THE DEVONIAN-CARBONIFEROUS BOUNDARY IN RUSSIAN EURASIA

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ABSTRACT

Separate approaches to boundary determination by the International and the Soviet Working Groups on the Devonian-Carboniferous Boundary resulted in different boundary positions. These variations result from principally different theoretical approaches to the concepts of "chronostratigraphic scale" and "chronostratigraphic boundary." A short review of the former Soviet Working Group's approach and terms is given.

INTRODUCTION

The problem of determining the Devonian-Carboniferous (D/C) boundary has long been controversial. Scientists from many countries have proposed different boundary positions and/or have used different theoretical approaches in its determination. Since 1976, the International and Soviet Working Groups on the Devonian-Carboniferous Boundary (IWGDC and SWGDC) have made significant progress in the mutual understanding about the position of this boundary. Due to this work, comprehensive information has been obtained on the biostratigraphy of transitional deposits, evolution of different fossils, geologic history, palaeobiogeography, and more. However, because of the different theoretical approaches of the IWGDC and SWGDC, their official opinions about the paleobiological marker of the D/C boundary standard still disagree.

I will confine this discussion to the most important conclusions drawn by the SWGDC in the last 15 years about Arctic and subarctic Russia. These conclusions are necessary for decoding the evolution of the paleobiosphere since the Late Famennian through Early Tournaisian and involve the general idea of determining chronostratigraphic boundaries, particularly the theoretical approach to determining "natural" (event) boundaries, which were mainly adopted by the former SWGDC.

A SHORT HISTORICAL REVIEW

Devonian-Carboniferous transitional deposits of Russian Eurasia vary in composition and environmental properties. In contrast to coeval deposits of Western Europe (e.g., Ruhr Basin and Thuringia), Russia is dominated by shallow-water sediments belonging to the "foraminifer-coral-brachiopod facies" and deep-water deposits of the "ammonoid" or "basinal facies," which are distributed only in a few paleobasins, e.g., Berchogur and Kolyma. Until recently, the French-Belgian standard (Heerlen, 1928) was used by Russian workers to determine the D/C boundary position. According to this standard, the bottom of Etroeungt beds (or Strunian), containing the *Wocklumeria genozone* and *kobeitusana zone*, is taken as the base of the Carboniferous. In Western Europe and North America, the position of the D/C boundary has been determined in terms of the Ruhr standard at the base of *Gattendorfia genozone* adopted at the 2nd Carboniferous Congress.

Correlation of transitional D/C deposits and determination of the D/C boundary in Russian Eurasia has also been hampered by changing ideas of the length of the Etroeungt (Strunian) timespan for both the Franco-Belgian (Dinant) Basin and Russian Eurasia territory (Table 1). These changing ideas have resulted in different stratigraphic levels being used as the D/C boundary in different paleobasins by different investigators.

