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# GENERAL OVERVIEW OF CARBONIFEROUS STRATIGRAPHY[1]

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(5 figures)

**ABSTRACT.-** A revised 'global stratigraphic chart' for the Carboniferous is given as a reaction on the one issued by the IUGS Commission on Stratigraphy (Cowie & Bassett, 1989). The underlying principles of the chronostratigraphic classification of the Carboniferous, both in the palaeoequatorial belt and the temperate to cold Angará and Gondwana regions are briefly discussed.

**KEY-WORDS.-** Carboniferous, chronostratigraphy.

**RESUME.-** Un tableau révisé de la "stratigraphie mondiale" pour le Carbonifère est présenté en réaction au tableau de l'IUGS Commission on Stratigraphy (Cowie & Bassett, 1989). Les principes fondamentaux de la classification chronostratigraphique du Carbonifère sont discutés brièvement tant pour la zone paléoéquatoriale que pour les régions tempérées-froides d'Angará et du Gondwana.

**MOTS-CLES.-** Carbonifère, chronostratigraphie.

## 1.- PREAMBLE

The primary stimulus for this paper is the Global Stratigraphic Chart (Cowie & Bassett, 1989) issued in the name of the I.U.G.S. Commission on Stratigraphy, and acknowledged as being derived from information supplied by Subcommissions and others. It includes both official stages and proposed ones which have not yet been sanctioned by the Subcommissions. This makes the chart a private venture by the officers of the IUGS Commission on Stratigraphy, although its publication in 'Episodes' gives it an official character. With regard to the Carboniferous, the choice of units is controversial in places, and it contains a number of errors which need to be corrected. One also notes the exclusive use of palaeoequatorial belt stratigraphy and the lack of attention to the problems of its application to the extensive Gondwana and Angará areas, i.e. almost half the world. The various assumptions and errors apparent in this chart have been discussed briefly at the SCCS meeting during the XII International Congress of Carboniferous and Permian Stratigraphy, held in Buenos Aires, 1991. It was agreed that correction was necessary and the present authors were commissioned to compile a charge list. This implied the confection of a new global chart for the Carboniferous. Since this may be construed as a major task, it has taken rather longer than was originally envisaged. It must be emphasised that the revised chart is essentially an excercise in correlation of regional chronostratigraphic classifications of palaeoequatorial belt areas and that it does not commit the IUGS Subcommission on Carboniferous Stratigraphy for a global scheme.

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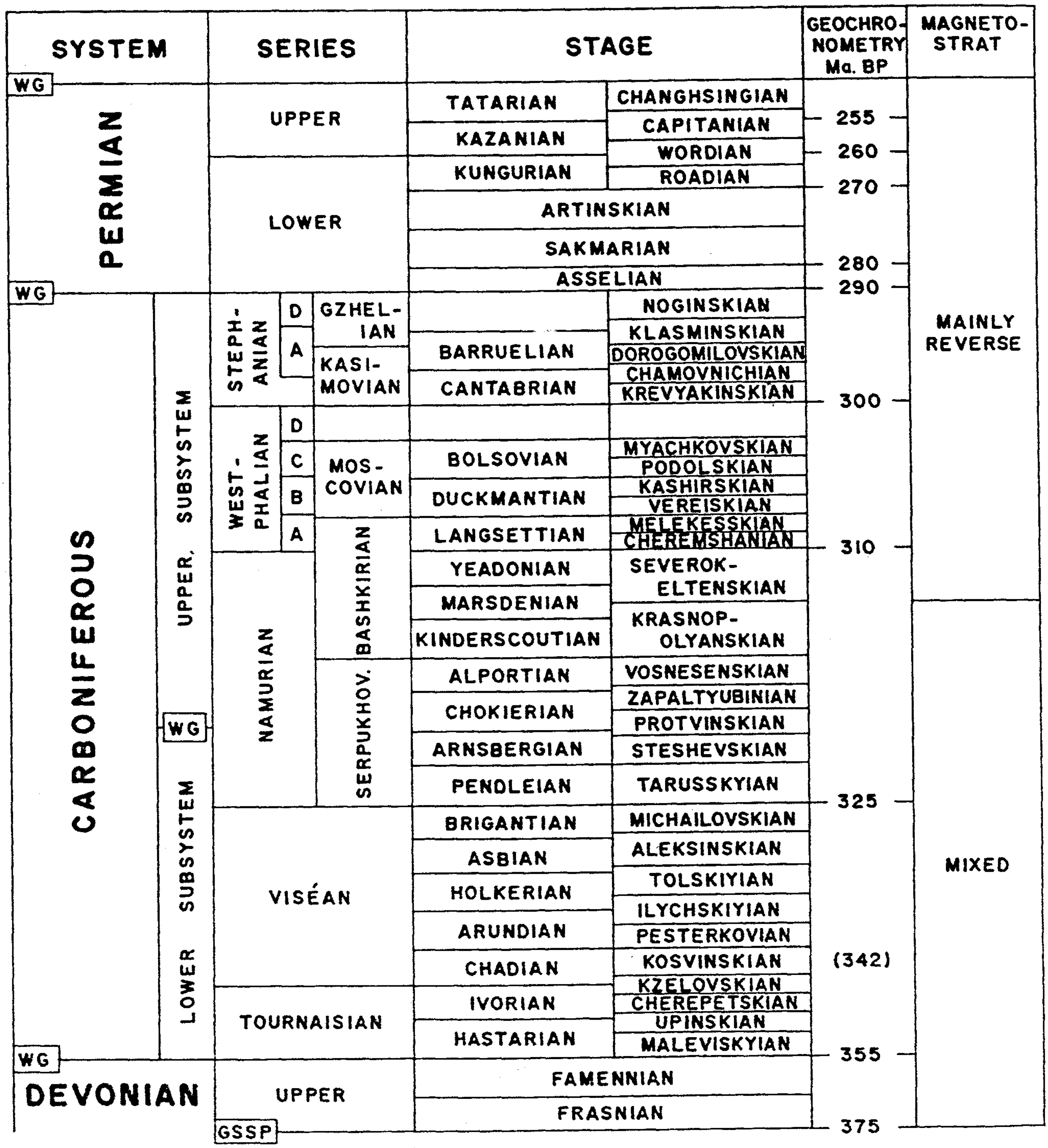


Fig. 1. Part of the IUGS Commission on Stratigraphy global stratigraphic chart compiled by Cowie & Bassett (1989) showing the uppermost Devonian, Carboniferous and Permian.

