

such great value in present-day inter-coalfield correlation. The depositional centres of these basins migrated but slightly during Westphalian times (cf. HEIDEMANN and TEICHMÜLLER, 1971, fig. 4) but at the close of this age widespread earth-movements (the earliest Asturian phase of the Hercynian orogeny) occurred which fundamentally altered the whole paleogeographical and stratigraphical environment of North-West Europe (STILLE, 1928).

These early Hercynian earth-movements resulted in block-faulting in North-West Germany (HEIDEMANN and TEICHMÜLLER, 1971,

1905, pp. 129-134; EARP, 1961, p. 179-180) of North Staffordshire, the Barren Group of the Manchester area (POOLE and WHITEMAN, 1955, p. 315; MAGRAW, 1960, p. 439), the primary red beds which occur high in the Zone of *Anthraconauta phillipsii* of the Nottingham area (EDWARDS, 1967, p. 61-62) and the Red Measures of the concealed south-east Yorkshire Coalfields (EDWARDS, 1951, pp. 75-78 and fig. 36). Farther north, the Barren Red Measures of the Midland Valley of Scotland were also formed at this time (WEIR and LEITCH *in* MACGREGOR and MACGREGOR, 1948,

p. 49). In the South-Western Province and the present-day Kent Coalfield subsidence continued and thick deposits of deltaic sandstones were built up from the debris of the rising Hercynian mountain chains which were forming to the south.

Subsequently the whole deltaic region together with parts of the adjacent Hercynian land-mass sank and the formation of continental red-beds temporarily ceased. The Wales-Brabant Massif was also finally overwhelmed and the area of Pennant Sandstone deposition (which was previously confined to the south of the Massif) spilled over into the Pennine Province (Fig. 2). Thus 334 m of the Arenaceous Coal Group with a conglomeratic sandstone at its base were deposited on Upper Devonian rocks in the Apley Barn Borehole of the Witney area (POOLE, 1969, pp. 23-24) and farther north 176 m were deposited on higher horizons of the Upper Devonian at Steeple Aston (POOLE, 1971, pp. 394-395). This sandstone facies then continues northwards into the Pennine Province as the Halesowen Group (61 to 150 m thick) where it overlies secondarily reddened earlier Coal Measures strata. Yet farther north the Halesowen Group passes into rhythmically-bedded normal Coal Measures with thin seams and fresh-water *Spirorbis*-limestone bands, i.e. the Newcastle Group of North Staffordshire and the Ardwick Limestone Group of South Lancashire.

In the Bristol Coalfield of the South-West Province of England, two important coal-bearing formations, the Farrington Group and the Radstock Group, overlie the sandstones of the Mangotsfield Group (KELLAWAY, 1971, pp. 1044-1047). These coal groups are separated by a thick (c. 175 m) group of primary red beds (the Barren Red Group) and overlain by a second group of red beds, the Publow Group (Fig. 2). When traced northwards through the Oxfordshire boreholes the Farrington-Witney Coal Group, the Barren Red-Crawley Group and the Radstock-Burford Coal Group pass into the upper part of the Halesowen Group. This indicates a delicate environmental balance between subsidence with coal swamp formation and uplift with the deposition of continental red-beds facies and erosion in places. Eventually, continental conditions prevailed over much of Britain with the formation of the Publow and Keele groups.

In Grea Britain, the highest rocks to appear beneath the sub-Permian unconformity are the Enville Group of South Staffordshire and their equivalents in the southern English Midlands. These rocks are currently classed by the Institute of Geological Sciences as Upper Coal Measures but because these massive sandstones and conglomerates contain fossils with Permian affinites such as *Walchia imbricata* SCHIMPER, *W. piniformis* (SCHLOTHEIM), amphibian or reptilian footprints belonging to various species of *Ichnium,* a labyrinthodont skull of *Dasyceps buckland* (LLOYD) and a maxilla of the reptile *Oxyodon britannicus* VON HUENE there is a strong case for including them in the basal Permian and to equate them with the Rötliegende rocks of the Continent (MURCHISON, 1839, pp. 54-55; HULL, 1869, p. 13; WICKHAM KING, 1899, p. 108; VON HUENE, 1908; HARDAKER, 1912, pp. 680-681; VERNON, 1912, pp. 603-609; BOULTON, 1933 and 1951, p. 39 and PATON, 1974) (*).