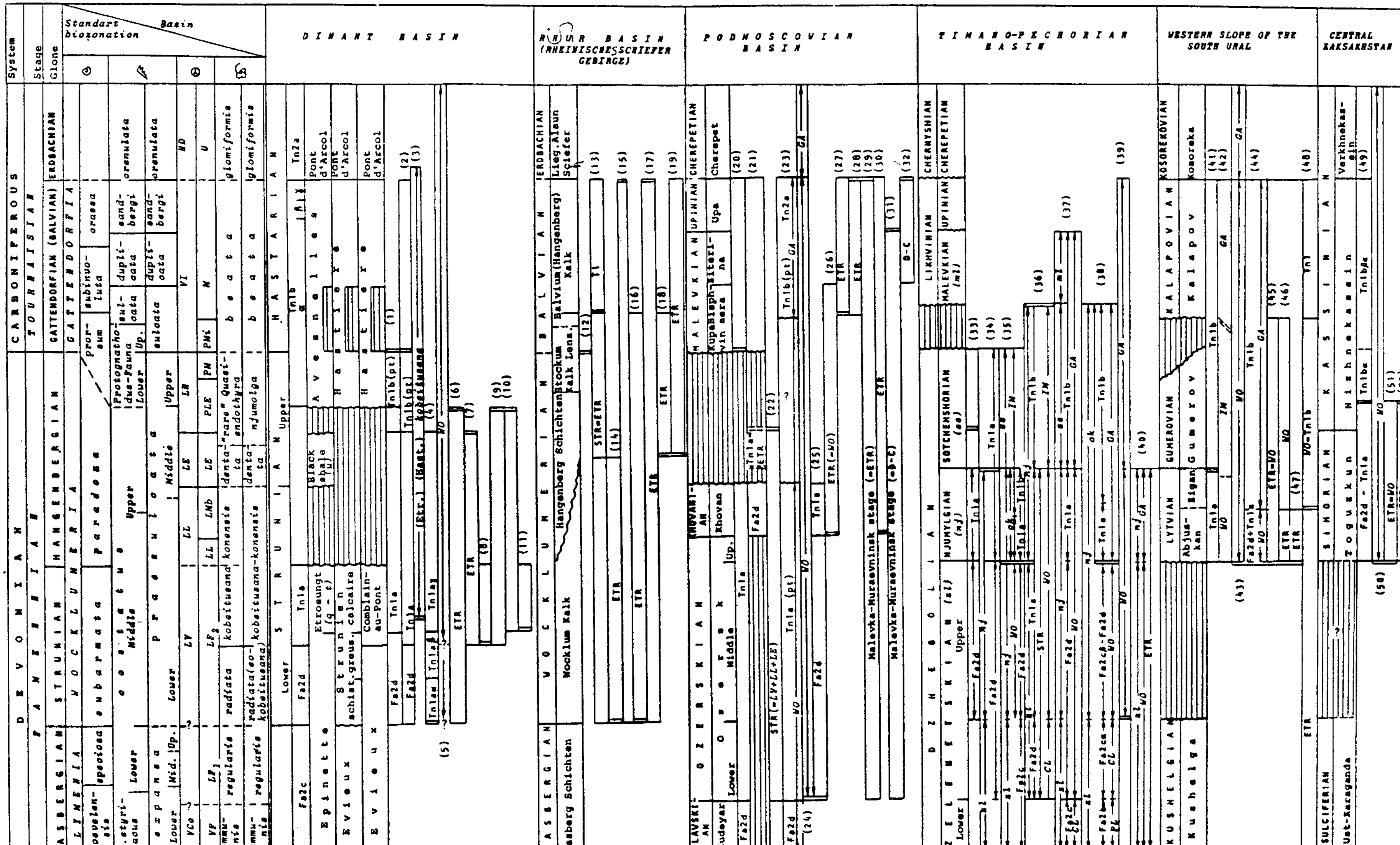
Recent investigation of the subdivision and correlation of transitional D/C deposits and determination of this boundary system in Russian Eurasia occurred in two stages. Stage 1 (pre-1975) work was done in preparation for the 1975 8th International Congress on Carboniferous Stratigraphy and Geology in Moscow. Mainly, "classical" reference sections were examined in the Donetz, Moscovian, and Timano-Pechorian basins, western slope of the South Urals, Kazakhstan, and others. The primary aim of this work was to prove the advantages of the official opinion of the Interdisciplinary Stratigraphic Committee that the D/C boundary coincides with the bottom of the *Wocklumeria genozone* and its equivalents. During stage 2 (post-1976), the D/C transition was studied over all of Russian Eurasia (including Pacific realm paleobasins) under the aegis of both the IWGDC and SWGDC to (1) search for a stratotype of the D/C boundary, which the IWGDC proposed to establish at the bottom of the *sulcata zone* (a primary goal) and (2) expand comprehensive investigations outside of "classical" distribution areas of transitional D/C deposits (e.g., East Siberia). This added new information about D/C transition stratigraphy.