## 2.- ORIGINS OF THE CHART

In the absence of a clear attribution of authorship and assuming that Cowie and Bassett are the compilers of information received, the origins of the Carboniferous section of the 'Global Chart' (Fig. 1) have had to be deduced by a sleuthing effort. It is noted that this chart bears a close resemblance to the one produced by Harland *et al.* (1989, p. 45), although the latter is more accurate (Fig. 2). Some of the apparent differences should probably be ascribed to errors of transcription, such as the loss of two Russian horizons ('stages') and the gap appearing opposite Westphalian D. Some of the Russian names also suffered from spelling mistakes.

The (more complete) chart in Harland *et al.* (1989) acknowledges the charts reproduced in Ramsbottom (1981), Bouroz *et al.* (1977-1978), Rotai (1979), Wagner & Higgins (1979), and two reports on the British Carboniferous (George *et al.*, 1976; Ramsbottom *et al.*, 1978). The main inspiration seems to have been the chart in Ramsbottom (1981), a 'grey' publication issued as a field guide to participants in the 1981 SCCS meeting, held in Leeds. This chart is an unacknowledged copy of the chart prepared as a discussion document by the then secretary of SCCS, C.F. Winkler Prins (Newsletter on Carboniferous Stratigraphy, no. 2, 1981). This is another grey publication.

It thus appears that the discussion document in the Newsletter gained credence by being copied without comment in a field guide, and by its subsequent incorporation in the more comprehensive chart of Harland *et al.* (1989) and, finally, in the 'Global Chart' of the IUGS Commission on Stratigraphy (Cowie & Bassett, 1989). The successive transcriptions may be blamed for unexplained minor changes in the correlations proposed and, of course, the loss of two Russian 'stages' and the Westphalian D error mentioned earlier.

Both Harland *et al.* (1989) and Cowie & Bassett (1989) translated Russian horizons into stages, a logical step if the stratotypes of these units are incontrovertible and no stratigraphic gaps are admitted between these units. However, this is still a tall order. It is also noted that the 'ian' ending is placed after the adjectival 'sky', e.g. Myachkovsky Horizon becomes Myachkovskian Stage, whereas this should have become Myachkovian.

It all appears an object lesson on how careful one should be in preparing a discussion document, and how the use of grey publications should be more carefully controlled.

## 3.- APPROACHES TO STRATIGRAPHIC CLASSIFICATION

It seems worthwhile to the present writers to discuss briefly the underlying principles of stratigraphic classification as applied to the Carboniferous.

A chronostratigraphic classification attempts the subdivision of geological time into more or less natural intervals which are represented by sedimentary rock units limited at the base by a horizon defined with reference to a stratotype fixed by international agreement. This implies (1) the search for what appear to be the most natural time intervals capable of being recognised worldwide, (2) a convenient basal limit to such intervals, and (3) the selection of a stratotype.

The classical approach to these aims is to use the evolutionary history of selected organisms and to try and detect evolutionary changes of a certain order of magnitude to punctuate geological time and to use these as the basis for a selection of chronostratigraphic boundaries. The implied requirements for this method to be fully operative are readily apparent. Whenever evolutionary changes have operated with sufficient rapidity to become apparent in the geological record, there is normally an external event exerting pressure on the organic world in order to provoke changes in composition and distribution pattern, which, in turn, allow taxa with successful evolutionary characters to come to the fore. More gradual evolutionary changes operating at times of limited stress on the organic world, are not likely to become sufficiently apparent for their use as stratigraphic markers.

A further consideration is the worldwide validity (application) of evolutionary events. Geological time as measured by biological changes is rather imprecise so that it is possible to discount the time taken by new taxa to achieve worldwide distribution as relatively short and insignificant in chronostratigraphic terms. This being the case, it appears reasonable to focus on certain biological changes and to expect these to mark a moment in geological time worldwide. However, all biological organisms are limited in their occurrence (distribution) by environmental considerations. It is often attempted to circumvent these considerations by selecting organisms which are subject to only limited environmental control. Classical examples of the latter are pelagic and nektonic marine forms belonging to the ammonoids, graptolites, foraminifera, conodonts, acritarchs, etc. This has given rise to a division into star organisms capable of providing the means for an 'orthostratigraphy' and more second rate organisms cast in a supporting rôle and providing the elements for a 'parastratigraphy' (Schindewolf, 1970). Although this approach appeals to the orderly