CLASSIFICATION

In the past, various attempts have been made to solve the problem of the correlation of the British Upper Coal Measures with their counterparts in North-West Europe. The base of the Upper Coal Measures in Great Britain is now taken at the top of the marine band which contains *Anthracoceras cambriense* BISAT as characteristic goniatite (STUBBLEFIELD and TROTTER, 1957, p. 3 and plate 1). In terms of the Westphalian classification, this horizon lies near the middle of Westphalian C (BLESS, CALVER and JOSTEN, 1972, p. 226). The *A. cambriense* Marine Band is also arbitrarily taken as the boundary between the non-marine bivalve *Anthracosia similis-Anthraconaia pulchra* Zone and the *Anthraconauta phillipsii* Zone. Furthermore DIX and TRUEMAN (1937, p. 197) noted that it is near this horizon that significant changes occur in the floral sequence. These authors also pointed out that higher in the sequence the floral change from Westphalian to Stephanian forms appears to take place gradually and that the non-marine bihalves are of little help in dividing Westphalian from Stephanian.

Previously, DIX in her classic 1934 paper had grouped the Upper Carboniferous of South Wales into nine floral zones the three uppermost ones of which (Zones G, H and I) equate with the Upper Coal Measures division as proposed by STUBBLEFIELD and TROTTER (1957).

(*) Since this paper was prepared, HAUBOLD and SARJEANT (*Z. ged. Wiss. Berlin I,* 1973, 8.S., 895-933) have demonstrated that the tetrapod tracks in the Keele and Enville Groups of Shropshire and South Staffordshire are of Stephanian B and Autunian (Lower Permian) ages.

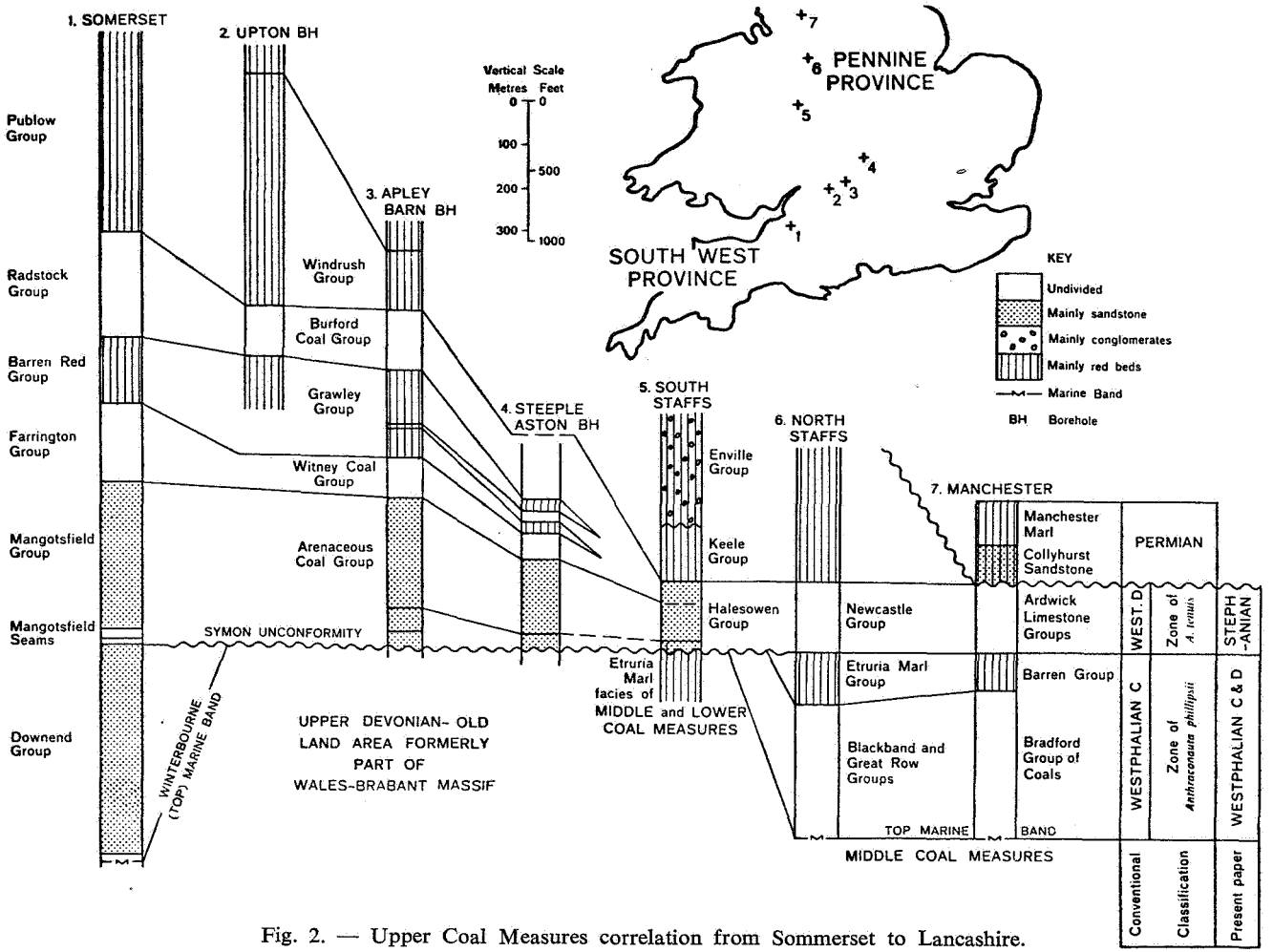

Fig. 2. — Upper Coal Measures correlation from Sommerset to Lancashire.