As recently as 1979, D/C transitional deposits were believed to range in age approximately the same everywhere, corresponding to Etroeungt beds (Strunian) of the Dinant Basin. Different paleontological features of so-called "Etroeungt" ("Strunian") deposits in various paleobasins were explained by the paleobiogeographic differentiation factor (e.g., Bouckaert and Simakov, 1979). Comprehensive research on the reference section of Omolon paleobasin shallow-water deposits during 1976-1979 (Simakov et al., 1979), comparative studies of the Omolon reference section with the reference sections of Dinant Basin (Shilo et al., 1984; Simakov et al., 1983; Simakov, 1986), and recent examination of D/C transitional deposits of the Dinant Basin (Conil et al., 1986; Van Steenwinkel, 1988) prove the imperfect character of the French-Belgian standard for shallow-water D/C deposits. It has become clear that Etroeungt and Strunian Formations (now placed in the Upper Famennian) in the Dinant Basin are separated from Avesnois and Hastiere Formations, respectively, by stratigraphic breaks indicating that D/C transitional deposits (especially their Devonian portion), which are outside of the Dinant Basin, do not correspond to the same time interval in different paleobasins. Therefore, deposits distinguished as stratigraphic- and time-equivalents of the Etroeungt and Strunian Formations of the Dinant Basin are not contemporaneous with each other or with subdivisions of the French-Belgium standard of the same name. New proposals suggest that the transitional Upper Famennian-Lower Tournaisian deposits be distinguished as Strunian, Hangenbergian, and Gattendorfian global zones, or *"glones"* (Simakov, 1986, 1989, 1990).

PALEOGEOGRAPHICAL FRAMEWORK

Devonian-Carboniferous deposits were considered to be represented by two sedimentary transgressive-regres-

Table 1. Changes in the understanding of the timespan of the Etroeungt (Strunian) deposits in different areas.[a]



[a] 1. Conil et al., 1986; 2. Conil et al., 1976; 3. Mamet et al., 1965; 4. Conil and Lys, 1964; 5. Boger, 1962; 6. Paul, 1939; 7. Paeckelmann and Schindewolf, 1937; 8. Dorlodot, 1901 and Heerlen, 1928; 9. Geologic Map, 1892; 10. Session extraordinaire . . ., 1853; 11. Dufrenoy and Beaumont, 1840; 12. IWG D/C, 1979; 13. Paeckelmann and Schindewolf, 1937; 14. Librovich, 1938; 15. Schindewolf, 1935; 16. Delepine, 1930; 17. Delepine, 1929; 18. Heerlen, 1928; 19. Schmidt, 1924; 20. Makhlina i dr., 1988; 21. Chizhova, 1988; 22. Byvsheva, 1984; 23. Chizhova, 1977; 24. Rotai and Stepanov, 1975; 25. Umnova, 1971; 26. Lipina, 1960; 27. Birina, 1948; 28. Sokolskaya, 1940 and 1941; 29. Ivanov and Ivanova, 19386; 30. Kredstovnikov and Terentieva, 1933; 31. Struve, 1886; 32. Venyukov, 1886; 33. Byvsheva i dr., 1988; 34. Durkina and Avkhimovich, 1988; 35. Chizhova, 1985; 36. Raznitsyn, 1982; 37. Durkina i dr., 1980; 38. Chizhova, 1977; 39. Raznitsyn, 1959; 40. Raznitsyn, 1955; 41. Kochetkova i dr., 1988; 42. Kochetkova i dr., 1985; 43. Rotai and Stepanov, 1975; 44.Sultanaev, 1973; 45. Krestovnikov, 1962; 46. Krestovnikov and Karpyshev, 1948; 47. Chernyshova, 1940; 48. Nalivkin, 1937; 49. Mrtynova and Vorontsova, 1988; 50. Rotai and Stepanov, 1975; 51. Simorin, 1949; 52. Simorin, 1956; 53. Kassin, 1931.

sive cycles manifesting themselves simultaneously everywhere in the Northern Hemisphere (Johnson et al., 1985, 1986; Tikhomirov, 1988; Karaulov and Grechishnikova, 1988). Schematically, this new subdivision of D/C transitional deposits allowed certain corrections to be made and the influences of global, regional, and local geologic events to be evaluated from the viewpoint of the history of some paleobasins and their systems.

Since Late Devonian through Early Carboniferous time, the general paleogeographic pattern of Russian Eurasia was influenced by the existence of the stable uplifts of the Eastern European (Russian) and Siberian platforms. Between these platforms and over their margins, sedimentary paleobasins formed under different tectonic and sedimentary conditions. These paleobasins are categorized by their type of destructional-accumulative relief and composition and thickness of their deposits (Simakov, 1993; Fig.1).

