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THE CHRONOSTRATIGRAPHIC UNITS OF THE UPPER CARBONIFEROUS IN EUROPE

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ABSTRACT: The history is traced of the various chronostratigraphic units recognised in the Upper Carboniferous of western Europe, and their stratotypes are discussed. A correlation is given for the chronostratigraphic units in the Middle and Upper Carboniferous series of Russia, in the light of predominantly marine successions in N.W. Spain, and suggestions are made for an integrated scheme of major units.

Introduction

The main chronostratigraphic divisions of the Carboniferous in Europe were established by MUNIER CHALMAS & DE LAPPARENT (1893), who distinguished three marine stages characterised by different faunas, viz. Dinantien[1], Moscovien[2] and Ouralien[1], and two stages, Westphalien[1] and Stéphanien, characterised by coal-measures facies. Most of the names had been used before (see footnotes), but the 'Note sur la Nomenclature des Terrains sédimentaires' provided the first formal framework for a subdivision into stages of the Carboniferous System. MUNIER CHALMAS & DE LAPPARENT gave precedence to the marine stages, Moscovian and Uralian, and regarded Westphalian and Stephanian as the equivalent units in non-marine facies. This marked a duality which was to remain in all subsequent classifications[3].

In western Europe the classification of Carboniferous strata was further taken in hand by the Congrès pour l'Avancement des Etudes de Stratigraphie Carbonifère which met in Heerlen in 1927, 1935, 1951 and 1958. The 1927 congress sanctioned the use of Namurian, a stage introduced by PURVES in 1883 and which corresponds to the Westphalien inférieur of MUNIER CHALMAS & DE LAPPARENT. It also introduced the A, B and C divisions for the remaining Westphalian (i.e. the Westphalien supérieur of MUNIER CHALMAS & DE LAPPARENT). The 1935 congress expanded the Westphalian upwards by recognising the presence of a Westphalian D division, and subdivided the Namurian into A, B and C. A subdivision of the Stephanian Stage into Stephanian A, B and C appeared in PRUVOST 1934, and was proposed in JONGMANS & PRUVOST (1950). This usage was followed by different authors and became finally incorporated in the stratigraphic scheme published in the Compte rendu of the 7th Carboniferous Congress which was held in Krefeld (1971).

It should be noted that the stratigraphic scheme elaborated by the Heerlen congresses was based entirely on the knowledge gained in

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(1) First named by DE LAPPARENT & MUNIER CHALMAS *in* DE LAPPARENT (1892) 'Traité de Géologie'. Ouralien replaced Gshelien which had been introduced by NIKITIN (1890). The latter name has been maintained in the present-day Russian classification.

(2) Name introduced by NIKITIN (1890).

(3) It was taken to its logical extreme by REMY & HAVLENA (1962), who introduced the term Sorabian for the non-marine equivalent of the Dinantian.

north-western Europe, showing paralic and non-marine developments of the Upper Carboniferous. Little or no notice was taken of the marine Carboniferous in Russia, where a separate classification became established. Although papers on the predominantly marine Carboniferous in Russia did appear in the Compte-rendus of successive congresses, there was no serious attempt at incorporating this information for an integrated European scheme of Carboniferous stratigraphic classification. Similarly, comparisons were made with the United States, but without making an attempt at an integrated scheme.

With the establishment of the Commission on Stratigraphy of the International Geological Congress at Algiers, 1952, it was also decided to constitute a Subcommission on Carboniferous Stratigraphy which would work alongside the other subcommissions dealing with the other systems, and with the Subcommission on Stratigraphic Classification (originally called the Subcommission on Stratigraphic Nomenclature). The Subcommission on Carboniferous Stratigraphy, under its Chairman, Prof. W.P. van Leckwijck, presented its first two reports in the Compte rendu of the Carboniferous Congress of 1958 and in the Proceedings of the International Geological Congress held at Copenhagen in 1960. This Subcommission was subsequently made accountable to the International Union of Geological Sciences. Its meetings were not necessarily coincident with those of the International Congress on Carboniferous Stratigraphy and Geology, and the initiative for making recommendations on the classification of Carboniferous stratigraphic units passed from the Congress to the Subcommission. However, in practice, the latter took care to hold its general meetings in conjunction with the Carboniferous Congress and its reports were read during the closing sessions of the congress at Paris (1963), Sheffield (1967) and Krefeld (1971). Additional meetings of the Subcommission were held in Copenhagen (1960), Sheffield (1965), Liège (1969), Spain (1970) and Czechoslovakia (1973). Reports were issued for all these meetings.

At present, the following classification of the Carboniferous System has been adopted (George & Wagner 1972, p. 142) (Table 1).

Major subdivisions

The main feature of this classification is the recognition of two subsystems, the Dinantian (or Lower Carboniferous) and the Silesian (or Upper Carboniferous). The name Silesian was introduced in Heerlen (1958) and the decision to recognise a Silesian division equal in rank to the Dinantian was ratified in Copenhagen, 1960 (Van Leckwijck 1964[a]). These main divisions of the Carboniferous in Europe are comparable although not wholly correlatable to Mississippian and Pennsylvanian, two systems of the American Palaeozoic which, together, equal the Carboniferous System of Europe. At the meeting in Heerlen, 1958, it was recommended that these major subdivisions of the Carboniferous System should not be regarded as subsystems, but this recommendation was deleted at Copenhagen. It therefore became inferred that Dinantian and Silesian, as well as Mississippian and Pennsylvanian should be regarded as subsystems, since the congress re-affirmed that the Carboniferous should be maintained as a single system.

The rank of the Dinantian and Silesian divisions as subsystems was further confirmed indirectly when the subordinate units Tournaisian, Viséan, Namurian, Westphalian and Stephanian were admitted as series. The first unit to be regarded as such was the Namurian which accommodated a number of stages as introduced by Bisat (1924), Hudson & Cotton (1943), Hudson (1945) and Hodson (1957) (see 'Interim Report of the Namurian Working Group' by W.H.C. Ramsbottom 1969). Once the Namurian had been recognised as a series (Van Leckwijck 1964[b]), it became inevitable that the Westphalian and Stephanian should also be regarded as series. Their major subdivisions (stages), carrying the informal connotations A, B, C and D, are in due time to be renamed in the more formal manner, just like the stages within the Namurian Series. One newly

TABLE 1
Chronostratigraphic units of the European Carboniferous.

SYSTEM	SUBSYSTEM	SERIES	STAGE
CARBONIFEROUS	SILESIAN	Stephanian	Stephanian C Stephanian B Stephanian A Cantabrian
		Westphalian	Westphalian D Westphalian C Westphalian B Westphalian A
		Namurian	Yeadonian Marsdenian Kinderscoutian Alportian Chokierian Arnsbergian Pendleian
	DINANTIAN	Viséan Tournaisian	....

described stage, the Cantabrian, the basal unit of the Stephanian Series, constitutes a precedent for the formal naming of stages now marked A, B and C.

Since the Dinantian was regarded as equivalent in rank to the Silesian, it also became inevitable to recognise the Tournaisian and the Viséan as series. However, no stages were recognised within these series. One reason for the failure to designate generally agreed stages for the Tournaisian and Viséan series may be that these units were subdivided into the goniatite zones I (*Gattendorfia* Stufe), II (*Pericyclus* Stufe) and III (*Goniatites* Stufe), as proposed by SCHINDEWOLF & PAECKELMANN and accepted by the second Heerlen congress (JONGMANS & GOTHAN 1937). On the basis of the decisions taken at that congress, the Tournaisian/Viséan boundary would lie within zone II. On the other hand, the boundary between these two units as recognised in Belgium (and which has been accepted as a stratotype by the Subcommission on Carboniferous Stratigraphy in Sheffield 1967) does not coincide with the Heerlen definition. This has created obvious difficulties which have not been removed by recent proposals to recognise stages with German stratotypes for the zones I, II and III (PAPROTH *et al.* 1971, SCHMIDT 1972).