As explained by DIX (1934, p. 790) more than one index species is given for each zone but each index species may not necessarily be confined only to one zone and that it is the floral assemblage as a whole which determines the zonal position. The specific flora of the Upper Coal Measures according to DIX are as follows :

Flora G. — Zone of *Neuropteris rarinervis, N. linguaefolia, Linopteris münsteri, Mariopteris sauveuri, M. latifolia, Sphenopteris striata, Renaultia chaerophylloides* and *Asolanus camptotaenia.*

Flora H. — Zone of *Mixoneura* (*Neuropteris*) *ovata, N. scheuchezeri, N. flexuosa, Ondontopteris lindleyana, Alethopteris serli, Asterotheca miltoni* (*Pecopteris abbreviata*), *A.* (*P.*) *cyathea, A.* (*P.*) *arborescens, Sphenopteris neuropteroides, S. macilenta, Diplotmema geniculatum, Sphenophyllum emarginatum* and *Annularia stellata.*

Flora I. — Zone of *Asterotheca* (*Pecopteris*) *lamurensis, Acitheca polymorpha, Dicksonites pluckeneti, Mixoneura odontoteris sp., Alethopteris grandini* and *Sphenophyllum oblongifolium.*

Earlier workers had already tried to find the basis of a floral correlation between Britain and the Continent. KIDSTON (1914, p. 74; 1923, p. 9) showed the predominance of Stephanian species in the flora of the Keele Beds of Staffordshire which he equated with the Radstock Group and the Continental Stephanian. KIDSTON (1925, p. 587) recorded *Callipteridium gigas,* a form characteristic of the Assise de Saint-Etienne of the architypal Stephanian in France (BERTRAND, 1928, p. 97), from the roof of the Wernffraith Seam near Neath in South Wales; this coal occurs near the top of DIX's Floral Zone H. It is notable perhaps that the presence of many different species of *Callipteridium* is taken on the Continent to indicate the commencement of the Permian. CROOKALL (1925, p. 398) showed that the Farrington Series (the type section of the Farrington Group) of Somerset also contained a plant assemblage similar to that of the Keele Group of North Staffordshire. JONGMANS (1928, *in* table opposite p. 394) correlated the flora of the Hamstead Beds (Enville Group) with that of the Continental Lover Stephanian.

In spite of this, CROOKALL (1931), in a comprehensive review of the Upper Coal Measures of Britain and France, completely rejected the viewpoint that beds of Stephanian age were present in British Coal Measures. He pointed out (p. 67) that although one Permian form (*Walchia imbricata*) and a few characteristic Stephanian forms have been found in these rocks, the bulk of the flora of the Hamstead Beds, the Keele Group and of the Radstock Group also occurs in the Upper Westphalian of the Continent.

DIX however returned to the attack in her 1934 paper (pp. 832-836) and correlated the uppermost beds of the Coal Measures of South Wales from a short distance above the Wernffraith Seam with the basal beds of the Assise de Rive de Gier of the Stephanian of the Loire coalfields, France. She concluded (p. 836) that the « presence of strata of Lower Stephanian age is established beyond question in the South Wales Coalfield ».

In this viewpoint she was supported by TRUEMAN (1947, pp. LXXVII-LXXVIII) who remarked upon the fact that there was no important floral break between the Westphalian and Stephanian where the sequence is continuous and stated (p. LXXVII) that it « may be necessary to draw an arbitrary line, although locally the *Conglomérat de Holz* of the Saar Basin affords a suitable base for the Stephanian ».

More recently, WAGNER (1966) has indicated the possibility of an Upper Stephanian or Autunian flora in the Ayrshire Coalfield of Scotland and CALVER (1969, p. 253) has reviewed the problem but without reaching a definite conclusion.

As one might expect from the lack of a floral break the miospores also are of little use in determining the Westphalian/Stephanian boundary. *Thymospora* is a characteristic Stephanian genus on the Continent but it is also known from Westphalian D. Dr. A.H.V. SMITH has recorded *Thymospora perverrucosa* (ALPERN) WILSON and VENTATACHALA from the No. 1 Seam at Upton (WORSSAM, 1963, p. 140) and from the thin coals at 350.06 m (1148 ft 6 in) and 381.61 m (1252 ft) in the Apley Barn Borehole (POOLE, 1969, pp. 51-52), these seams lying within the Windrush Group of the Oxfordshire Coalfield. Dr. SMITH has also found that *Thymospora pseudothiessenii* is common in several seams belonging to the Burford Coal Group (Radstock Group) in the Steeple Aston and Apley Barn boreholes and *Thymospora sp.* was even recorded from the lowest seam encountered in the Steeple Aston Borehole well down in the Arenaceous Coal Group (Halesowen Sandstone). Dr. SMITH assigns all the Carboniferous spores from the Apley Barn and Steeple Aston boreholes to the Assemblage XI of SMITH and BUTTERWORTH (1967) which they equate with Westphalian D.