Thus, Russian Eurasia at the end of the Famennian and beginning of Carboniferous time was subdivided by paleobasins of the Urals system into two realms with opposite transgressive-regressive trends; Atlantic and Pacific. The first realm occupied all paleobasins of the Russian platform and Variscian geosynclines of Western Europe. The transgression and regression maxima within the Atlantic realm commonly occurred in the Strunian and Hangenbergian, respectively, with regressions usually accompanied by sedimentation breaks.

The Pacific realm covered the Kazakhstan-Altay, Siberian platform, and North-East paleobasin systems. Within this realm, the regression and transgression maxima occurred during the Strunian and Hangenbergian, respectively. Therefore, sedimentation was continuous in paleobasins bordering the Siberian platform since latest Famennian-late Tournaisian time. Correspondingly, identified within the Pacific realm are continuous sequences of the D/C transition that contain deposits of different environments; from back-shelf to basinal. These sequences are very important for determining the connection between paleobiologic events and chronostratigraphic boundaries--a determination that depends on what we mean by these terms.

It is a serious question because different opinions on the meaning of the general notion of "chronostratigraphic boundary" lead to different practical approaches in determining concrete boundaries. Differences in the final solution to the D/C boundary problem are explained by fundamental theoretical discrepancies in the notions of "chronostratigraphic scale" (CS) and "chronostratigraphic boundary" between those adopted by the IWGDC from the International Stratigraphic Guide (ISG) (1976) and the ones developed by the SWGDC. The theoretical background of the ISG is well known., but I would like to give a short explanation of what the notions of CS and chronostratigraphic boundary mean to the SWGDC.