The level of subdivision within the Dinantian is obviously not as high as that reached within the Silesian, and the question may well be asked whether these two units should really be regarded as being of the same rank. In this respect, it may be significant that MUNIER CHALMAS & DE LAPPARENT (1893) intended the Dinantian to be equivalent in rank to the Westphalian and the Stephanian. Also in terms of absolute time, it appears that the Dinantian unit is more nearly equivalent to any of the component series of the Silesian than to the latter unit in its entirety. FRANCIS &

TABLE 2
Correlation of major chronostratigraphic units in the Carboniferous of Western Europe and Russia.

WEST EUROPEAN UNITS		RUSSIAN UNITS	
Subsystem	Series	Series	Stage
Silesian	Stephanian	Upper Carboniferous	Orenburgian Gzhelian
	Westphalian	Middle Carboniferous	Moscovian Bashkirian
	Namurian	Lower Carboniferous	'Namurian' (4) Viséan Tournaisian
Dinantian	Viséan		
	Tournaisian		

WOODLAND (1964) attributed some 20 million years to the Dinantian, 10-15 m.y. to the Namurian, 20 m.y. to the Westphalian, and 10-15 m.y. to the Stephanian. Although these figures are only rough approximations based on limited data of varying reliability, they do support the general impression that the Dinantian occupies a good deal less time than the Silesian.

If the Carboniferous is to be maintained as a single system (as the Heerlen congress of 1958 has re-affirmed), then it may be recommended to abolish the subsystems and to subdivide into the following series: Dinantian, Namurian, Westphalian, Stephanian. Apart from the fact that these are units of more or less equivalent time value which can be readily subdivided into stages (Tournaisian and Viséan would then come into line with Pendleian, Arnsbergian, etc.), it might also facilitate the eventual integration of West European chronostratigraphic units with those recognised in the U.S.S.R. where the Carboniferous System is subdivided into the Lower, Middle and Upper Carboniferous series. These series reflect the threefold division made by MUNIER CHALMAS & DE LAPPARENT, but there are differences in composition. The Russian Lower Carboniferous includes a Namurian Stage which is equivalent to the lower and middle Namurian of western Europe. The next stage in the Russian classification is the Bashkirian which forms part of the Middle Carboniferous, and which is mainly equivalent to the upper Namurian of western Europe. It also reaches some way into the lower Westphalian. Most of the Russian Middle Carboniferous is taken up by the Moscovian which is broadly equivalent to the Westphalian. The Gzhelian and Orenburgian stages of the Upper Carboniferous are together almost exactly equivalent to the Stephanian (Table 2).

It would appear that the West European and Russian schemes might be brought into line quite readily by returning to the threefold division recommended by MUNIER CHALMAS &

(4) The Subcommission on Carboniferous Stratigraphy has formulated a demand for the renaming of the Russian 'Namurian' since the latter is only partly equivalent to the Namurian of western Europe (VAN LECKWIJCK 1964[a]).

De Lapparent. On the West European side this would require the abandonment of the traditional Upper Carboniferous or Silesian. Alternatively, the term Silesian might be used for the Namurian and Westphalian together (thus returning to the Westphalian *-sensu lato-* of Munier Chalmas & De Lapparent). This would allow the introduction of three main divisions, viz. the Lower Carboniferous (or Dinantian), the Middle Carboniferous (or Silesian), and the Upper Carboniferous (or Stephanian). The threefold division in Russia could be maintained, but it would be necessary to transfer the Russian 'Namurian' to the Middle Carboniferous. Alternatively, the Namurian of western Europe might be split into two parts, the lower part to be attached to the Lower Carboniferous and the upper part to the Middle Carboniferous.

History of the stages of the Upper Carboniferous (Silesian) in Western Europe

Namurian

The Upper Carboniferous stages recognised by the first Heerlen congress (1927), viz. Namurian, Westphalian and Stephanian, were subdivided into units marked A, B, C and D by successive congresses. It is interesting to follow the thinking behind the various steps taken to effect the subdivision. The first Heerlen congress accepted the notion, current at the time, that a stage could be subdivided into zones (biozones). Since the goniatite faunas provided the best means for the correlation of marine and partly marine strata, the Namurian was subdivided into a number of goniatite zones. W.S. Bisat's work in England was taken as a basis for this subdivision, and the *Eumorphoceras* (E), *Homoceras* (H) and *Reticuloceras* (R) zones were taken as the component parts of the Namurian Stage. The second congress (1935) recognised that the lower part of the *Gastrioceras* Zone (G_1) was also included, and introduced A, B and C divisions corresponding to the E-H zones (Namurian A), $R_1 - R_2$ zones (Namurian B) and G_1 Zone (Namurian C). Various areas were mentioned for the occurrence of these units, but no attempt was made, to regard any of these as a type area. There appears to have been a general feeling that the goniatite zones were world-wide and sufficient in themselves to effect widespread correlation.

Westphalian A, B, C.

The usefulness of the goniatite faunas being generally admitted, there was a conscious attempt to extend the goniatite zonation upwards into the Westphalian. Indeed, the base of the Westphalian was taken at the Sarnsbank Marine Band with *Gastrioceras subcrenatum*, the latter being regarded as the index goniatite. This decision taken at Heerlen in 1927, was modified in 1935 by eliminating the reference to the marine band since it was felt that the occurrence of *Gastrioceras subcrenatum* would furnish an international marker which should not be linked to any particular locality. In practice, however, the occasional marine bands in the Westphalian strata of north-western Europe are used as index horizons marking widespread transgressions on the continental shelf. The faunas occurring in these horizons have only limited zonal value, the transgressions being too sporadic for the stratigraphic ranges of the faunal elements to be established. There are also depth controls on the distribution of these elements, and these impose a restriction on the faunal composition.

Within the peculiar conditions of the paralic coal-measures of north-western Europe, which are generally non-marine with only sporadic marine transgressions of an apparently eustatic nature (Trueman 1946), the marine bands furnish undoubtedly the most reliable means of correlation. Therefore, it is understandable that the Heerlen congresses should have selected the most prominent marine bands as the boundary horizons between the A, B and C subdivisions of the Westphalian. If one is only dealing with paralic coal-measures formed on slowly subsiding shelf areas, the eustatic transgressions can be distinguished and used for inter-regional correlation. However, in tectonically active areas as well as in predominantly marine basins, these eustatic transgressions are less likely to produce distinctive horizons, and in this case one can only correlate on the predominant kind of fossil remains. For the paralic coal-measures of north-western Europe these are generally plants and, in some cases, non-marine bivalves. The boundary between the Westphalian B and C, placed at the Aegir Marine Band by the first Heerlen congress and maintained at this horizon ever since, has been criticised by BOUROZ *et al.* (1969) as being irrelevant in terms of floral and faunal changes which would operate at a different horizon in the succession. It is true, of course, that a physical boundary between stratigraphic units in a succession used as a standard for correlations further afield should be selected in such a manner that its approximate position can be established elsewhere. In other words, it should also be a convenient boundary between floral and/or faunal zones. Regrettably, this point was not considered when the Aegir Marine Band was selected as the Westphalian B/C boundary, and one must wonder if this may impair the usefulness of this horizon when correlations are attempted with areas outside north-western Europe. On the other hand, a major eustatic transgression should have a widespread effect all over the world.