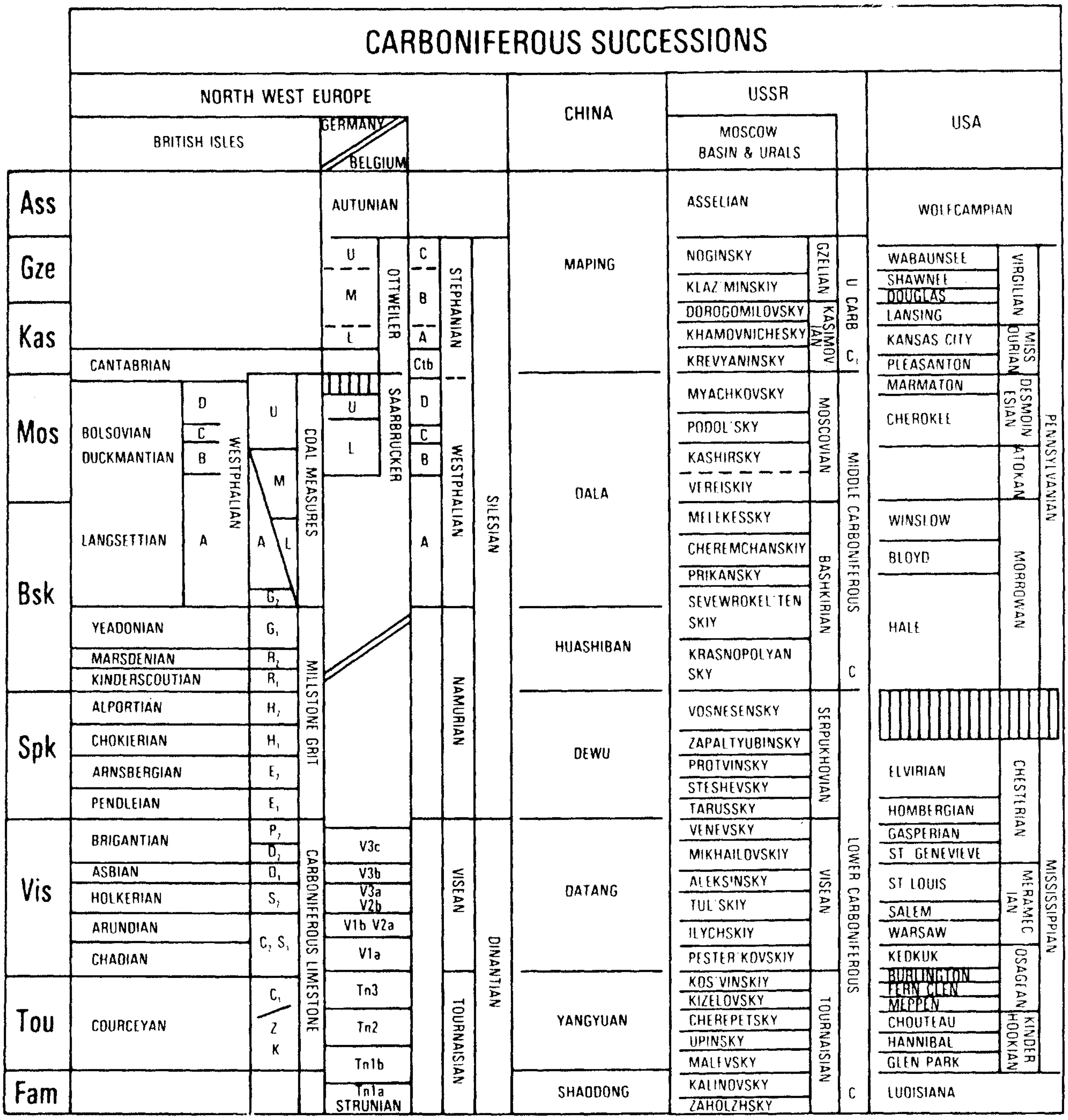


Fig. 2. Chart with selected Carboniferous successions (from Harland *et al.*, 1989, p. 45).

mind, it begs the question on a number of points. First of all, there is no apparent likelihood that any organism save man and bacteria/virusses managed to achieve worldwide distribution at times of environmental stress, either climatic, tectonically, or otherwise induced. Again, save man, organisms tend to be either aquatic or terrestrial which is another limitation on the subdivision of a stratigraphic record which includes marine, lacustrine and wholly terrestrial sedimentary intervals. It is obviously of little use to impose a marine standard on wholly terrestrial sedimentary successions, particularly at intervals such as the later Carboniferous and part of the Permian when terrestrial environments were very widespread. It is further observed that evolutionary changes in organisms must be reflected in measurable characters to be of any practical use.

Since all these requirements add up to a utopian situation, the practising chronostratigrapher has usually tempered his biostratigraphic approach by different considerations. Without abandoning the analysis of more or less significant changes in the organic world, attempts are made to observe also the physical changes which operated in the course of geological history and to relate these to the biological changes. Again, these physical changes are most important at times of environmental stress. When dealing with such times, the chronostratigrapher should probably pay particular attention to the physical changes and their effect on the organic world, rather than attempt to minimise them and concentrate on the so-called 'orthostratigraphic' organisms.

This means that a uniform approach to chronostratigraphic classification valid for all periods of geological time is too simplistic. It is not a matter of filling in forms for an apparently successful administration. What may be reasonably successful in one part of the geological column may well be doomed to failure in another.

With regard to the Carboniferous, there is increasing recognition of the fact that this period coincided with an ice age (Pennsylvanian times - Late Carboniferous) (e.g. Maynard & Leeder, 1992) and the runner-up to an ice age (Mississippian - Early Carboniferous). These were times of environmental stress which exerted considerable control on the evolutionary activity and distribution of organisms. It is readily apparent that overall biological changes will reflect the environmental stresses and may well be worldwide, but that specific changes in selected organisms will not possess worldwide validity. The cause-effect relationship will have to be evaluated in each case and the result compared with physical changes in the Carboniferous world history in order to provide a framework for chronostratigraphic subdivision.

The history of Carboniferous stratigraphic classification in the different parts of the world provides a clear indication of the mixture of different criteria employed.

Three broad areas at different palaeolatitudes are distinguished, viz. the warm palaeoequatorial belt (widening and narrowing at times of worldwide temperature changes), and cooler southern and northern hemisphere areas which are broadly but not completely identified with Gondwana and Angará. Very different chronostratigraphic schemes have evolved for these different areas, with the amount of detail being markedly less in the climatically adverse regions at the higher palaeolatitudes, where floras and faunas were much less diverse. It is also observed that the relatively high proportion of terrestrial strata laid down in Late Carboniferous (Pennsylvanian) times, when sea level was generally low, has resulted in a a variety of different chronostratigraphic schemes with variable emphasis on marine and non- marine organisms, depending on local developments. Physical, inorganic events have also played a role in the different schemes adopted, and sea-level changes have figured prominently in certain attempts at regional and even global correlation. The following chapters will briefly analyse the various stratigraphic classifications involved. Several of these appear in one guise or another in the rather mixed bag which appears in Cowie & Bassett's 'Global Chart'. It is noted that the 'Global Chart' does not yet propose a single set of stratigraphic units worldwide (thus acknowledging the rather special problem existing with regard to Carboniferous chronostratigraphy). It is, in effect, a correlation chart involving units of West European and Russian/Ukrainian stratigraphic classifications.