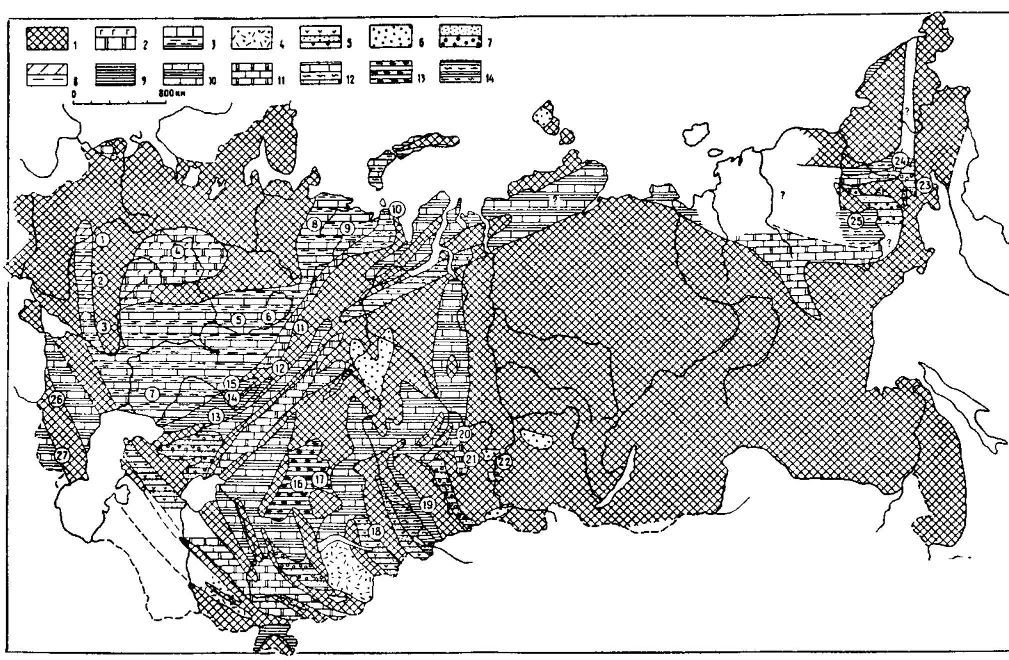


Fig.1. Late Famennian-early Tournasian paleobiogeographical framework or Russian Eurasia. 1. uplift and washing areas; 2. Passive-destructional relief paleobasins containing lagoon dolomite marls with gypsum and anhydrite; 3. sharply differentiated carbonates and shales, often bituminous; 4. paleobasins with tectonovolcanic destructional relief containing terrestrial volcano-sedimentary deposits; 5. mixed marine and terrestrial volcano-sedimentary deposits; 6. paleobasins with active tectonic destructional relief containing terrigenous sediments; 7. parallic and neritic mainly siliciclastic deposits; 8. lagoon and shelf marls and clay with intercalcating gypsum and bituminous shales; 9. shallow calyey silts, often tubidites; 10. shallow terrigenous carbonate deposits; 11. chemical-biogenic deposits of a carbonate platform; 12. sharply differentiated shallow carbonate and depressional condensed shale and siliceous sediments; 13. sharply differentiated shallow carbonates and depressional clayey carbonate (griotte-like) condensed deposits; 14. clay-silicieous condensed deep sediments. Paleobasins: East European Realm; 1. Pripyat, 2. Dneprov-Donetz, 3. Donetz, 4. Submoscow; Volga-Urals System; 5. depression type section, 6. side type section, 7. Caspian Sea; Timano-Pechorian Syestem; 8. depression type section, 9. side type section; Urals System; 10. Kozhim, 11. Kiselov, 12. Pribel, 13. Mugodzhary, 14. Magnitnaya Gora, 15. Zilair; Kazakhstan-Altay Realm; 16. Teniz, 17. Karaganda, 18. Dzhungar-Balkhash, 19. Rudny-Altay, 20. Eltsov, 21. Kuznets, 22. Minusin; Eastern Siberian Realm; 23. Gizhiga, 24. Omolon, 25. Kolyma; Caucasus-Tien Shan(?) realm, 26. North Caucasus, 27. Elbourz.

THE CHRONOSTRATIGRAPHIC SCALE: SUBDIVISIONS AND BOUNDARIES

By analogy with the modern calendar, the CS may be regarded as conforming to a conceptual time model, which is used as a global counting system for temporal coordination of geologic phenomena in different areas. To perform this role, the CS should be a system with discriminate subdivisions in all syndepositional stratified sediments: continental, paralic, neritic, and abyssal. In essence, the material (substantial) basis for elaborating the CS may be models of processes occurring in any system, the cyclic-irreversible development of which is represented in the geologic record. The relatively stable conditions of such a system correspond to CS units, whose boundaries coincide with the events connected with alterations in these relatively stable conditions.

Thus, in general, *a chronostratigraphic boundary may be defined as an event determined in the geologic record that corresponds with a compositional and/or structural change of a relatively stable state within the system, the evolutionary model of which is adopted as basis of the CS.*

In principle, it does not matter what evolutionary model of what kind of system (geologic, paleoecologic, or paleobiologic) is used to delineate the CS, because chronostratigraphic boundaries established in terms of the development of a selected system as the base for the CS would be represented by records of the events initiating alterations in a relatively stable state of that system. Consequently, *any chronostratigraphic boundary must coincide with (or be marked by) an event that is discernable in the geologic record.*

A specific chronostratigraphic boundary is an event, a saltation in a continuous process, which, for the D/C, is irrespective of whether the boundary is defined in terms of ***Clymennida*** extinction or the first appearance of ***Siphonodella sulcata***. In both cases, it equates with an event. The practical application of a selected "natural" chronostratigraphic boundary is entirely dependent on the **scale** of the adopted event. If it is a global event, with corresponding transformations (not necessarily identical) in composition and/or structure of assemblages in different groups and occurred in various environments, then we can be optimistic as to its practicality. Conversely, the selection of a "microevent," which does not correspond to any other patterns of change, as a boundary will prove unsatisfactory and will have a very short timespan. If we chose microevents to determine chronostratigraphic boundaries, as recommended by the ISG, we give future generations of stratigraphers guaranteed permanent employment!

It is useful to examine two salient questions regarding "event" chronostratigraphic boundaries.

1. Records of events marking "natural" boundaries between adjacent chronostratigraphic units are always represented by appreciable stratigraphic intervals: the "transitional" members, zones, horizons, or stages (until recently, the Strunian was regarded as a typical example of one of these). Thus, chronostratigraphic event boundaries resemble **ecotones** (the spatial transition between ecosystems). The intervals between adjacent chronostratigraphic units are appropriately referred to as **strato-** or **phylotones** and correspond to specific time-intervals; **chronotones** (Simakov, 1984; 1986).