Westphalian D

In the paralic coal-measures of north-western Europe there are no obvious marine bands above the horizon of the Top Marine Band in mid-Westphalian C. The boundary between Westphalian C and D is therefore not at any marine horizon. The position of this boundary has been the subject of controversy as the result of an ambiguity in the definition of the Westphalian D unit. On the one hand, the Westphalian D was referred to as equivalent to the '*Zone à Mixoneura*' of BERTRAND but, on the other hand, it was regarded as being represented by the Assise de la Houve in Lorraine (compare BERTRAND 1937). In a recent report on the Westphalian D, delivered by J. P. LAVEINE in Prague 1973, it was pointed out that this implied a contradiction since the basal part of the Assise de la Houve does not contain the elements of the *Neuropteris ovata* group which are comprised under the term '*Mixoneura*' as used by BERTRAND. A later recommendation by the Subcommission on Carboniferous Stratigraphy (VAN LECKWIJCK 1964c), following a proposal made by W. REMY, emphasised the biostratigraphic aspect by stating that the base of Westphalian D should coincide with the first occurrence of *Neuropteris ovata*. The Westphalian D thus became the first chronostratigraphic unit linked unequivocally to a fossil plant occurrence. It is always a little worrying if a chronostratigraphic boundary is linked to the incoming of a single taxon, but a revision of the floral elements found in the vicinity of the first occurrence of *Neuropteris ovata* in Lorraine (the conceptual type area of the Westphalian D Stage) has shown that important changes in floral composition occur both below and above the level of this first occurrence (LAVEINE, in press). Although the passage from one floral zone to another is gradual (as can be expected in a continuous sequence of strata showing similar facies throughout), the first occurrence of *Neuropteris ovata* may well be used in the eventual selection of an agreed stratotype for the Westphalian D Stage. The recommendation made by the Subcommission on Carboniferous Stratigraphy during its meeting in Paris, 1963, may therefore be allowed to stand.

It is understandable that the definition of Westphalian D was linked to floral zones, for the Saar-Lorraine Coalfield, serving as the conceptual type area, shows entirely non-marine coal-measures of upper Westphalian age. This coalfield occupies an isolated position near the northern margin of the Mid-European Chain, and its upper Westphalian and Stephanian strata were formed independently from the paralic coal-measures area of north-western Europe. Within the Saar-Lorraine Coalfield the Westphalian C and D coal-measures are overlain disconformably by Stephanian deposits consisting of three grey coal-bearing intervals in a red bed succession. These coal-bearing intervals were correlated across to central France with Stephanian A, B and C.

Stephanian

Since this is the only area in north-western Europe where Stephanian strata overlie Westphalian D rocks (albeit disconformably), the Saar-Lorraine region has played an important role in the definition of the Westphalian/Stephanian boundary. In fact, the lowermost Stephanian rock unit in Saar-Lorraine, i.e. the Holz Conglomerate, was accepted by the Heerlen congresses of 1927 and 1935 as forming the boundary between Westphalian and Stephanian. This decision sowed the seeds of confusion because it implied that there were two different type areas for the Stephanian, viz. one in the St. Etienne (Loire) Basin of central France and the other in Saar-Lorraine.

The historical stratotype of the Stephanian is in the Loire Basin where it comprises the succession from the Assise de Rive-de-Gier to that of the Bois d'Avaize inclusive, and the term was stated to apply generally to the coal-measures on the eastern side of the Plateau Central (MUNIER CHALMAS & DE LAPPARENT 1893, p. 451). The Stephanian succession in the Loire Basin consists of three parts, viz. the Assise de Rive-de-Gier, the Assise de St. Etienne, and the Assise d'Avaize. These formations have been equated with Stephanian A, B and C by PRUVOST (1934, p. 112) and JONGMANS & PRUVOST (1950). In the St. Etienne Coalfield, as elsewhere in central and south-central France, the Stephanian strata lie with angular unconformity on the metamorphic and intrusive rocks of the Massif Central. It is also known that the basal Stephanian deposits are of different ages in different parts of this general area. The detailed correlations made most recently on the basis of cineritic tonstein bands in the different coalfields of this area (BOUROZ 1972), have shown without any doubt that the earliest Stephanian strata of the Massif Central are in the Cévennes region. Unconformable Stephanian deposits were formed here in advance of those found at Rive-de-Gier in the Loire Basin, where the type Stephanian A is situated. The floras of the Assise de Rive-de-Gier, found in the brief coal-measure interval known as Faisceau de la Peronnière, are rather incomplete and there has been a tendency to regard the better known floral assemblages of the Zone de Lentin of Carmaux, on the southern edge of the Massif Central, as characteristic of Stephanian A. It is in the Carmaux Coalfield where the Stephanian A/B boundary was described most recently (DOUBINGER & VETTER 1969) in terms of the floral succession, which is particularly well developed in that area. However, the Zone de Lentin at Carmaux is later in age than the Faisceau de la Peronnière at Rive-de-Gier (Loire), whilst it should also be noted that the Stériles de Gagnières, at the base of the Stephanian strata of the Cévennes, were deposited even earlier than the Stephanian A of Rive-de-Gier (BOUROZ 1972). The Stériles de Gagnières contain only sporadic, drifted plant remains as well as non-marine faunal elements of limited zonal value.

Admitting the fact that Stephanian A, B and C related primarily to the Assise de Rive-de-Gier, Assise de St. Etienne, and Assise d'Avaize of the St. Etienne (Loire) Coalfield, one may doubt the accuracy of the correlation with Stephanian A, B and C, as distinguished in the Saar-Lorraine area. There is reason to venture the opinion that the basal part of the so-called Stephanian A of Saar-Lorraine is correlatable to the Zone de Lentin of Carmaux rather than the Faisceau de la Peronnière of Rive-de-Gier. It is also apparent that the top part of Stephanian A in Saar-Lorraine should be assigned to early Stephanian B in terms of the floral succession known from the Massif Central (compare GERMER *et al.* 1968).

The absence of Westphalian deposits in the Massif Central has made it impossible to establish the relationship between Westphalian and Stephanian in that area. However, the classical Stephanian floras of central France are quite different to those of the Westphalian, and although some of the difference may be ascribed to habitat and palaeogeographical considerations, there is likely to be a substantial time gap between the two series as originally described. Also in the Saar-Lorraine Coalfield, where the

Stephanian is in superposition with upper Westphalian strata, there is a stratigraphic gap associated with the Holz Conglomerate. Although the presence of a discontinuity at the level of the Holz Conglomerate has been admitted for some time (compare, for instance, JONGMANS & GOTHAN 1937, p. 23), the size of the stratigraphic gap associated with the Westphalian/Stephanian boundary in Saar-Lorraine remained the subject of debate until very recently (GERMER *et al.* 1968, BOUROZ *et al.* 1972). It is now recognised as being of sizeable proportions, equal to at least a full division of either the Westphalian or the Stephanian series.

In fact, the only continuous succession of upper Westphalian and lower Stephanian strata in western Europe has been described most recently from north-western Spain, a little known area at the time when the Holz Conglomerate was designated as the Westphalian/Stephanian boundary horizon. The much more complete Spanish succession has allowed gauging the stratigraphic gap existing below the Holz Conglomerate, and this gap has proved to be a very substantial one. The result of the investigations in Spain has been to designate a stage, the Cantabrian Stage, following upon Westphalian D and preceding Stephanian A (WAGNER 1966). This stage has been assigned to the Stephanian Series, in view of the fact that it corresponds at least partly to the lower Stephanian of the Cévennes, shown to be earlier than Stephanian A. A stratotype for the Cantabrian Stage has recently been designated in the province of Palencia, N.W. Spain (BOUROZ *et al.* 1972). The same area has provided a new boundary-stratotype of the Stephanian A Stage (GEORGE & WAGNER 1972).

The Stephanian, as based on the rocks in central France, has always caused the greatest difficulties in correlation. The first and second Heerlen congresses failed to discuss its subdivision, and it was not until the note published by JONGMANS & PRUVOST (1950) that the Stephanian A, B and C divisions became established (to which the Cantabrian division has been added later). A further division, the Stephanian D, was proposed by DOUBINGER (1956) for the 'étage ambigu autuno-stéphanien' of GRAND' EURY (1877), which formed a transition to the Autunian. Most recently, a modified proposal for the recognition of a Stephanian D Stage has been presented by BOUROZ & DOUBINGER (in press).