## 4.- WEST EUROPEAN CLASSIFICATION

This is perhaps the best known scheme evolved for part of the palaeoequatorial belt. It has been the result of successive Congresses on Carboniferous Stratigraphy and Geology organised initially by W.J. Jongmans, W. Gothan & A. Renier (1927) in the mining town of Heerlen, The Netherlands. The 'Heerlen Classification' was based on stratigraphic developments in different parts of Northwest Europe and contained elements of both biostratigraphy and physical correlation. The West European chronostratigraphic succession, built up of units recognised in various basins in different palaeogeographical areas, contained at least one major gap in the stratigraphic record and suffered generally from the mixture of criteria which had been applied. Despite these imperfections, it has been widely used and has generally withstood the test of time. Successive changes introduced at various Carboniferous congresses and meetings of the IUGS Subcommission on Carboniferous Stratigraphy (SCCS) have resulted in the following classification as approved by various decisions of SCCS (Fig. 3).

No stages are officially recognised for the Tournaisian and Viséan series, but two rival successions of proposed stages exist for the Dinantian limestones in Britain and Belgium, respectively

| Subsystems | Series | Stages |
|---|---|---|
| Silesian | Stephanian | Stephanian C<br>Stephanian B<br>Barruelian<br>Cantabrian |
| | Westphalian | Wesphalmian D<br>Bolsovian<br>Druckmantian<br>Langsetian |
| | Namurian | Yeadonian<br>Marsdenian<br>Kinderscoutian<br>Alportian<br>Chokierian<br>Arnsbergian<br>Pendleian |
| Dinantian | Viséan | |
| | Tournaisian | |

Fig. 3. Official classification for the Carboniferous of western Europe.

| | |
|---|---|
| Brigantian | Warnantian |
| Asbian | |
| Holkerian | Livian |
| Arundian | |
| Chadian | Moliniacian |
| | Ivorian |
| Courceyan | Hastarian |

Fig. 4. Local stage names for the Dinantian in limestone facies: in Britain (left) and Belgium (right).

(George *et al.*, 1976; Conil *et al.*, 1977). The British scheme was subsequently modified by Ramsbottom & Mitchell (1980) with the aim to adapt to the international series Tournaisian and Viséan. Their basal stage, Courceyan, being equivalent to the Tournaisian Series, was abandoned, and acceptance of the constituent stages of Belgian origin, Hastarian and Ivorian, was advocated (Fig. 4). However, in a critical analysis of the British Dinantian stages, Riley (1993) notes that neither the Courceyan/Chadian boundary nor the top of the Ivorian in Belgium (Conil *et al.*, 1990, fig. 5) coincide with the base of the Viséan. He reverts to Courceyan for the British succession. Riley's analysis shows that the stratotypes of the British Dinantian stages need adjustment and, in some cases, redefinition. These stages, introduced as 'regional stages applicable only in the British provinces' (George *et al.*, 1976, p.5), have been used fairly extensively, but have never been discussed in meetings of the SCCS. They obviously need to be proposed formally and submitted to a vote of the SCCS membership before they can be admitted as forming part of the regional Carboniferous

| WESTERN EUROPE | | | ex USSR (mainly Russian Platform) | | Approximate absolute ages in Ma: |
|---|---|---|---|---|---|
| | L.P. Autunian | | Sokoljegorsky | L. Permian | |
| | -?- | | | | 290 |
| | | | Noginsky | Gzhelian | |
| | Stephanian | Stephanian C | Pavlovo-Posadsky | | |
| | | Stephanian B | Amerevsky<br>Rechitsky | | |
| | | | Yauzsky | Kasimovian | |
| | | Barruelian | | Dorogomilovsky | |
| | | | Khamovnichesky<br>Krevyakinsky | | |
| | | Cantabrian | | | |
| | | | Myachkovsky | Moscovian | 305 |
| | Westphalian | Westphalian D | Podolsky | | |
| | | Bolsovian | Kashirsky | | |
| | | Duckmantian | | | |
| | | Langsettian | Vereisky | | |
| | | | | | 315 |
| UPPER SUBSYSTEM (PENNSYLVANIAN) | Namurian | | Asatausky* | Bashkirian | |
| | | Yeadonian | Tashastinsky*<br>Askynbashsky* | | |
| | | Marsdenian | | Akavassky* | |
| | | Kinderscoutian | Syuransky* | | |
| | | Alportian<br>Chokierian | Voznesensky** | Serpukhovian | |
| .... | | | | | M.C.B. 320 |
| | | | | Zapaltyubinsky** | |
| | | Arnsbergian<br>Pendleian | | Protvinsky<br>Steshevsky<br>Tarussky | |
| | | | | | 325 |
| LOWER SUBSYSTEM (MISSISSIPPIAN) | Viséan | Brigantian***<br>Asbian*** | Venevsky<br>Mikhailovsky<br>Aleksinsky | Viséan | |
| | | Holkerian***<br>Arundian***<br>Chadian*** | Tulsky<br>Bobrikovsky<br>Radaevsky | | |
| | | | | Kosvinsky | |
| | | | | | 345 |
| | Tournaisian | Courceyan*** | Kizelovsky*<br>Cherepetsky<br>Karakubsky**<br>Upinsky<br>Malevsky | Tournaisian | |
| | | | Kalinovsky | | 355 |
| | U.D. Famennian | | Zavolzhsky | Famennian | |

* = type section in the Urals;
** = type section in the Donbass;
*** = British provincial stages.
M.C.B. = Mid-Carboniferous Boundary.

Fig. 5. Correlation scheme for the main chronostrati-graphic subdivisions in the ex-USSR and western Europe (compare Wagner & Winkler Prins, in press).

chronostratigraphy of western Europe. This should provide the opportunity to judge their validity in a wider context. Although Cowie & Bassett (1989) are careful to point out that their inclusion in the 'Global Chart' does not constitute formal approval, these British regional stages should not have appeared in a more international context before having passed scrutiny by SCCS.