One might conclude from a study of the floral and microspore assemblages that no great evolutionary changes occured in the plants during Upper Westphalian-Stephanian times and that what differences in their assemblages which exist from place to place are merely reflections of differing environments.

The faunas of the Upper Coal Measures also offer little in the way of diagnostic species. Where species are well-known they invariably turn out to be long-ranging forms or facies-linked. The South Lancashire sequence is well-known from many National Coal Board deep cored boreholes. Above the Top Marine Band (Fig. 2) the highly fossiliferous Bradford Coal Group is estimated to be some 365 m (1200 ft) thick in the Manchester area (POOLE and WHITEMAN, 1955, pp. 295-299). This group, together with the succeeding Barren Group of primary red beds, is assigned to the Zone of *Anthraconauta phillipsii*. *A. phillipsii* continues to range upwards through the overlying Ardwick Limestone Group (the base of which is taken as the local lower limit of the Zone of *Anthraconauta tenuis*), and even into the Upper Group of St. Helens (TROTTER, 1952, p. 264). Forerunners of *A. tenuis* first appear in the upper half of the Bradford Coal Group but typical forms became abundant in the Ardwick Limestone Group and continue into the Upper Group. Thus the lower limit of the *A. tenuis* Zone in Lancashire (and elsewhere) is in part a stratigraphical boundary and not a purely palaeontological one. Recently, EAGAR (1973, pp. 400-404) has shown that these forms are facies-linked and that their relative abundance is directly related to the amount of organic carbon in the associated sediment, *A. phillipsii* favouring a high-carbon environment and *A. tenuis* a low one. Similar difficulties have been experienced in trying to set an upper limit to this zone. TRUEMAN (1941) erected a succeeding Zone of *Anthraconaia prolifera* to accommodate the Radstock Group of the Bristol-Somerset Coalfield, basing the zone on the presence of *Anthraconaia prolifera* (WATERLOT) and the absence of *Anthraconauta*. However, it is known (M.A. CALVER, *personal communication*) that *A. tenuis* occurs in the Radstock Group and in the succeeding Publow Group. TRUEMAN equated the *A. prolifera* Zone with the Stephanian of the Continent as the Lower Stephanian of the Saar Coalfield contains abundant examples of *A. prolifera*. It would appear that the absolute vertical range of *A. prolifera* has yet to be established (see below), and it is possible that it is a facies-related form.

In Britain, *A. prolifera* has been recorded from the Upper Group of S.W. Lancashire (TROTTER, 1952, p. 264), the Ardwick Limestone Group, the Keele and Newcastle groups of Staffordshire (CALVER, 1969, p. 253; MELVILLE, 1957, pp. 332-334), the Windrush Group of Oxfordshire (WORSSAM, 1963, p. 112), the Burford Coal Group of Oxfordshire (POOLE, 1969, p. 21) and the Radstock Group of Somerset. A similar species, *Anthraconaia pruvosti* (CHERNYSHEV) has been recorded at various localities in Britain from the *A. tenuis* Zone. However, WEIR (1967, p. 405) suggested that the *Anthracomya calcifera* PRUVOST 1925 *non* HIND, from supposed Stephanian of St.-Pierre-la-Cour, was probably more closely related to *Anthraconaia pruvosti* than *A. prolifera*, and added (p. 406) that « it would appear that the distinction of these stages [i.e. Westphalian and Stephanian] by lamellibranchs of the *pruvosti-prolifera* group alone is of doubtful validity » (see also CALVER, 1969, p. 253).

Among the arthropods, *Euestheria simoni* PRUVOST is locally abundant in British coalfields in the *A. phillipsii* and *A. tenuis* zones. Similar, though stunted forms of *Euestheria* were recorded from the Windrush Group of the Upton Borehole (WORSSAM, 1963, p. 124) and *Euestheria limbata* (GOLDENBERG) was found in the highest beds of the Windrush Group and in the Burford Coal Group in the Witney Borehole (POOLE, 1969, pp. 54-55); is also recorded from the Keele Group of North Staffordshire (CALVER, 1969, p. 253). The exact range of this latter fossil is unknown but in NW Germany its presence is taken as proof of the Stephanian (FABIAN, 1971, p. 98).