The recognition of the Stephanian and of its constituent units relied almost entirely on fossil floras which showed a general composition different to that of Westphalian floral assemblages. Gradual changes were recorded from lower to upper Stephanian, but the general aspect of the classical Stephanian floras is a distinctive one if compared to the Westphalian floras. The marked difference between the Westphalian and Stephanian floras is at least partly due to a difference in age, and this has become very apparent since the substantial size of the stratigraphic break associated with the Holz Conglomerate in Saar-Lorraine has been realised. However, the difference in composition between Westphalian and Stephanian floral assemblages are also due to some extent to the different palaeogeographic setting of the original Westphalian and Stephanian type areas. JONGMANS (1952) made a distinction between paralic, paralo-limnic and limnic basins, and he employed the term 'Westphalian E' for those floras of Stephanian age which occurred in paralic and paralo-limnic basins. The floras of the intramontane limnic basins of central France were thus set apart quite clearly. Although his choice of the term 'Westphalian E' was unfortunate (since a difference in floral facies was meant and not a chronostratigraphic difference), the distinction is a valid one, from the palaeogeographical point of view as well as that of local habitat. Floras of the coastal plain are richer in species, probably as a result of better opportunities for migration and the consequent mixing of floras, whilst the intramontane areas show a smaller number of species among which there are endemic elements. It is also noted that the paralic and paralo-limnic basins of Stephanian age show a higher proportion of true ferns (*Pecopteris* and *Sphenopteris*) and generally rare remains of gymnosperms, whereas the latter are quite diversified in the intramontane Stephanian floras. Pteridosperms occur in both floral facies, but the proportion of occurrences may be quite different. In the intramontane basins there may be a relatively high proportion of species which lived in drier hill slope and upland environments. Altogether, there can be sharp differences in the composition of coastal plain (paralic and paralo-limnic) and intramontane (limnic) floral assemblages. JONGMANS (1952) emphasised the common presence of *Neuropteris ovata* in the paralic and paralo-limnic basins of Stephanian age, whereas this species is exceedingly rare and practically absent in the intramontane basins of the classical Stephanian of central France and of Saar-Lorraine. Much has been made of *Neuropteris ovata*, and BODE (1973) even goes so far as to insist that the biozone of *Neuropteris ovata* should be regarded as equivalent to a single, basic chronostratigraphic unit. Such an extreme point of view would result in the lumping together of Westphalian D, Cantabrian, Stephanian A and Stephanian B with part of Stephanian C into a single unit, and it is difficult to see what advantage could possibly be gained. The top occurrence of *Neuropteris ovata* is found in rocks of quite different ages in different parts of the world (as has been pointed out already by several authors), and it is clear that this species provides one of the best examples of the inadvisability of linking a chronostratigraphic unit to a single taxon.

Stephanian D/ Autunian

The upper limit of the Stephanian is a problem that is usually solved by reference to the first occurrence of *Callipteris* which is taken as indicating the presence of Rotliegend or Autunian (JONGMANS & GOTHAN 1937, p. 24, REMY 1964). However, a more marked change in floral characteristics occurs at a somewhat higher level, and BOUROZ & DOUBINGER (in press) have recently suggested that the base of the Autunian should be placed at the Assise de Muse of the Autun Basin. The Assise de Muse shows several species of *Callipteris* as well as a marked predominance of saccate pollen (*ca.* 80%) in the microflora. The Stephanian D division of the same authors shows the first appearance of *Callipteris* in the context of an upper Stephanian macrofloral assemblage, whilst the microflora shows relatively few saccate pollen (*ca.* 10%) and a predominance of monolete and trilete spores (*ca.* 80%). This amounts to a revision of the Stephanian/Autunian boundary, with due reference to the Stephanian and Autunian type sections in central France. The proposals made by BOUROZ & DOUBINGER will have to be discussed during the next meeting of the Subcommission on Carboniferous Stratigraphy in conjunction with the broader issue of the Carboniferous/Permian boundary which is linked, to a large extent, to marine faunas.

Criteria for the definition of Upper Carboniferous stages

It will be clear from the preceding chapter that the stratigraphic scheme elaborated by the Heerlen congresses and modified subsequently by the Subcommission on Carboniferous Stratigraphy consists of units which have been based on a variety of criteria.

For the Namurian Series the various subdivisions were straight biozones which have been converted afterwards into stages by the formal designation of type sections. These stratotypes allow correlation by means of several biological groups, among which goniatites take pride of place. In fact, the stage boundaries have been made to coincide with the boundaries between the goniatite zones. However, the stratotypes also provide conodonts and miospores as additional correlatory elements of importance. These stratotypes are useful and accessible, and it only needs some additional reference sections with macrofloral assemblages and different ones containing foraminiferal remains in limestone facies, in order to obtain a broad spectrum of correlatory elements.

The Westphalian stages A, B and C were based on rock sequences which relied for correlation on the lower boundary horizons, i.e. the marine bands representing widespread eustatic transgressions. Additionally, the fossil contents of the intervening coal-measures were available for correlation, but no attempt was made here to make the stage boundaries coincide with zonal boundaries([5]) There is only a limited number of biological groups that can be used for correlations with those regions which are not on the relatively stable shelf areas susceptible to the effects of a eustatic rise of sea level. These are primarily floras (both macro- and microfloras) with non-marine bivalves, the marine faunas of the sporadic marine bands serving mainly to identify the individual transgressions. The latter can hardly be used for a zonal scheme, since the total ranges of the (fairly restricted) marine faunal elements present cannot be established from the sporadic marine intervals that have been recorded on the shelf areas. Only boundary-stratotypes have been recognised thus far, and these are likely to be selected in localities of the East Pennine Coalfield of England (GEORGE & WAGNER 1972). These stratotypes have not been recognised in Westphalia because the 'Richtschnitte' (standard sections) for the Westphalian A, B and C stages in western Germany are in coal mines and are, therefore, not permanently accessible. There is an obvious need for additional reference sections providing more complete marine faunas, particularly with regard to fusulinid foraminifera and brachiopods. The problem will be one of correlation between the predominantly terrestrial stratotypes and the mainly marine reference sections which, in western (and central) Europe, can only be found in north-western Spain.

The Westphalian D Stage, for which no formal stratotype has been designated as yet, is linked at its lower boundary to the first appearance of *Neuropteris ovata*. The concept of Westphalian D is historically linked to the upper part of the coal-measure succession below the Holz Conglomerate in Lorraine. Since this is an entirely non-marine succession, one looks mainly to the floras for correlation further afield (the use of cineritic tonstein bands, though extremely valuable for correlation with areas even as far away as the Nord-Charleroi Basin in the Franco-Belgian border region, is unlikely to be successful for long range correlation). It is understood that the Saar-Lorraine Coalfield is not in itself likely to furnish the Westphalian D stratotype, despite its historical connection. The Assise de la Houve in Lorraine is only known from subsurface exposures, which are only temporarily accessible, and its equivalent strata in Saarland are too little exposed on the surface to be seriously considered for stratotypic purposes. Also, the Saar-Lorraine Basin is rather isolated palaeogeographically and thus contains a number of endemic plant species. It also shows the absence or near-absence of other species likely to provide correlation with other areas where Westphalian D strata occur. The sequence in Saar-Lorraine is also totally non-marine, thus imposing a restriction on the number of biostratigraphic elements available for inter-regional correlation. However, its floral assemblages are sufficiently similar to those occurring elsewhere in Westphalian D strata, to provide a starting point for correlations with the ultimate aim of selecting a suitable stratotype in a different region but without changing fundamentally the chronostratigraphic interval as originally described from Saar-Lorraine. This is the method adopted by the Working Group on Westphalian D, led by J.P. LAVEINE, who has already provided a revision of the Westphalian D flora of Lorraine, and who is presently engaged in the attempts at correlation which should precede the selection of the definitive stratotype. This method may well be regarded as the proper procedure to follow in any study leading towards the designation of an international stratotype.