A third classification of Dinantian stages has been proposed for the so-called 'Kulm' facies in Germany (a misnomer), where ammonoid faunas constitute the basic biostratigraphic reference. Three stages have been distinguished, viz. the Balvian, Erdbachian and Aprathian (compare Paproth, 1977). The middle stage is of long duration and spans both the higher Tournaisian and the lower Viséan. The international status of these stages is in doubt, particularly since they were conceived as alternatives to the Tournaisian and Viséan subdivisions of the Dinantian.

The Tournaisian and Viséan were upgraded to series when the Namurian, Westphalian and Stephanian units became series (George & Wagner, 1972). Originally described as stages, they were based on limestone successions in Belgium. With regard to biostratigraphy, small foraminifera were used to adjust boundaries between constituent units of lithostratigraphic origin, viz. Tn1, 2, 3, V1, 2, 3 with subunits a, b, c, d. These connotations are still used quite commonly in correlation charts and specialists are aware that these refer basically to foraminiferal biostratigraphy. Boundaries between the stratotypes of these units were often adjusted to conform to current knowledge of the stratigraphic ranges of significant taxa. Conodont biostratigraphy, though not wholly concordant, was fitted largely into the existing (Belgian) stratigraphic framework.

The Namurian Series (van Leckwijck, 1964) was subdivided into stages by Bisat (1928) with subsequent modifications by Hudson & Cotton (1943), Hudson (1945) and Hodson (1957). These stages were recognised on the basis of successive goniatite faunas occurring in bands representing marine transgressions or deepening of marine areas (i.e. the basal parts of mesothems sensu Ramsbottom, 1977). Stratotypes were instituted in Great Britain and Ireland, with the peculiarity that some stage names (Arnsbergian, Chokierian) referred to localities in western Germany and Belgium. (An instance of geographically derived stage names which do not refer to the actual stratotypes used.) The history of stage names and a discussion of the stratotypes can be found in Ramsbottom (1969). The entire set of Namurian stages has been accepted by SCCS (George & Wagner, 1969, p. XLIV, p. 186).

The Westphalian Series was originally (Jongmans, 1928) subdivided into the informal units A, B, C (to which Westphalian D was added at a later date: Jongmans & Gothan, 1937). Lower boundaries of these A, B, C, units were placed at the *subcrenatum, vanderbeckei* and *aegiranum* marine bands, i.e. at large scale eustatic transgressions. Although the goniatites occurring in these marine bands were used as biostratigraphic markers, their rôle was restricted to the identification of the marine transgressive events. The restricted nature of the goniatite faunas involved, and the sporadic occurrence of the marine bands prevented a full goniatite biostratigraphy to be worked out in the Northwest European paralic area. Floral and non-marine bivalve zones were fitted into the framework of the marine transgressive events, in sofar as possible. The Westphalian A, B, C stages were renamed Langsettian, Duckmantian and Bolsovian, with boundary stratotypes at the *subcrenatum, vanderbeckei* and *aegiranum* marine bands in localities in central England (Engel, 1989).

The Westphalian D was instituted on a wholly non-marine succession (Assise de la Houve) in the Saar-Lorraine Basin, outside the paralic area of NW Europe. Biostratigraphic support was provided by megafloral remains (Laveine, 1977). The limited fossil contents make the Assise de la Houve unsuitable as a stratotype and the search is on for a different stratotype elsewhere (Wagner & Alvarez-Vázquez, 1991).

The Stephanian Series was recognised on the non-marine strata in the intramontane basins of the Massif Central in France. The relevant successions, starting at somewhat different stratigraphic levels in the different basins, lie unconformably on metamorphic and igneous basement. Since a direct relationship to Westphalian is absent, a correlation with Saar-Lorraine has been attempted on floral contents. However, quite apart from the somewhat unsatisfactory nature of this correlation, the presence of a major stratigraphic gap between the Westphalian and Stephanian successions of Saar-Lorraine has created uncertainties. Jongmans & Pruvost (1950) subdivided the Stephanian into A, B and C subdivisions on the basis of the succession in the St Etienne (Loire) Coalfield as a nominal stratotype. The Stephanian A division was particularly unsatisfactory at St Etienne, and correlation usually employed a rival succession at Carmaux on the south side of the Massif Central.

Later work in the mixed marine and terrestrial strata of the Cantabrian Mountains, NW Spain, has permitted studying the Westphalian/Stephanian transition, absent elsewhere in western Europe. Currently, the Stephanian Series is subdivided into four stages, viz. the Cantabrian and Barruelian stages of the lower Stephanian and the Stephanian B and C of the upper Stephanian. The Cantabrian and Barruelian have their stratotypes in the Cantabrian Mountains (Wagner & Winkler Prins, 1985; Engel, 1989), whereas the Stephanian B and C have not yet been formally named and lack internationally recognised stratotypes. In Cowie & Bassett's 'Global Chart' the Cantabrian and Barruelian are recognised, but the Stephanian B and C are not specifically included. On the other hand, a Stephanian D division is included. This refers to a stage proposed by Bouroz & Doubinger (1977), who created it out of the top part of Stephanian C and the basal part of Autunian (which they redefined). This procedure has been questioned and the Stephanian D Stage has not been sanctioned by SCCS. It is noted that this questionable unit appears in the 'Global Chart' without any form of qualification. Harland *et al.* (1989) correctly omitted Stephanian D, but placed the base of the Autunian in exactly the same position as the base of the Asselian. This implies acceptance of the redefinition of Autunian as proposed by Bouroz & Doubinger (1977).

The history of the European classification shows its origins to lie in a compromise between local practice in different parts of western Europe. The informal names Westphalian D, Stephanian B and Stephanian C are left over from the time when these were regarded as substages. There is a formal SCCS recommendation to replace these units by properly named stages with internationally recognised stratotypes (George & Wagner, 1972). The regional West European classification (George, 1969, p. 189) lacks a broad concept underlying its structure. For a discussion on the origins of the chronostratigraphic units in the Silesian (Upper Carboniferous in the West European sense) see Wagner (1974).