Examples of *Leaia* s.l. are known from various horizons in the British Coal Measures, particularly in the *A. tenuis* zone, but the ranges of the named species have not been defined. The type of *Leaia williamsoniana* JONES came from the Ardwick Limestone Group and the species is recorded from equivalent beds in SW Lancashire (TROTTER, 1952, p. 265). Leaiids are characteristics of the roof measures of the Coleford High Delf in the Forest of Dean Coalfield from which *Leaia paralella* RAYMOND, *L. bristolensis* RAYMOND and *Hemicycloleaia boltoni* RAYMOND are recorded (WELCH and TROTTER, 1961, p. 108). These species also occur in the Arenaceous Coal Group of the Apley Barn Borehole (POOLE, 1969, p. 24) and the latter two also range upwards into the Burford Coal Group (*ibid.*, p. 21), where *Leaia baentschiana* GEINITZ also occurs. In the Bristol Coalfield, the earliest record of *Leaia* is from the base of the

Mangotsfield Group (KELLAWAY *in* POOLE, 1969, pp. 31-32). Farther north, *Leaia sp.* was recorded in basal Coalport Group (Halesowen Group) some 7.6 m (25 ft) above the Symon Unconformity in the NCB Madeley Wood No. 4 Borehole near Coalbrookdale. It is notable perhaps that on the Continent, *Leaia* spp. although present in the Westphalian are commonly found in Stephanian sediments.

The pulmonate gastropod *Anthracopupa* cf. *britannica* COX has, with the exception of the record from high Westphalian A. of Durham (RICHARDSON and FRANCIS, 1971, p. 243), to date only been found in the highest British

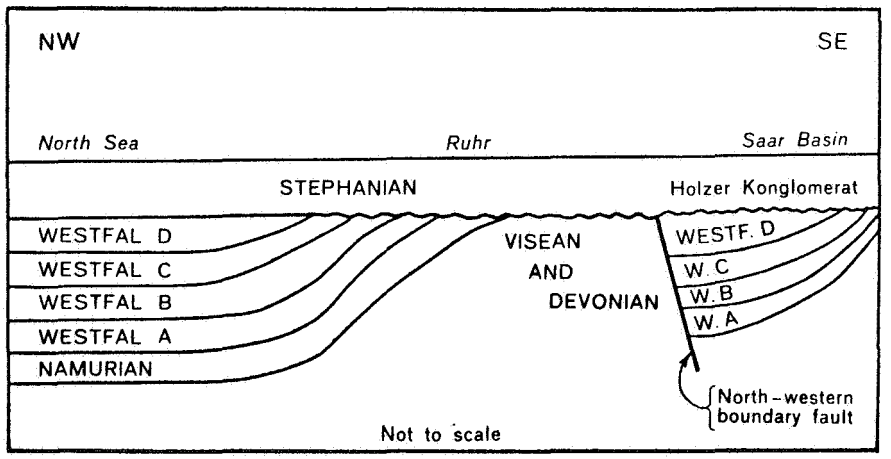

Fig. 3. — Diagrammatic cross-section showing the relationship of the Westphalian and Stephanian deposits in North-West Germany.

Coal Measures and has not been recorded on the Continent. In the Upper Coal Measures it has been discovered in the Keele Beds of Worcestershire (COX, 1926), the Keele Beds of Warwickshire (STUBBLEFIELD *in* MITCHELL, 1942, p. 19), the Keele Beds of N. Staffordshire (CALVER, 1964, p. 62) and the Windrush and Burford Coal groups in Oxfordshire (CALVER *in* WORSSAM, 1963, p. 121; POOLE, 1969, p. 17).

Ostracods are common in the British Upper Coal Measures with species of *Carbonita* occurring throughout but unfortunately they all appear to be long-ranging forms.

THE HOLZER KONGLOMERAT AND THE SYMON UNCONFORMITY

As shown above, the absence of any completely diagnostic fossils in the uppermost beds of Coal Measures age has resulted in the present-day confusion and controversy regarding the position of the base of (and even the presence of) the Stephanian in Great Britain. If however a purely stratigraphical solution is sought, then there can be only one horizon which accords with the general stratigraphical, palaeogeographical and palaeontological evidence. The base of the North-West German Stephanian succession is taken at the Holzer Konglomerat (Conglomérat de Holz) which lies at the base of the Ottweiler Group in the Saar Coalfield. This conglomerate unconformably overlies folded and eroded Westphalian deposits which had previously been laid down in a long, narrow, fault-controlled limnic basin (KNEUPER, 1971). Continuous movement of the basement blocks during Westphalian times directly affected the rate of sedimentation so that in the Saar basin, the greatest sedimentary thicknesses are found in a zone immediately adjacent to its north-western boundary fault. These earth-movements ceased at the commencement of Stephanian times so that these later deposits overstep directly onto older rocks outside the narrow Westphalian basin. When traced farther to the north-east, from the Ruhr to the North Sea Basin, the Stephanian gradually rests upon younger rocks (HEDEMAN and TEICHMÜLLER, 1971, fig. 3) and eventually bears an apparently conformable relationship to the highest Westphalian deposits (Fig. 3). The basal Stephanian sandstones thin to the north and pass into a limestone-bearing sequence. In the North Sea area, some of these limestones have been found to contain marine

fossils such as echinoderms (HEIDEMAN and TEICHMÜLLER, 1971, p. 144).