The unsatisfactory boundary between the Westphalian and the Stephanian series, which was selected at the Holz Conglomerate of Saar-Lorraine by the Heerlen congress

([5]) In Britain the non-marine bivalve zonal boundaries were everywhere put at levels coincident with the stage boundaries (marine bands) and other prominent marker bands.

of 1935, has been abandoned in favour of a new boundary-stratotype selected between upper Westphalian D and lower Cantabrian (basal Stephanian) in a continuous sequence of strata in north-western Spain. The well-exposed type section of the Cantabrian Stage in the Cordillera Cantábrica is perhaps the most adequate of all the Upper Carboniferous stratotypes adopted thus far. It contains alternating marine and terrestrial strata which allow correlations on the basis of several groups of fossils, including fusulinid foraminifera, brachiopods and land plants (WAGNER *et al.* in press). The floral assemblages of the Cantabrian stratotype show a general composition similar to that of paralic Westphalian floras, as the result of a similar kind of environment. There is a gradual transition upwards from the upper Westphalian D floras into the lower Cantabrian ones, and no abrupt changeover as happens in a discontinuous sequence, either as the result of a stratigraphic break (as in Saar-Lorraine) or of a marked change in the environment.

The boundary-stratotype of the Stephanian A Stage has also been chosen in north-western Spain, and it also shows marine and terrestrial strata which allow for adequate long range correlations.

The stratotypes of the other stages in the Stephanian Series have not yet been designated. The traditional type area of the Stephanian B and C stages is the Loire Basin, but this suffers from an exclusively terrestrial facies in an intermontane (limnic)basin. Therefore, only the fossil flora and occasional elements of non-marine fauna are available for long range correlation. Stratotypes in this area would undoubtedly suffer from the restrictions imposed by a single group of fossils being the only one available for effective correlation, and within this group one would have to take into account the effect of endemic species and a general composition of the flora which reflects the special palaeogeographical position and the local habitats.

The Stephanian D Stage, as proposed most recently by BOUROZ & DOUBINGER (in press), forms the transition to the Autunian which may or may not be part of the Permian System. This stage, with a stratotype in the St. Etienne (Loire) Basin, would be characterised by the first appearance of *Callipteris* in the context of a Stephanian C flora. The purely terrestrial environment imposes the same limitations on the flora, as mentioned before, with the additional peculiarity that the Autunian (or Rotliegend) saw a widespread climatic change in Europe as the result of which the humid coal-measure environment was replaced by a much drier habitat. In any particular area this climatic change is likely to have had a dramatic effect on the general composition of the flora, thus providing a clearly marked biostratigraphic boundary which can be used for the selection of a chronostratigraphic boundary-stratotype. Indeed, such a changeover has been recorded by BOUROZ & DOUBINGER (in press), particularly with regard to the microflora, and they have proposed a boundary-stratotype between Stephanian D and Autunian, which takes this into account. However, there is no guarantee that such a climatic change would operate synchronously in different parts of the world or even in different parts of Europe. In fact, this is most unlikely, and it is known that there are certain places in the world (e.g. China and Korea) where this changeover did not take place and where floras of a humid habitat continued to be present and evolved gradually throughout Permian times. The normal successor to the Carboniferous coal-measure floras is found in the Cathaysian Province. Only the Alpine region seems to contain marine strata of ages equivalent to Stephanian and Autunian, but the effective correlations have not yet been made for more than the occasional locality, and it is unlikely that the Alpine region will be capable of providing reasonable stratotypes in view of its intricate tectonic structure.

It is realised that the question of the Stephanian/Autunian boundary is likely to be of relatively local interest, and that the main problem will centre on the Carboniferous/Permian boundary on a world-wide basis. The latter may well be quite different in position to the Stephanian/Autunian boundary, and it is difficult to see how western

Europe, with its special palaeogeographical conditions, may effectively contribute to the solution of this problem (compare BOUROZ & DOUBINGER, in press).

The selection of stratotypes with regard to an integrated european scheme of Carboniferous chronostratigraphic units

General

From the discussion so far, it is evident that the criteria used for the recognition of stages in the different parts of the Upper Carboniferous sequence in western Europe have differed quite markedly, with regard to the special facies and palaeogeographic conditions operating in the regions first studied. This has tended to produce a patchwork of chronostratigraphic units relying for their correlation on quite different biostratigraphical or even lithostratigraphical criteria. The multiplicity of approaches used for the recognition of the various stages has been moderated to some extent by the efforts of the I.U.G.S. Subcommission on Carboniferous Stratigraphy which is concerned with the selection of stratotypes for these chronostratigraphic units and with the application of similar criteria to all of them. A certain consensus on these criteria has emerged.

It is clear that a stratotype will have to be permanently accessible as a standard reference section for correlation, and that this implies good permanent exposure. Temporary exposures in coal mines and boreholes, however well studied, are obviously not acceptable for stratotypic purposes. A stratotype will also be of limited use if it contains only a limited range of facies, since this implies only a limited number of biological groups capable of providing the elements of long range correlation. Marker bands, however widespread and important for a fine correlation on the regional scale (e.g. marine bands formed as the result of eustatic transgressions, and cinerites produced by large emissions of volcanic ash), cannot furnish more than convenient boundaries between stratigraphic units in more or less comprehensive local areas. For the wider correlations one has to use the biological elements, however imprecise the boundaries between biozones may be. Therefore, it is of considerable importance to avoid selecting stratotypes in areas showing only a limited range of facies.

Present West European stratotypes

At present, a fairly large number of chronostratigraphic units in the Carboniferous of western Europe are still based on rocks in limited facies. In the case of the Namurian stratotypes, one regrets the almost complete absence of plant macrofossils, and one should consider the possibility of selecting auxiliary reference sections which are fully correlated with the stratotypes and which do contain the macrofloras. On the other hand, the Namurian stratotypes are better than most in containing goniatite and conodont faunas as well as abundant and well preserved microfloras.

Much more serious is the position with regard to the Westphalian and most of the Stephanian stratotypes. As the matter stands at present, the Westphalian A, B and C stratotypes remain in the belt of paralic coal-measures on the margin of the North Atlantean Continent of northwestern Europe. For the correlations within this area reliance is placed mainly on the principal marine bands which provide accurate lithological markers. On the world-wide scale, however, the elements of correlation available in these stratotypes are macro- and microfloras, together with non-marine bivalves. It is doubtful that these can be regarded as totally adequate since the range of biological groups available is strictly limited. The general absence of marine faunas is a serious drawback which cannot be offset by the sporadic and rather limited faunas present in the marine bands.

The Westphalian D Stage, which was originally based on the sequence in the Lorraine Coalfield, can only be identified effectively by means of fossil floras. A stratotype has yet to be designated, and is certainly to be found outside the Saar-Lorraine Coalfield since this area is not only deficient in the range of fossils available but also in the amount of exposure which is mainly in coal mines.

The top of the Westphalian Series is determined by the base of the Cantabrian Stage, the basal chronostratigraphic unit of the Stephanian Series. The Cantabrian Stage has an adequate stratotype in north-western Spain where alternating marine and terrestrial deposits, both abundantly fossiliferous, provide the elements of correlation not only with western Europe (e.g. the Cévennes region of southern France) but also with European Russia and North America.

The Stephanian A Stage has a designated boundary-stratotype in north-western Spain, in the same section which also provides the stratotype for the upper Cantabrian. The full extent of the Stephanian A Stage remains to be determined, since the boundary-stratotype of Stephanian B has not yet been designated. The Stephanian A in Spain is also partly marine, and its lower part contains brachiopod and other marine faunas capable of providing correlation with the U.S.S.R. and North America. It also contains the floral elements necessary for the correlation with the rocks traditionally regarded as Stephanian A (e.g. the Zone de Lentin of Carmaux) in central France.

The Stephanian B and C stages have not yet come up for scrutiny by the Subcommission on Carboniferous Stratigraphy. Their traditional type area is in the St. Etienne (Loire) Basin, which is entirely non-marine and one of the classical limnic basins of central France. The Stephanian B and C strata found in the intramontane basins of central France are unsuitable for stratotypes. Not only do they offer a very limited range of fossils for correlation (i.e. macro- and microfloras together with occasional fish faunas and other non-marine animals), but the classical Stephanian B and C floras of central France are rather special as a result of their palaeogeographical position and the nature of the limnic basins found well within the hinterland area of the Mid-European Chain. Most of the Stephanian basins in western Europe are of a similar nature and show comparable drawbacks. Only in north-western Spain the Stephanian B and C strata were laid down in a coastal basin, with predominantly non-marine facies but showing occasional marine influences. A more marine development of Stephanian B and C is present in the Carnic Alps (Austria/Italy). It is clear that the Stephanian B and C strata of both the Carnic Alps and north-western Spain will have to be considered for the designation of effective stratotypes for these two stages.