## 5.- RUSSIAN CHRONOSTRATIGRAPHY

In the former USSR relatively large chronostratigraphic units called stages but approximately as large as the series in western Europe, are used in conjunction with smaller subunits called 'horizons' and which are broadly comparable with the West European stages. The 'horizons' are in effect local stages or substages with different sets for the different major areas, such as the Russian Platform (Moscow Syneclise and Volga-Urals area), Urals, and Donets Basin. In the 'Global Chart' of Cowie & Bassett (1989), the stages of universal application within Russia (with the exception of the Angará area to be discussed later) are called series and certain horizons from the Russian Platform, the Donets Basin and the Urals are called stages.

The succession of horizons in the Russian Platform area (Moscow Syneclise in particular) hides a number of stratigraphic gaps which are filled elsewhere. Important gaps are associated with the upper parts of Serpukhovian and Bashkirian. Both the Bashkirian and the Moscovian show overstep in the Moscow Syneclise. Although the Serpukhovian is typified by a succession in the southern part of the Moscow Syneclise (Tarussky, Steshevsky and Protvinsky horizons), the upper part of this stage is absent in the Moscow area and is recognised with reference to the Zapaltyubinsky and Voznesensky horizons of the Donets Basin. The Bashkirian is typified by a succession in the South Urals (Gornaya Bashkiria), but Cowie & Bassett (1989) accept as stages the Krasnopolyansky, Severo-Keltmensky (misspelt in their chart), Cheremshansky, and Melekessky horizons of the Russian Platform (leaving out the Prikamsky Horizon in the middle part - an unexplained omission). Since the Russian Platform succession is problematical due to the presence of stratigraphic breaks, this choice is open to criticism. For the Tournaisian and Viséan stages (with different lower boundaries to those of the Tournaisian and Viséan series in western Europe) a mixture of Russian Platform and Urals horizons have been used for the subdivision in Cowie & Bassett's scheme. It is unclear why some units have been preferred over others. Also the correlations between the selected Russian units and the British succession cannot be checked easily, although the position of the Tournaisian/Viséan boundary shown on the chart is at variance with that currently admitted by Russian authors.

It is noted that foraminiferal faunas are the preferred biostratigraphic tool in the Carboniferous of the former USSR. This tends to favour limestone successions. The inherent weakness of such successions is the presence of stratigraphic gaps as occur, in fact, in the Russian Platform successions. The problems associated with stratigraphic breaks explain the oft expressed preference for the Donets Basin as providing the standard succession of Carboniferous strata in the former USSR (Aisenverg *et al.*, 1979; Rotai, 1979). The varied facies present in the Donets Basin allow different biostratigraphic elements to come into play.

In conclusion, it appears that Cowie and Bassett's decision to convert certain horizons in the Russian Platform area (Moscow Syneclise above all) and the South Urals into stages of more general validity is not only debatable on formal grounds (such a decision should have been left to Russian and Ukrainian workers), but unsound in the selection of units.

The correlations between Russian 'horizons' and West European stages in Cowie & Bassett's 'Global Chart' contain a number of discrepancies in the higher part of the column. A draughtsman's error is suspected for the gap shown between Myachkovian and Krevyakinian. Although a stratigraphic break is present between Moscovian and Kasimovian limestones in the Moscow Syneclise, this is not of such a magnitude as to comprise the entire Westphalian D, as is shown on the chart.

Problems of scientific interpretation appear with the base of the Moscovian for which published information (Wagner & Bowman, 1983) suggests a position within the Langsettian (ex Westphalian A) and not at the base of the Duckmantian as the 'Global Chart' indicates. It is possible that the apparent shift to the base of the Duckmantian is merely due to transcription and does not reflect a change in opinion. It should be noted here that still unpublished information does, in fact, tend to lower the base of the Moscovian to near the base of the Langsettian. Further problems exist with regard to boundaries within the Moscovian. There is information on marine faunas and terrestrial floras in western Europe, showing the Podolsky/ Myachkovsky transition to lie within lower Westphalian D (Wagner & Alvarez-Vázquez, 1991) and not within the Bolsovian (ex Westphalian C), as the 'Global Chart' suggests. The upper Myachkovsky is known to coincide with lower Cantabrian (Wagner & Winkler Prins, 1985) and the lowermost Kasimovian Krevyakinsky Horizon comprises all or most of the upper Cantabrian (*op. cit.*). Also in this case the 'Global Chart' shows boundaries which are unsupported by factual information. Furthermore, the base of the Gzhelian is shown as lying within the Barruelian (ex Stephanian A). Although the factual information is inconclusive, it seems preferable to place the base of the Gzhelian at a higher level, i.e. within the Stephanian B, as Wagner & Higgins (1979) have suggested. It is noted that the 'Global Chart' uses an obsolete subdivision of the Gzhelian.

## 6.- NORTH AMERICAN CLASSIFICATION

There does not seem to be a standard North American subdivision into stages on the European model. A main division into Mississippian and Pennsylvanian systems acknowledges a general regression at the end of Early Carboniferous times. Sedimentation recommenced at somewhat different times in the different areas, so that the base of the Pennsylvanian corresponds to different horizons.

The U.S. Geological Survey recognises Lower and Upper Mississippian series and Lower, Middle and Upper Pennsylvanian series. These are subdivided into 'provincial series' (probably to be equated with stages) which differ for the major basins and sometimes between the individual states (compare Craig & Connor, 1979; McKee & Crosby, 1975). Some of the provincial series gained wider currency than others, but there is no apparent standardisation. (Rather similar, in fact, to what has happened with the 'horizons' in the former USSR.)

The Lower Mississippian is commonly divided into the Kinderhookian and the Osagean, and the Upper Mississippian into Meramecian and Chesterian. These are based on marine successions with a high proportion of limestones. Correlations rely on small foraminifera, benthic invertebrate faunas, conodonts, and, where suitable facies are developed, ammonoids. Plant fossils are used to a lesser extent, although the Chesterian in particular is often dated on spore assemblages.