Similarly in Great Britain there is evidence of only one widespread intra-Upper Coal Measures unconformity which behaves in this fashion. This is the Symon Unconformity (SCOTT, 1861) of the Coalbrookdale Coalfield (Fig. 4) and its equivalents in the South Staffordshire Coalfield at the base of the Halesowen Group (WHITEHEAD and EASTWOOD, 1927, p. 87), in the Forest of Wyre Coalfield at the base of the Highley Group (WHITEHEAD and POCOCK, 1947, fig. 9), in the Forest of Dean gressive in places and, like the lower part of the Stephanian, suffers an enormous reduction in thickness when traced from its source areas in the south across the former Wales-Brabant Massif into the North Sea depositional centre.

The significance of the unconformity is that it represented the time when the Westphalian pattern of sedimentation in separate small basins ceased whereas the main centre of Stephanian deposition was situated in the Ems-North Sea depression into which all the deposits of North West Europe are apparently graded.

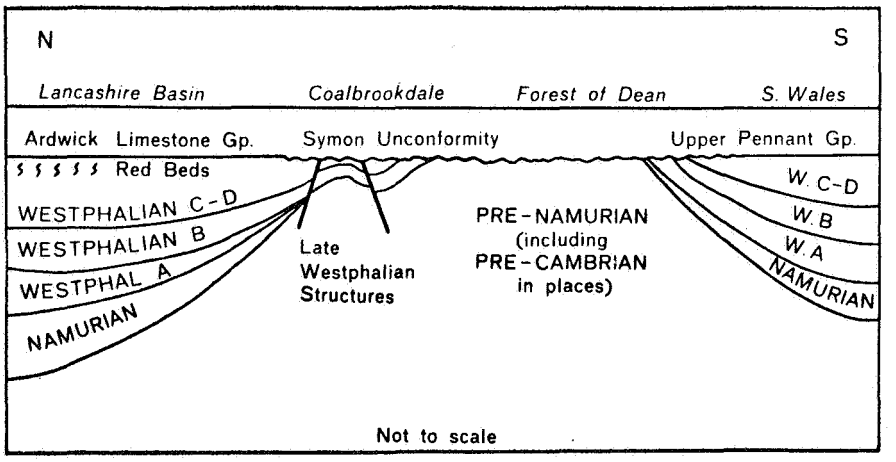

Fig. 4. — Diagrammatic cross-section showing the relationship of the Symon Unconformity to the Westphalian deposits in Great Britain.

Coalfield at the base of the Upper Coal Measures (SIBLY, 1912, pp. 420-422), at the base of the Upper Coal Measures in the concealed Oxfordshire Coalfield (POOLE, 1969, p. 24) and at the base of the Ardwick Limestone Group in the Lancashire Coalfield (POOLE and WHITEMAN, 1955, p. 316).

The suggested correlation of the Upper Coal Measures means effectively that the non-marine bivalve Zone of *Anthraconauta tenuis* and the equivalent miospore Zone of *Thymospora obscura* (SMITH and BUTTERWORTH, 1967) are placed in the Stephanian rather than equated with Westphalian D as at present. As defined above, the British Stephanian falls broadly into two divisions, a lower predominantly arenaceous and coal-bearing facies and an upper predominantly continental red facies (Fig. 3). It is noteworthy, and perhaps not to be unexpected, that the upper red facies (the Publow-Windrush-Keele groups) is trans-

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REFERENCES

BERTRAND, P., 1928, Stratigraphie du Westphalien et du Stéphanien dans les différents bassins houillers français. *Cong. Strat. Carb. Heerlen, 1927,* 93-116.

BLESS, M.J.M., CALVER, M.A. & JOSTEN, K-H., 1972, Report of the Working Group on the Westphalien C in N.W. Europe. *Compte Rendu VII^e Cong. Intern. Strat. Géol. Carbonif. Krefeld* 1971,**1,** 223-230.

BOULTON, W.S., 1933, The Rocks between the Carboniferous and the Trias in the Birmingham district. *Q. Jl. geol. Soc. Lond.*, **89**, 53-86.

— 1951, Permian Rocks of the Midlands. *Geol. Mag.*, **88**, 36-40.

CALVER, M.A., 1964, In *Sum. Prog. Geol. Surv.* for 1963, **62.**

— 1969, Westphalian of Britain. *Compte Rendu VI^e Cong. Intern. Strat. Géol. Carbonif. Sheffield 1967*, **1**, 233-254.