The Stephanian D Stage, as proposed most recently by BOUROZ & DOUBINGER (in press), forms a transition to the Autunian. Its biostratigraphic elements are entirely non-marine (mainly macro- and microfloras).

If one looks towards a future integration of the West European and Russian chronostratigraphic units, it will be necessary to provide first of all the elements of correlation between these two different sets of units. In part, these elements are present in the form of land plants and the occasional goniatite faunas in the Russian and West European sequences. However, most of the Russian chronostratigraphic units are based on sequences with marine faunas including fusulinid foraminifera. Within western Europe these foraminiferal faunas are only present in north-western Spain and in the Carnic Alps. The same areas also contain the additional marine faunas, such as brachiopods, gastropods, bivalves, ostracodes, corals and bryozoans, which play a subsidiary rôle in the recognition of the Russian units. Goniatites are also present, albeit in small numbers.

N. W. Spain, a link with the Russian Carboniferous (Table 3)

Of the two areas mentioned, the Cantabrian Cordillera of N.W. Spain stands out as containing the most complete Upper Carboniferous successions, with the richest marine faunas and terrestrial floras. The stratigraphic sequences of this area are quite well known and capable of being studied in great detail. The exposures are very good and the predominantly isoclinal folding has provided long sections within relatively small areas. The Alpine sequences may be less com-

TABLE 3

Approximate correlation of West European and Russian chronostratigraphic units as suggested by the evidence in N.W. Spain

WEST EUROPEAN STAGES (Upper Carboniferous only)	U.S.S.R. UNITS		
	Substages	*Stages*	*Series*
Stephanian C	Gzhelian *sensu stricto*	GZHELIAN	UPPER CARBONIFEROUS
Stephanian B			
Stephanian A	Kasimovian		
Cantabrian			
Westphalian D	Myachkovian	MOSCOVIAN	MIDDLE CARBONIFEROUS
Westphalian C	Podolskian		
Westphalian B	Kashirian		
Westphalian A	Vereyan		
Yeadonian		BASHKIRIAN	
Marsdenian		"NAMURIAN"	LOWER CARBONIFEROUS
Kinderscoutian			
Alportian			
Chokierian			
Arnsbergian			
Pendleian			

plete and are less easily studied because of the tectonic complexity of this area.

It would make good sense to try and to select stratotypes for the maximum number of stages in the Westphalian and Stephanian series as exposed in the Cantabrian Cordillera of N.W. Spain. Both the Westphalian and Stephanian series are developed in a limited facies range in the classical areas of Britain, Germany, France and Belgium (unlike the Namurian which shows a development much more suitable for stratotypic purposes in this area of north-western Europe). On the contrary, in N.W. Spain both the various stages of the Westphalian and the two stages of the lower Stephanian (Cantabrian and Stephanian A) are developed in marine facies interleaved with terrestrial deposits, thus providing excellent stratotypes with a wide range of fossil organisms. The macro- and microfloras present in the Spanish rocks are adequate for a reasonable correlation with the classical Westphalian successions of north-western Europe. The proximity of the Spanish area to north-western Europe also ensures a more immediate correlation with the traditional Westphalian successions than may be possible between the latter and a more distant region, such as the Donetz Basin. The fusulinid foraminifera and other marine faunal elements which are present in such abundance in the Spanish Carboniferous, provide the means for an instant correlation with the Bashkirian, Moscovian and Kasimovian to Gzhelian units of the Russian classification. They also allow correlation with the marine successions of the North American Continent. One does not need to stress that Spain occupies a key position geographically, sited, as it is, between the Russian and North American areas, and belonging to western Europe.

The combined occurrence of fully marine faunas and continental floras in the Carboniferous of N.W. Spain, and the consequent opportunities for a world-wide correlation, have been known for some time. DELEPINE (1938) presented the first general correlation between Russia, N.W. Spain and north-western Europe. However, only a limited knowledge of the Spanish faunas and floras had been gained at that time, and his correlation thus remained highly tentative. This situation has now changed considerably. Over the last twenty years great strides have been made in the investigation of Carboniferous strata in N.W. Spain, and even though some parts of the Cantabrian Cordillera are still not known in detail, other parts of this mountainous area with its well exposed, long and uninterrupted sedimentary sequence of Upper Carboniferous rocks are now known just as well, if not better, than some of the classical regions in north-western Europe.

In 1958, at the fourth Heerlen congress, the Commission on the Stratigraphy of the Carboniferous of the National Committee of Soviet Geologists (STEPANOV *et al.* 1962) presented a correlation between the units of two classical Russian sequences on the one hand (viz. of the Donetz and Moscow basins), and West European and North American units on the other. This correlation had to rely mainly on floral evidence from the Donetz Basin for its comparisons with the various stages of the Westphalian in north-western Europe. Goniatite faunas were very few and far between in both areas, and precious few other marine faunas were known from north-western Europe. The fusulinid-bearing limestones of the Donbass sequence provided the mainstay of correlation with the Moscow Basin, with its Moscovian divisions of Vereyan, Kashirian, Podolskian and Myachkovian. The correlations proposed by the Russian Committee excited widespread interest and they have often been applied since (e.g. for the Fossil Record published by the Geological Society of London), without having been submitted to a critical examination.

In the Cantabrian Cordillera of N W. Spain, where marine faunas allow a direct correlation with the Moscow Basin and where the macro- and microfloras exist for an immediate comparison with north-western Europe, the Russian correlation was inevitably put to the test. It soon became evident that certain parts of the proposed correlation were less convincing than others. The first doubts were expressed by WAGNER & WAGNER-GENTIS (1963) and soon afterwards VAN GINKEL (1965) proposed certain emendations to the Russian correlation scheme. VAN GINKEL's emendations were based primarily on the evidence of fusulinid faunas identified by himself and on published records of macrofloras studied by the present writer. Most of the information available to VAN GINKEL came from spot samples taken from successions which were not always fully understood. Consequently, the proposed emendations were perhaps a little premature.

The difficulties centred on the lower and upper limits of the Bashkirian Stage. The Russian Committee had correlated its base with the base of Namurian C, and its top with the limit between Westphalian B and C. VAN GINKEL (1965) proposed that the base of the Bashkirian should be lowered to the base of Namurian B or to a position within Namurian A, and that the top of the Bashkirian should also be lowered, viz. to a position coinciding approximately with the Namurian C (Yeadonian) and Westphalian A boundary. A more comprehensive study of the various elements of flora and fauna (including miospores, sporadic macrofloral remains, foraminifera, goniatites and brachiopods) obtained from a single succession of strata in northern León (MOORE *et al.* 1971) provided a useful check on VAN GINKEL's suggestions. It proved that the Russian correlation appeared to be substantially correct in equating the lower Bashkirian with at least part of Namurian C. On the other hand, the top of the Bashkirian (and consequently the base of the Moscovian) was certainly to be placed in a position lower than that suggested by the Russian correlation, although perhaps not quite as low as proposed by VAN GINKEL. The second subdivision of the Moscovian, i.e. the Kashirian, was found to be equivalent to most of the Westphalian B and the lower part of Westphalian C. The exact position of the Bashkirian/Moscovian (Vereyan) boundary could not be established on the Spanish evidence but it seems likely to fall within the Westphalian A division of the West European classification. This amounted to a substantial revision of the Russian correlation scheme and it proved that the elements of the correlations proposed by the Russian Committee should be submitted to a careful analysis before it is put into operation. With regard to the upper limit of the Moscovian, it was suggested by STEPANOV *et al.* (1960) that the Myachkovian/Kasimovian boundary should coincide with that between Westphalian D and Stephanian. This conclusion has been proved substantially correct, but the recent recognition of the Cantabrian Stage at the base of the Stephanian Series in western Eurôpe has provided further precision. Fusulinid faunas as well as brachiopod assemblages obtained from the Cantabrian stratotype (VAN GINKEL 1972, WINKLER PRINS *in* WAGNER & VARKER 1971, WAGNER *et al.* in press) have suggested that the Myachkovian/Kasimovian boundary lies within the Cantabrian, either in the lower part of this stage or, more likely towards its middle part. The upper Cantabrian is clearly of Kasimovian age on both the brachiopod and fusulinid faunas. VAN GINKEL (1972) has further suggested that the top of the Kasimovian would lie within Stephanian B, but this conclusion is still highly tentative in view of the limited floral evidence associated with the fusulinids of the *Triticites* Zone in Spain.