The Lower, Middle and Upper Pennsylvanian are subdivided into a number of 'provincial series', which are different for the different areas, and also for mainly marine and principally terrestrial successions. Wide currency has been given to the rather condensed succession of the Ozark Platform of Oklahoma/Arkansas, where goniatites and conodonts have permitted correlations across the Atlantic and, notably, with the British Isles. The Morrowan and Atokan of the Lower Pennsylvanian are involved here. Adjoining shelf and basinal areas display Desmoinesian and Missourian 'provincial series' for the Middle Pennsylvanian and Virgilian and Garyan for the Upper Pennsylvanian. These are all based on predominantly marine developments of strata which extend into Missouri and Kansas Mid-Continent areas, west of the Illinois Basin. The same 'provincial series' are employed in Illinois.

Correlations with western Europe are often given in a simplistic manner showing the apparent coincidence of chronostratigraphic boundaries (e.g. Ramsbottom & Saunders, 1985, fig. 5). However, the underlying biostratigraphies are not normally the same and zonal boundaries are not likely to be identical unless they are consciously made to fit an existing scheme.

## 7.- GONDWANA AND ANGARA AREAS

It is noted that the 'Global Chart' only reflects the stratigraphic classifications erected for the different regions of the palaeoequatorial belt. It does not take into account the extensive areas at higher palaeolatitudes. This is regrettable because there is an implied assumption that stratigraphic subdivisions distinguished with the aid of tropical/subtropical faunas and floras may be recognised worldwide. This is not only uncertain, but untrue for later Carboniferous times when the Pennsylvanian Ice Age became established. Floral and faunal diversity fell off sharply at the higher palaeolatitudes in the Pennsylvanian world. Certain groups became restricted to the palaeoequatorial belt and the species contents of other groups became very different for the different palaeolatitudes.

This is the reason why the general framework of Pennsylvanian stratigraphy should really be established in agreement with worldwide climatic events sufficiently important to change the distribution pattern of floras and faunas everywhere. Regional classifications may then be fitted into this general framework, it being understood that the stressful environments of the higher palaeolatitudes will not allow the same amount of biostratigraphic detail as the warm seas and land surfaces of the palaeoequatorial belt (with Palaeotethyan marine faunas and Amerosinian terrestrial floras).

The literature on 'Upper Carboniferous' (Pennsylvanian) stratigraphy in the Gondwana and Angará areas is full of failed attempts to adapt to palaeoequatorial belt chronostratigraphy based on biostratigraphic criteria. In a recent analysis, Wagner (in press) proposed the recognition of three major climatic events for worldwide chronostratigraphic use, viz. (1) the effective commencement of the Pennsylvanian Ice Age, (2) a warming event in late Pennsylvanian times (Alykaevo Event of Meyen, 1982) and (3) the waning of the ice age at the end of the Pennsylvanian. The biostratigraphic response to these events has been different at the different palaeolatitudes, but the shift in floral and faunal distributions should be noticeable worldwide.

The commencement of the Ice Age is regarded as having had an instant response at the higher palaeolatitudes where the lowering of temperature provoked a marked loss in diversity of floras and faunas. The same cause apparently had a delayed effect on shallow marine faunas and terrestrial floras in the palaeoequatorial belt regions, where the general lowering of sea level at the end of the Mississippian seems to have resulted in shifts in population favouring opportunistic taxa. This apparently generated faunal and floral changes of sufficient magnitude to show up in the biostratigraphic record. In the Australian part of the Gondwana area the biological changes attributable to a substantial lowering in temperature seem to have operated at the end of the Viséan (Roberts *et al.*, 1985; González, 1990). In the palaeoequatorial belt the delayed effect due to the general fall in sea level does not show up in the record until lower Namurian E2c (see Wagner, in press). Although two different stratigraphic levels are involved, the same general cause is suspected. After an analysis of the biological changes in the palaeoequatorial belt faunas and floras, the IUGS-SCCS settled its so-called mid-Carboniferous boundary at a level within the lower Namurian, which is apparently coincident with the end of the Mississippian. This boundary is currently classed as subsystemic (Engel, 1989), but American geologists generally consider it to be systemic, a point of view which may well be supported if the importance of the climatic event is taken into consideration.

In the Gondwana area it is difficult to subdivide the Pennsylvanian on biostratigraphic grounds. Magnetic reversal stratigraphy is practiced in conjunction with palynology and, to a certain extent, macropalaeobotany, to effect subdivision but the results are often debatable. In the high palaeolatitude Angará area the poorly diversified *Rufloria* 1 Assemblage is followed by the more highly diversified *Rufloria* 2 Assemblage of later Pennsylvanian age. This changeover is known as the Alykaevo Climatic Optimum (Meyen, 1982). It may be assumed that this warming event may well be the same climatic change which produced a decrease in wet, lycophyte-rich peat-forming environments at the transition between Middle and Late Pennsylvanian times in the palaeoequatorial belt (Phillips & Cross, 1991). If this is so, the means exist to correlate between areas of high palaeolatitude and the palaeoequatorial belt. Probably, the *Potonieisporites* Zone of tree pollen in the higher Pennsylvanian of Gondwana also marks a climatic amelioration due to the same event (Wagner, in press).

Even more marked warming occurred at the end of the Pennsylvanian. This was associated with the introduction of thermophile plants into marginal areas of Gondwana and Angará, and with a fairly generalised transgression on the margin of the Gondwana Continent. At the same time, a progressive increase in drier areas took place in the palaeoequatorial belt regions, as well as a general shift of peat-forming environments towards the middle latitudes. Permian coals mainly occur in the Gondwana and Angará areas, with a notable exception occurring in China which lay in the palaeoequatorial belt.

## 8.- CURRENT PROPOSALS FOR A GENERAL SUBDIVISION

At the SCCS meeting in Beijing, 1987, the decision was taken to subdivide the Carboniferous into two subsystems, provisionally named lower and upper subdivisions. Although these two subdivisions closely resemble Mississippian and Pennsylvanian, these traditional names have not (yet?) been adopted. On the other hand, Harland *et al.* (1989) have no qualms in using Mississippian and Pennsylvanian (following Bouroz *et al.*, 1977-1978). The use of these names does not preclude the recognition of a boundary stratotype outside North America.