According to the ISG, boundaries of chronostratigraphic units are viewed as sharp isochronous demarcative hypersurfaces engirding the globe. Such a representation is pragmatically justifiable because it makes use of the CS easier, presenting an unfamiliar form of the traditional modern calendar. The ISG procedure for identifying paleobiologic criteria for chronostratigraphic boundaries allows their application only as *conceptual symbols of natural (event) chronostratigraphic boundaries.* These boundaries are represented on the arrow of time by points separating adjacent chronostratigraphic units. It is important to note that such a representation of chronostratigraphic boundaries, defined in their stratotypes by "golden spikes," is a *mere symbol for real (observed) chronostratigraphic boundaries represented in the geologic record by transitional lithology and stratigraphy or phylotones.*

Contradictions between observations in the real world and our postulated notions of what chronostratigraphic boundaries <u>must be</u> are the essence of the natural *versus* artificial boundaries antinomy. The solution of this problem requires either a system of conventions or compromises permitting coordination between theoretical notions of chronostratigraphic boundaries and observations from nature. It is underscored that agreed-upon operational procedures are necessary to determine and trace chronostratigraphic boundaries because of two objective laws: *(1) metachronic development of various fossil groups and phyla and (2) ecologic control of fossil distribution* (Simakov, 1986).

2. Because the CS is a <u>global counting system</u>, only records of events within a chosen system that reflect the influence of global factors affecting the development of other systems should be taken for defining a chronostratigraphic boundary. A modern CS should reflect the evolution of appropriate orthochronologic fossils and should not be a biostratigraphic (orthostratigraphic) scale based on various evolutionary aspects of a single fossil group.

Chronostratigraphic boundaries should not be marked by occurrences or disappearances of select species or subspecies, which usually reflect local environmental perturbations. Chronostratigraphic boundaries should coincide only with orthostratigraphic boundaries that are marked by transformations within the archetypes of genera or higher taxa. From this standpoint, for example, there would be no reason to regard the "*Cymaclymenia evoluta zone*" as a useful chronostratigraphic unit because it clearly reflects local sedimentological change in the Ruhr Basin (Korn, 1988). Conversely, the *Parawocklumeria paradoxa zone* was introduced into the CS because the beginning phase coincided with considerable change not only in ***Clymeniida*** but in other fossil groups as well (e.g., Simakov, 1990).

The choice of globally traceable events for definition of chronostratigraphic boundaries can be a problem. Because it involves paleobiologic events, its resolution amounts to determining the scale of those events that can be regarded as responses of orthochronologic fossil groups to some global factor. It reduces to the choice of a "boundary event" in the development of an orthochronologic fossil group within the specified stratigraphic interval, e.g., phylotone. Other paleobiologic events, such as those marked by the zonal boundaries in parastratigraphic scales, may be included later. These zonal boundaries may turn out to be isochronous with formally recognized paleobiologic reference points (e.g., standard or symbol of "natural" boundaries) and may enable the tracing of these boundaries through deposition of different facies. Thus, they may be perceived, figuratively, as an isochronous "knife blade" cutting across natural bodies (Simakov, 1984, 1986).

TWO APPROACHES - TWO DECISIONS

Investigations of the D/C boundary throughout Western Europe, North America, China, and Russian Eurasia have resulted in a convergence of the Russian and foreign viewpoints, in spite of the essentially different IWGDC and SWGDC approaches.

The IWGDC followed the recommendations of the ISG and dealt mainly with the search for a stratotype of the boundary, established by joining *praesulcata-sulcata zones* in terms of the conodont standard. In this search, insufficient attention was paid to evidence of this boundary in different facies. As a result, the orthochronological boundary marker adopted by IWGDC may be traced only by conodonts and only in depressional and slope facies where representatives of ***Siphonodella*** are mainly distributed. It is nearly impossible to establish the D/C boundary by conodonts in inner- and back-shelf deposits, usually represented by carbonate rocks, which are extensive in Russian Eurasia, USA, Canada, China, and elsewhere. Thus, the conodont orthochronological standard preferred by the IWGDC does not solve problems with the cephalopod standard caused by limited distribution of ammonoids and corresponding facies. Moreover, because the transition between *Siphonodella praesulcata* and *S. sulcata* takes place within a stratigraphic interval of a few centimeters, it is impossible discriminate any parachronological markers for tracing the D/C boundary, established in terms of the conodont standard.