It is clear that the Spanish Carboniferous has a vital rôle to play in the correlation between the chronostratigraphic units in western Europe and in the U.S.S.R. Additional work in Spain as well as in the U.S.S.R. should allow further precision, and it is also desirable that the Carnic Alps should be drawn into the process of correlation, particularly with regard to the higher stages of the Stephanian and the Gzhelian and Orenburgian stages of the Russian Upper Carboniferous.

At present, the evidence obtained from N.W. Spain suggests the following correlation as being the most probable (compare WAGNER & WINKLER PRINS *in* WAGNER 1971, p. 36) (Table 3).

Conclusions

1. The West European chronostratigraphic units for the Upper Carboniferous, historically based on a variety of biostratigraphical and lithological criteria, are currently being re-examined by the I.U.G.S. Subcommission on Carboniferous Stratigraphy, and put on a more equal footing by the designation of a stratotype for each stage. The stages within the Namurian Series show a reasonably adequate number of biological elements in their stratotypes for the latter to be effective, even though auxiliary reference sections may be recognised as well. The stratotypes for Westphalian A, B and C, historically situated on the shelf of the North Atlantean Continent and in the Variscan marginal trough, should probably be chosen outside these northern European regions which are deficient in terms of facies and in the number of fossil groups available for correlation. The predominantly marine succession in N.W. Spain may, eventually, provide better stratotypes. The same is true, even to a larger extent, for the

Westphalian D, which has been based originally on a non-marine sequence in Saar-Lorraine. The stratotypes for the two lower Stephanian stages, Cantabrian and Stephanian A, have already been designated in N.W. Spain. The Stephanian B and C stages, traditionally based on sequences in central France, can be based more effectively on successions in N.W. Spain, but the sequences present in the Carnic Alps should also be taken into consideration.

2. It should be a primary aim of the I.U.G.S. Subcommission on Carboniferous Stratigraphy to study the possibility of an integrated scheme of Carboniferous chronostratigraphic units for all of Europe. This involves collecting information on the correlation of units recognised in western Europe with those of the U.S.S.R.

3. Consideration may be given to the recognition of series in the West European Carboniferous in such a way as to facilitate a broad comparison with the Lower, Middle and Upper Carboniferous of the Russian classification. This would involve classifying the Dinantian as a series (rather than a subsystem) and emending the Silesian by making it into the Middle Carboniferous unit containing the Namurian and Westphalian only (i.e. the old Westphalian of MUNIER CHALMAS & DE LAPPARENT). Since the Namurian Series of western Europe comprises the upper part of the Russian Lower Carboniferous (Russian 'Namurian') and the lower part of the Russian Middle Carboniferous (Bashkirian), it would be reasonable to request the Soviet Committee on Carboniferous Stratigraphy to transfer the Russian Namurian to the Middle Carboniferous, and to leave only the Dinantian in the Lower Carboniferous. Otherwise, the Namurien Series would be split asunder. Agreement on the equivalence of the series in the West European and Russian chronostratigraphic schemes may facilitate future agreement on the constituent stages in an integrated European classification which should be regarded as an attainable objective.

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TABLE 4

Major Carboniferous units in Europe (Lower and Middle Carboniferous boundary adjusted and rank of West European units revised in accordance with the proposals outlined in the present paper).

RUSSIAN SERIES	WEST EUROPEAN SERIES
Upper Carboniferous (Gzhelian, Orenburgian)	Stephanian
Middle Carboniferous ('Namurian', Bashkirian, Moscovian)	Westphalian } Silesian Namurian }
Lower Carboniferous (Tournaisian, Viséan)	Dinantian

AISENVERG, D.E., BRAZHNIKOVA, N.E., NOVIK, K.O., ROTAY, A.P. (Editor) & SHULGA, P.L. (1960). Carboniferous Stratigraphy of the Donetz Basin. *C.R. 4e Congrès Carbonifère, Heerlen 1958*, I, pp. 1-12.

BERTRAND, P. (1937). Tableaux des flores successives du Westphalien supérieur et du Stéphanien. *C.R. 2e Congrès Carbonifère, Heerlen 1935*, I, pp. 67-79.

BISAT, W.S. (1924). The Carboniferous goniatites of the north of England and their zones. *Proc. Yorkshire Geol. Soc.*, XX, pp. 40-124, pls. I-X.

BISAT, W.S. (1928). The Carboniferous goniatite zones of England and their Continental equivalents. *C.R. 1er Congrès Carbonifère, Heerlen 1927*, pp. 117-133, pls. VI, VI A.

BODE, H. (1973). Westfal D und Kantabrium. *C.R. 7e Congrès Carbonifère, Krefeld 1971*, II, pp. 139-143.

BOUROZ, A. (1972). Utilisation des marqueurs d'origine volcanique en stratigraphie. Exemples d'application dans les gisements houillers. *Mém. Bureau Recherches géol. min.*, 77, pp. 473-487, pls. A-C.

BOUROZ, A., CHALARD, J., CORSIN, P. & LAVEINE, J.P. (1969). Le stratotype du Westphalien C dans le bassin houiller du Nord et du Pas-de-Calais: limites et contenu paléontologique. *C.R. 6e Congrès Carbonifère, Sheffield 1967*, I, pp. 99-105.

BOUROZ, A. & DOUBINGER, J. (in press). Report on the Stephanian-Autunian boundary and on the contents of upper Stephanian and Autunian in their stratotypes. Paper presented at the Meeting of the IUGS Subcommission on Carboniferous Stratigraphy in Prague 1973.

BOUROZ, A., KNIGHT, J.A., WAGNER, R.H. & WINKLER PRINS, C.F. (1972). Sur la limite Westphalien-Stéphanien et sur les subdivisions du Stéphanien inférieur *sensu lato*. (Rapport du groupe de travail sur le Stéphanien). *C.R. 7e Congrès Carbonifère, Krefeld 1971*, I, pp. 241-261.

DELEPINE, G. (1938). Corrélations entre le Carbonifère moyen de la Russie et celui de l'Europe occidentale. *Bull. Soc. géol. France*, (5), VIII, pp. 593-598.

DOUBINGER, J. (1956). Contribution à l'étude des flores autuno-stéphaniennes. *Mém. Soc. géol. France*, (N.S.), XXXV, 75, pp. 1-180, pls. I-XVII.

DOUBINGER, J. & VETTER, P. (1969). Observations et réflexions sur les zones paléobotaniques des bassins de Carmaux et de Decazeville. *C.R. 6e Congrès Carbonifère, Sheffield 1967*, I, pp. 171-182.

DUPONT, E., MOURLON, M. & PURVES, J.C. (1883). Explication de la feuille de Natoye. *Mus. roy. Hist. nat. Belgique, Expl. Carte géol. du Royaume*, pp. 1-50.

FRANCIS, E.H. & WOODLAND, A.W. (1964). The Carboniferous period. '*The Phanerozoic Time-Scale*', *Quart. Jl. geol. Soc. London*, 120 S, pp. 221-232.