During the SCCS meeting at Provo, 1989, six levels were selected as important for the eventual recognition of major chronostratigraphic boundaries within the Carboniferous (see Newsletter on Carboniferous Stratigraphy, no. 8, p. 5, 1990). Although biozones based on foraminifera, goniatites and conodonts were emphasised, the approximately coincident boundaries of recognised regional chronostratigraphic units were stated as well.

It is noted that Project 6, dealing with the selection of a level close to the Moscovian/Kasimovian and Desmoinesian/Missourian boundary, involves the middle to upper Carboniferous boundary admitted by Bouroz *et al.* (1977-1978). All the other projects involve boundaries which are less important historically, or even entirely new.

## 9.- CONCLUSIONS

1. The unauthorised, unacknowledged use of discussion documents in grey publications, such as the Newsletter on Carboniferous Stratigraphy, should be discouraged.

2. The publication of a poorly constrained Carboniferous chronostratigraphy in the IUGS journal 'Episodes' by officers of the Commission on Stratigraphy has done a disservice to the Subcommission on Carboniferous Stratigraphy, which is likely to be blamed for the inaccuracies.

3. The historical process of regional Carboniferous chronostratigraphic classifications having been erected in different parts of the world may be explained, at least in part, by the biostratigraphic differences induced by climatic diversity. A correct appraisal of the climatic effects (temperature, sea-level changes) will be necessary for a general framework to be established for Carboniferous chronostratigraphy worldwide.

## 10.- SUMMARY CHART

Figure 5 provides the necessary corrections to the Carboniferous part of the 'Global Chart' published by Cowie & Bassett (1989). The present writers believe the information in Fig. 5 now to be substantially correct.

It is noted that the chart provides a correlation between chronostratigraphic units in western Europe and Russia/Ukraine. Both are regional chronostratigraphies and as such not globally binding. Their inclusion in a global chart by officers of the IUGS Commission on Stratigraphy (ICS) reflects the lack of an internationally agreed set of Carboniferous chronostratigraphic units of worldwide application. This is not an historical accident but due to the complexities inherent to a Period with extreme climatic differentiation imposing restrictions on biologically constrained units. It is the considered opinion of the present writers that globally valid chronostratigraphic units in the Carboniferous can only be recognised with reference to the climatic events which exerted such a marked control on faunal and floral distribution and development. The search for globally valid stratotypes will have to take this into account (compare Cowie *et al.*, 1986) and not focus exclusively on biological (evolutionary) changes in a limited part of the world, viz. the palaeoequatorial belt.

## 11.- POST SCRIPTUM

The summary chart was submitted to the SCCS membership present in Liège (June 1993) and, through Newsletter on Carboniferous Stratigraphy, 11, p. 10 (July 1993) to the membership at large. Comments were invited from SCCS members, but none were received.

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# ERRATUM

## GENERAL OVERVIEW OF CARBONIFEROUS STRATIGRAPHY

### (R.H. WAGNER & C.F. WINKLER PRINS)

ANN. SOC. GEOL. BELG. 116 (1993/1) : 163-174, 1994

The Editor of Annales de la Société géologique de Belgique informs that the above paper was published from a computer disc submitted before refereeing and which was not the definitive one available at the time of printing.The confusion is partially explained by the fact that the authors have sent no less than five successive versions of their manuscript. A controlled version of Figure 5, the main item of the published paper, is given below.

| | WESTERN EUROPE | | ex USSR (mainly Russian Platform) | | Approximate absolute ages in Ma: |
|---|---|---|---|---|---|
| L.P. | Autunian | | Sokoljegorsky | L. Permian | |
| - -?- - | | | | | 290 |
| | | | Noginsky | Gzhelian | |
| | Stephanian | Stephanian C | Pavlovo-Posadsky | | |
| | | Stephanian B | Amerevsky | | |
| | | | Rechitsky | | |
| | | | Yauzsky | Kasimovian | |
| | | Barruelian | Dorogomilovsky | | |
| | | | Khamovnichesky | | |
| | | | Krevyakinsky | | |
| UPPER SUBSYSTEM (PENNSYLVANIAN) | | Cantabrian | | | |
| | | | Myachkovsky | Moscovian | 305 |
| | Westphalian | Westphalian D | | | |
| | | | Podolsky | | |
| | | Bolsovian | | | |
| | | | Kashirsky | | |
| | | Duckmantian | | | |
| | | Langsettian | Vereisky | | |
| | | | | | 315 |
| | | | Asatausky* | Bashkirian | |
| | Namurian | Yeadonian | Tashastinsky* | | |
| | | | Askynbashsky* | | |
| | | Marsdenian | Akavassky* | | |
| | | Kinderscoutian | Syuransky* | | |
| | | Alportian | Voznesensky** | Serpukhovian | |
| | | Chokierian | | | |
| | | | | M.C.B. | 320 |
| | | | Zapaltyubinsky** | | |
| | | Arnsbergian | Protvinsky | | |
| | | Pendleian | Steshevsky | | |
| | | | Tarussky | | |
| | | | | | 325 |
| LOWER SUBSYSTEM (MISSISSIPPIAN) | Viséan | Brigantian*** | Venevsky | Viséan | |
| | | Asbian*** | Mikhailovsky | | |
| | | | Aleksinsky | | |
| | | Holkerian*** | Tulsky | | |
| | | Arundian*** | Bobrikovsky | | |
| | | Chadian*** | Radaevsky | | |
| | | | Kosvinsky | | |
| | | | | | 345 |
| | Tournaisian | Courceyan*** | Kizelovsky* | Tournaisian | |
| | | | Cherepetsky | | |
| | | | Karakubsky** | | |
| | | | Upinsky | | |
| | | | Malevsky | | |
| | | | Kalinovsky | | 355 |
| U.D. | Famennian | | Zavolzhsky | Famennian | |

* = type section in the Urals; ** = type section in the Donbass; *** = British local stages.
M.C.B. = Mid-Carboniferous Boundary.

Fig. 5. Correlation scheme for the main chronostratigraphic subdivisions in the ex USSR and western Europe