COX, L.R., 1926, *Anthracopupa britannica sp. nov.*, a Land Gastropod from the Red Beds of the Uppermost Coal Measures of Northern Worcestershire. *Q. Jl. geol. Soc. Lond.*, **82**, 401-410.

CROOKALL, R., 1925, On the Fossil Flora of the Bristol and Somerset Coalfield. *Geol. Mag.*, **62**, 385-410.

— 1931, Correlation of the British and French Upper Coal Measures. *Sum. Prog. geol. Surv. Gt. Brit.* (1930), 62-69.

DIX, E., 1934, The Sequence of Floras in the Upper Carboniferous, with special reference to South Wales. *Trans. Roy. Soc. Edin.*, **57**, 787-838.

DIX, E. & TRUEMAN, A.E., 1937, The value of non-marine lamellibranchs for the correlation of the Upper Carboniferous. *Congres. Strat. Carb. Heerlen 1935*, 185-201.

EAGAR, R.M.C., 1973, Variation in Shape of Shell in Relation to Palaeoecological Station in some non-marine Bivalvia of the Coal Measures of South-East Kentucky and of Britain. *Cong. Strat. Carb. Krefeld* 1971, Band II, 387-416.

EARP, J.R., 1961, Exploratory Boreholes in the North Staffordshire Coalfield. *Bull. geol. Surv. Gt. Brit.*, **17**, 153-190.

EDWARDS, W.N., 1951, The Concealed Coalfield of Yorkshire and Nottinghamshire, 3rd edit. *Mem. geol. Surv.*

— 1967, Geology of the country around Ollerton. *Mem. geol. Surv.*

FABIAN, H.J., 1971, Das Oberkarbon in Untergrund von Nordwestdeutschand — Stratigraphie und Tektonik. *Fortschr. Geol. Rheinld. u. Westf.*, 87-99.

GIBSON, W., 1905, The Geology of the North Staffordshire Coalfields. *Mem. geol. Surv.*

HARDAKER, W.H., 1912, On the Discovery of a Fossil-bearing Horizon in the "Permian" Rocks of Hamstead Quarries, near Birmingham, *Q. Jl. geol. Soc. Lond.*, **68**, 639-683.

HEDEMANN, H.A. & TEICHMÜLLER, R., 1971, 6. Die palaogeographische Entwicklung des Oberkarbons, *in* Die Karbonablagerungen in der Bundesrepublik Deutschland. III. A. Der paralische Raum. *Fortschr. Geol. Rheinld. u. Westf.*, **19**, 129-142.

HOARE, R.M., 1960, Red Beds in the Coal Measures of the West Midlands. *Trans. Inst. Min. Eng.*, **119**, 185-198.

HUENE, F. VON, 1908, Neue und verkante Pelycosaurier — Reste aus Europe. *Centralb. für Min. Geol. Pal. Jahrb.*, 431-434.

HULL, E., 1869, Triassic and Permian Rocks of the Midland Counties of England. *Mem. geol. Surv.*

JONGMANS, W.J., 1928, Geschichte, Einrichtung und Arbeitsmethoden des « Geologisch Bureau voor het Nederlandische Myngebied » in Heerlen. (Neiderl. Limburg). *Cong. Strat. Carb. Heerlen, 1927*, 311-397.

KELLAWAY, G.A., 1971, The Upper Coal Measures of South-West England compared with those of South Wales and the Southern Midlands. *Compte Rendu VI^e Cong. Strat. Géol. Carbonif. Sheffield 1967*, **1**, 1039-1056.

KELLAWAY, G.A. & WELSH, F.B.A., 1948, *British Regional Geology. The Bristol and Gloucester District (2nd edit., 9th imp. 1964).* Geol. Surv. G.B. London.

KIDSTON, R., 1914, On the Fossil Flora of the Staffordshire Coalfields. Part III. The Fossil Flora of the Westphalian Series of the South Staffordshire Coalfield. *Trans. Roy. Soc. Edin.*, **50**, 73-190.

— 1923-5, Fossil Plants of the Carboniferous Rocks of Great Britain. *Mem. Geol. Surv. Palaeont.*, **ii.**

KNEUPER, G., 1971, Das Saar — Nahe — Gebeit. *Fortschr. Geol. Rheinld. u. Westf.*, **19**, 143-158.

KRYNINE, P.D., 1949, The Origin of the Red Beds. *N.Y. Acad. Sci. Trans.*, **2**, 60-68.

MACGREGOR, M. & MACGREGOR, A.G., 1948, The Midland Valley of Scotland. 2nd edit. revised. *British Regional Geology, geol. Surv.*

MAGRAW, D., 1960, Exploratory Boreholes in the Central part of the South Lancashire Coalfield. *The Mining Engineer*, 433-448.