GEORGE, T.N. & WAGNER, R.H. (1972). I.U.G.S. Subcommission on Carboniferous Stratigraphy. Proceedings and Report of the General Assembly at Krefeld, August 21-22. *C.R. 7e Congrès Carbonifère, Krefeld 1971*, I, pp. 139-147.

GERMER, R., KNEUPER, G.K. & WAGNER, R.H. (1968). Zur Westfal/Stefan-Grenze und zur Frage der asturischen Faltungsphase im Saarbrücker Hauptsattel. *Geologica et Palaeontologica*, 2, pp. 59-71, Tafn 1-2.

GINKEL, A.C. van (1965). Spanish Carboniferous fusulinids and their significance for correlation purposes. *Leidse Geol. Meded.*, 34, pp. 173-225, app. and encl.

GINKEL, A.C. van (1972). Correlation of the Myachkovian and Kasimovian in the U.S.S.R. with the West European subdivision. *Leidse Geol. Meded.*, 49, pp. 1-7.

GORSKY, I.I., STEPANOV, D.L. *et al.* (1960). Contribution to the Stratigraphical Colloquium. *C.R. 4e Congrès Carbonifère, Heerlen 1958*, I, pp. 229-231.

GRAND'EURY, F.C. (1877). Flore carbonifère du département de la Loire. *Mém. Acad. Sci., Paris*, pp. 1-624, pls. I-XXXIV, pls. A-D.

HODSON, F. (1957). Marker horizons in the Namurian of Britain, Ireland, Belgium and Western Germany. *Publ. Ass. Et. Pal. Strat. Houill.*, 24, pp. 1-26, pls. 1-7.

HUDSON, R.G.S. (1945). The Goniatite Zones of the Namurian. *Geol. Mag.*, 82, pp. 1-9.

HUDSON, R.G.S. & COTTON, G. (1943). The Namurian of Alport Dale. *Proc. Yorkshire Geol. Soc.*, XXV, pp. 142-173.

JONGMANS, W.J. (1952). Some problems on Carboniferous stratigraphy. *C.R. 3e Congrès Carbonifère, Heerlen 1951*, I, pp. 295-306.

JONGMANS, W.J. & GOTHAN, W. (1937). Betrachtungen über die Ergebnisse des zweiten Kongresses für Karbonstratigraphie. *C.R. 2e Congrès Carbonifère, Heerlen 1935*, I, pp. 1-40.

JONGMANS, W.J. & PRUVOST, P. (1950). Les subdivisions du Carbonifère continental. *Bull. Soc. géol. France*, (5), XX, pp. 335-344.

LAPPARENT, A. de (1892). Traité de Géologie. 3e Edition.

LAVEINE, J.P. (in press). Report on the Westphalian D. Paper presented at the Meeting of the IUGS Subcommission on Carboniferous Stratigraphy in Prague 1973.

LECKWIJCK, W.P. van (1964[a]). Account of the meeting of the Subcommission on Carboniferous Stratigraphy, 19th August 1960. *Rept. 21st Session Int. Geol. Congress, Norden 1960*, pt. XXVIII, pp. 284-290.

LECKWIJCK, W.P. van (1964[b]). Le Namurien en Belgique et dans les régions limitrophes (Stratigraphie, Paléogéographie, Paléontologie, Sédimentologie, Puissances). *Mém. Acad. roy. Belgique, Cl. Sci.*, (2), XVI, 2, pp. 1-58, Figs. 1-11.

LECKWIJCK, W.P. van (1964[c]). Rapport sur les résultats des travaux de la Sous-Commission de Stratigraphie du Carbonifère. *C.R. 5e Congrès Carbonifère, Paris 1963*, I, pp. xxxv-xxxix.

MOORE, L.R., NEVES, R., WAGNER, R.H. & WAGNER-GENTIS, C.H.T. (1971). The stratigraphy of Namurian and Westphalian rocks in the Villamanín area of northern León, N.W. Spain. *In* 'The Carboniferous of Northwest Spain', *Trabajos de Geologia, Fac. Ci. Univ. Oviedo*, 3, pp. 307-363, pls. 1-8.

MUNIER CHALMAS, E. & LAPPARENT, A. de (1893). Note sur la Nomenclature des Terrains sédimentaires. *Bull. Soc. géol. France*, (3), XXI, pp. 438-493.

NIKITIN, S.V. (1890). Dépôts carbonifères et puits artésiens dans la région de Moscou, *Mém. Comité géol.*, V, 2 vol. in 4°.

PAPROTH, E. *et al.* (1971). Die stratigraphische Gliederung des Dinantiums und seiner Ablagerungen in Deutschland. *Newsl. Stratigr.*, I, 4, pp. 7-18, Table (composed by 'Arbeitsgemeinschaft für Dinant-Stratigraphie').

PRUVOST, P. (1934). Bassin houiller de la Sarre et de la Lorraine. III. Description géologique. *Et. Gîtes Min. France*, pp. 1-175, pls. I-III (carte et coupes).

PURVES, J.C. (1883). Sur la délimitation et la constitution de l'étage houiller inférieur de la Belgique. *Bull. Acad. roy. Belgique*, (3), 2, pp. 514-568, pl. I.

RAMSBOTTOM, W.H.C. (1969). The Namurian of Britain. *C.R. 6e Congrès Carbonifère, Sheffield 1967*, I, pp. 219-232, figs. 1-19.

REMY, W. (1964). Zur Untergliederung des Stéphanien und Autunien. Grenze Stéphanien/Autunien. *C.R. 5e Congrès Carbonifère, Paris 1963*, I, pp. 177-187.

REMY, W. & HAVLENA, V. (1962). Zur floristischen Abgrenzung von Devon, Karbon und Perm im terrestrisch-limnisch entwickelten Raum des euramerischen Florenbereichs in Europa. *Fortschr. Geol. Rheinl. Westf.*, 3, 2, pp. 735-752.

SCHMIDT, H. (1972). Balvium: Neuer Name für Unterkarbon I. *C.R. 7e Congrès Carbonifère, Krefeld 1971*, I, pp. 205-207.

STEPANOV, D.L. *et al.* (1962). The Carboniferous System and its main stratigraphic subdivisions. Report of the Commission on the Stratigraphy of the Carboniferous of the National Committee of Soviet Geologists. *C.R. 4e Congrès Carbonifère, Heerlen 1958*, III, pp. 645-656.

TRUEMAN, A.E. (1946). Stratigraphical problems in the Coal Measures of Europe and North America. *Quart. Jl. geol. Soc. London*, CII, pp. xlix-xcii, pl. A.

WAGNER, R.H. (1966). El significado de la flora en la Estratigrafía del Carbonífero superior. *Bol. R. Soc. Esp. Hist. Nat.* (Geol.), 64, pp. 203-208.

WAGNER, R.H. (1971). Account of the International Field Meeting on the Carboniferous of the Cordillera Cantábrica, 19-26 Sept. 1970. *In* 'The Carboniferous of Northwest Spain', *Trabajos de Geologia, Fac. Ci. Univ. Oviedo*, 3, pp. 1-39, pls. 1-5.

WAGNER, R.H., PARK, R.K., WINKLER PRINS, C.F. & LYS, M. (in press). The post-Leonian basin in Palencia: A report on the stratotype of the Cantabrian Stage. Paper presented at the Meeting of the U.G.S. Subcommission on Carboniferous Stratigraphy, Prague 1973.

WAGNER, R.H. & VARKER, W.J. (1971). The distribution and development of post-Leonian strata (upper Westphalian D, Cantabrian, Stephanian A) in northern Palencia, Spain. *In* 'The Carboniferous of Northwest Spain', *Trabajos de Geologia, Fac. Ci. Univ. Oviedo*, 4, pp. 533-601, pls. 1-2.

WAGNER, R.H. & WAGNER-GENTIS, C.H.T. (1963). Summary of the Stratigraphy of Upper Palaeozoic Rocks in NE. Palencia, Spain. *Proc. Kon. Nederl. Akad. Wetenschappen*, (B), LXVI, 3, pp. 149-163.