The SWGDC approach to the study of the D/C boundary focuses on the stage-by-stage development of different fossils such as ammonoids (Bogoslovsky, 1988), foraminifera (Reitlinger and Durkina, 1988), ostracods (Chizhova, 1988), conodonts (Barskov et al., 1988), brachiopods (Rzhonsnitskaya, 1988; Simakov, 1990), and other groups since Late Famennian through Early Tournaisian time (Golubtzov, 1988). Evidence exists of significant changes in the composition and relations of all of these fossil groups due to the transformations and extinction of taxa with Devonian archetypes and appearance of taxa with Carboniferous and ephemeridic archetypes that became widespread (Fig.2).

Similar changes in composition and/or relationships within fossil assemblages are not contemporaneous in different fossil groups and proceed within a certain timespan or stratigraphic range--not "momentarily." These changes are also found to be different within the same fossil group or phyla in different paleobasins and even in different facies zones (e.g., Simakov, 1990). The peculiar ecotone-like character of "natural" boundaries that are marked by a bioevent (Simakov, 1984) requires (1) the reasoned acceptance of the evolutionary pattern of only one fossil group as the orthochronologic standard to subdivide the transitional sequences and determine the D/C boundary and (2) the adoption of such an evolutionary event of this group as the natural boundary that is coincident with significant alterations in the composition and/or relationship of other fossil assemblages with concurrent range areas embracing the entire environmental spectrum, from continental to depressional facies (Simakov, 1986).

The SWGDC considered models of evolutionary patterns for different fossil groups (foraminifera, ostracoda, conodonts, miospores, etc.) as the orthochronological standard for the D/C transition. But in the course of prolonged discussions, it was argued that the cephalopod standard should remain in use for subdividing the middle Paleozoic-Mesozoic sequences because it has been used for more than 100 years. The D/C natural boundary is assumed to correspond to the so-called first ***Ammonoidea*** crisis, in the course of which the Devonian representatives of this superorder became extinct (except ***Imitoceras***, which gave rise to Carboniferous ammonoids) (Bogoslovsky, 1988). The timespan corresponding to the crisis in ammonoid evolution contains very specific "*Acutimitoceras-Fauna*," which mark the position of the *Acutimitoceras-phylotone*. Inside this interval, the "golden spike" of the D/C boundary is proposed by the SWGDC to be officially established in conformity with the recommendations of the ISG (1976).

Because the *Acutimitocers phylotone* includes the zonal boundaries of different parastratigraphic scales, such as miospores, foraminifera, conodonts, etc., complications can be avoided while choosing the parachronologic markers for tracing the D/C boundary in deposits of any facies (Table 2).

CONCLUSIONS

The main difficulties of determining the D/C boundary (until the early 1980's) were caused not by wrong paleobiological standards adopted by the 2nd Carboniferous Congress but by the placement of many of the "classical" D/C transition sequences in an incomplete Western and Eastern Europe system: Late Devonian and Early Tournaisian deposits separated by sedimentological breaks or lacuns. A widely held assumption that transitional deposits in all paleobasins are the same ("Strunian") age is incorrect because new research shows that in different paleobasins, Latest Famennian deposits belong to different glones--whether Strunian or Hangenbergian. Another source of difficulty in establishing and tracing the D/C boundary is due to a principally incorrect theoretical approach adopted by the ISG, underlain by the concept of "absolute" time of I. Newton (Simakov, 1984). Full continuous sequences of D/C transitional deposits discovered in Arctic areas of North East Russia and South China make new subdivisions possible and allow much better understanding of the real paleogeography during the Late Famennian and Early Tournaisian timespans in Russian Eurasia territory.

Despite their different theoretical approaches, the IWGDC and SWGDC have reached a mutual understanding on the position of the D/C boundary. At this point, one shouldn't adopt these decisions as final. The IWGDC has proposed to establish the official paleobiologic (conodont) standard of the D/C as coincident with the junction of the *Siphonodella praesulcata* and *S. sulcata* zones in La-Sierra section (Montagne Noire, France), which is a specially chosen stratotype. But because of the theoretical approach used by the IWGDC in the framework of the ISG (1976), the global tracing of this boundary is not provided; the objective choice of parachronologic markers that might be used for this purpose is not feasible, and attempts to choose them must therefore proceed through "*trivial*" (or *ad hoc*) convention. The SWGDC essentially has solved the problems of the natural D/C boundary position and its tracing but has failed to find a stratotype to fix its official nomenclature standard.