MELVILLE, R.V., 1947, The Non-marine lamellibranchs of the North Staffordshire Coalfield. *Ann. Mag. Nat. Hist.* (11), **13**, 289-337.

MITCHELL, G.H., 1942, The Geology of the Warwickshire Coalfield. *Geol. Surv. Wartime Pamphlet*, No. 25.

MURCHISON, R.I., 1839, Silurian System.

PATON, R.L., 1947, Lower Permian Pelycosaurs from the English Midlands. *Palaeontology*, **17**, 541-552.

POOLE, E.G., 1966, Trial boreholes on the site of a reservoir at Eymore Farm, near Bewdley, Worcestershire. *Bull. geol. Surv. Gt. Brit.* **24**, 131-155.

— 1969, The Stratigraphy of the Geological Survey Apley Barn Borehole, Witney, Oxfordshire, *Bull. geol. Surv. Gt. Brit.*, **29**, 1-104.

— 1971, The Oxfordshire Coalfield. *Nature*, **232**, 394-395.

POOLE, E.G. & WHITEMAN, A.J., 1955, Exploratory Boreholes in the Prestwich area of the South Lancashire Coalfield. *Trans. Inst. Min. Eng.*, **114**, 291-317.

RICHARDSON, G. & FRANCIS, E.H., 1971, Fragmental clayrock (FCR) in coal-bearing sequences in Scotland and North-East England. *Proc. Yorks. Geol. Soc.*, **38,** 229-260.

SCOTT, M.W.T., 1861, On the Symon Fault in the Coalbrookdale Coalfield. *Q. Jl. geol. Soc. Lond.*, **17,** 457-467.

SIBLY, T.F., 1912, The Carboniferous Succession in the Forest of Dean Coalfield. Geol. Mag., **9,** 417-422.

SMITH, A.H.V. & BUTTERWORTH, M.A., 1967, Miospores in the Coal Seams of the Carboniferous of Great Britain. *Pal. Ass. Spec. Paper No. 1,* 1-324.

STILLE, H., 1929, Zur Einführung in die Phasen der palaozoischen Gebirgsbildung. *Zeitscht. deutsch. geol. Gesellsch. 1928,* **80,** 1-25.

STUBBLEFIELD, C.J. & TROTTER, F.M., 1957, Divisions of the Coal Measures on Geological Surveys maps of England and Wales. *Bull. geol. Surv. Gt. Brit.*, **13,** 1-5.

TROTTER, F.M., 1952, Exploratory Borings in South-West Lancashire. *Trans. Inst. Min. Eng.*, **112,** 261-284.

— 1953, Reddened Beds of Carboniferous age in North-West England and their origin. *Proc. Yorks. geol. Soc.*, **29,** 1-20.

TRUEMAN, A.E., 1941, The Periods of Coal Formation represented in the British Coal Measures. *Geol .Mag.*, **78,** 71-76.

— 1947, Stratigraphical problems in the Coal Measures of Europe and North America. *Q. Jl. geol. Soc. Lond.*, **102,** XLIX-XCIII.

— 1948, Stratigraphical problems in the Coalfields of Great Britain. *Q. Jl. geol. Soc. Lond.*, **103,** LXV-CIV.

TRUEMAN, A.E. & WEIR, J., 1946, A monograph of British Carboniferous non-marine lamellibranchs. *Palaeontogr. Soc.* [*Monogr.*].

VERNON, R.D., 1912, On the Geology and Palaeontology of the Warwickshire Coalfield. *Q. Jl. geol. Soc. Lond.*, **68,** 587-638.

WAGNER, R.H., 1966, On the presence of probably Upper Stephanian beds in Ayrshire, Scotland. *Scott. J. Geol.*, **2,** 122-123.

WEIR, J., 1967, A monograph of British Carboniferous non-marine lamellibranchs. *Palaeontogr. Soc.* [*Monogr.*], **1,** 373-413.

WELCH, F.B.A. & TROTTNER, F.M., 1961, Geology of the Country around Monmouth and Shepstown. *Mem. Geol. Surv.*

WHITEHEAD, T.H. & EASTWOOD, T., 1927, The Geology of the Southern part of the South Staffordshire Coalfield. *Mem. Geol. Surv.*

WHITEHEAD, T.H., & POCOCK, R.W., 1947, Dudley and Bridgnorth. *Mem. Geol. Surv.*

WICKHAM KING, W., 1899, The Permian Conglomerates of the Lower Severn Basin. *Q. Jl. geol. Soc. Lond.*, **55,** 97-128.

WILLS, L.J., 1951, *A palaeogeographical atlas of the British Isles and adjacent parts of Europe.* Blackie and Son, London.

WORSSAM, B.C., 1963, The stratigraphy of the Geological Survey Upton Borehole, Oxfordshire. *Bull. geol. Surv. Gt. Brit.*, 20, 107-162.