Thus, despite the resolutions made, the problem of the D/C boundary still remains--good luck for its decision to future generations of stratigraphers!

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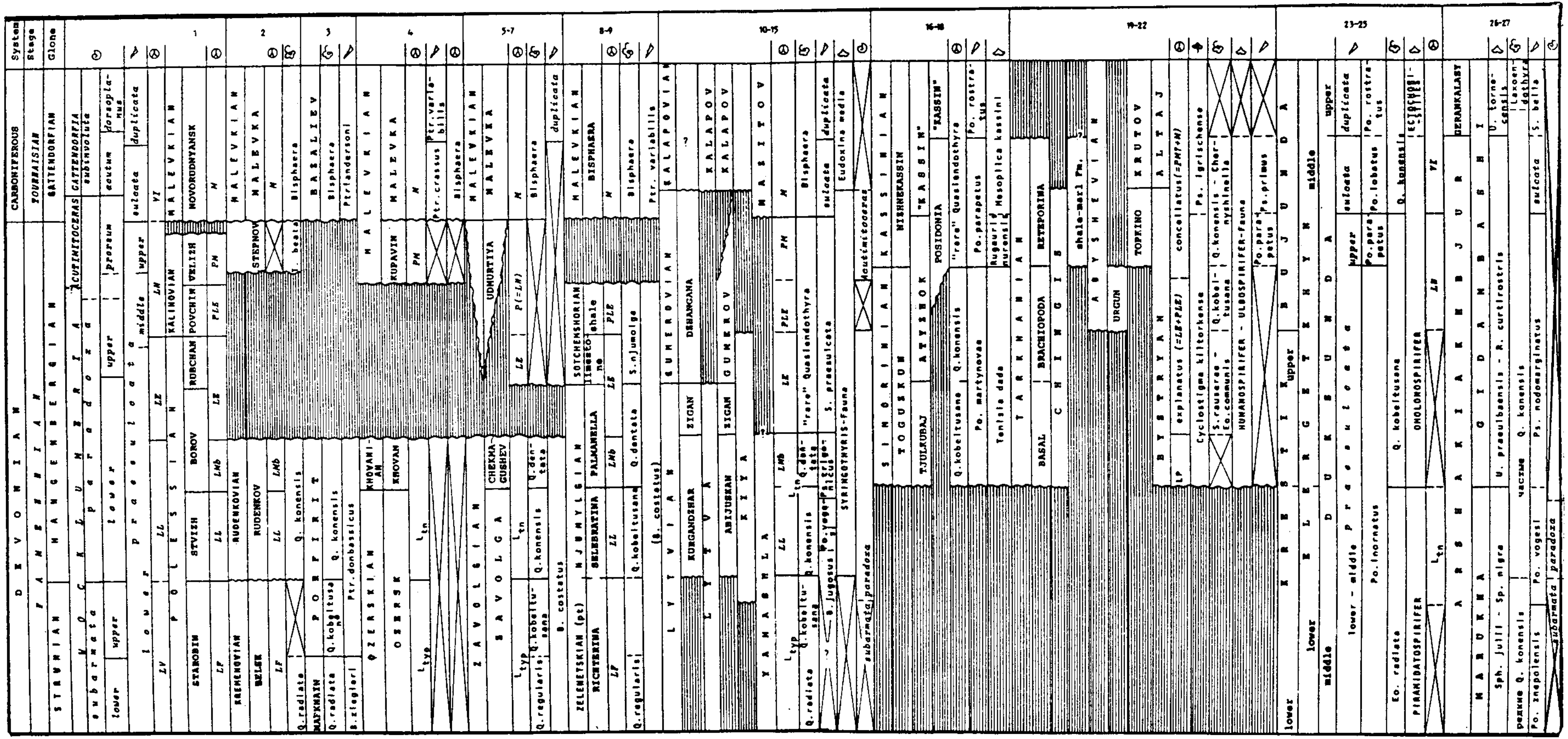
Table 2. Biostratigraphic correlation of the Devonian-Carboniferous transitional deposits in Russian Eurasia (numbers of columns correspond to the number of paleobasins shown in Fig.1).



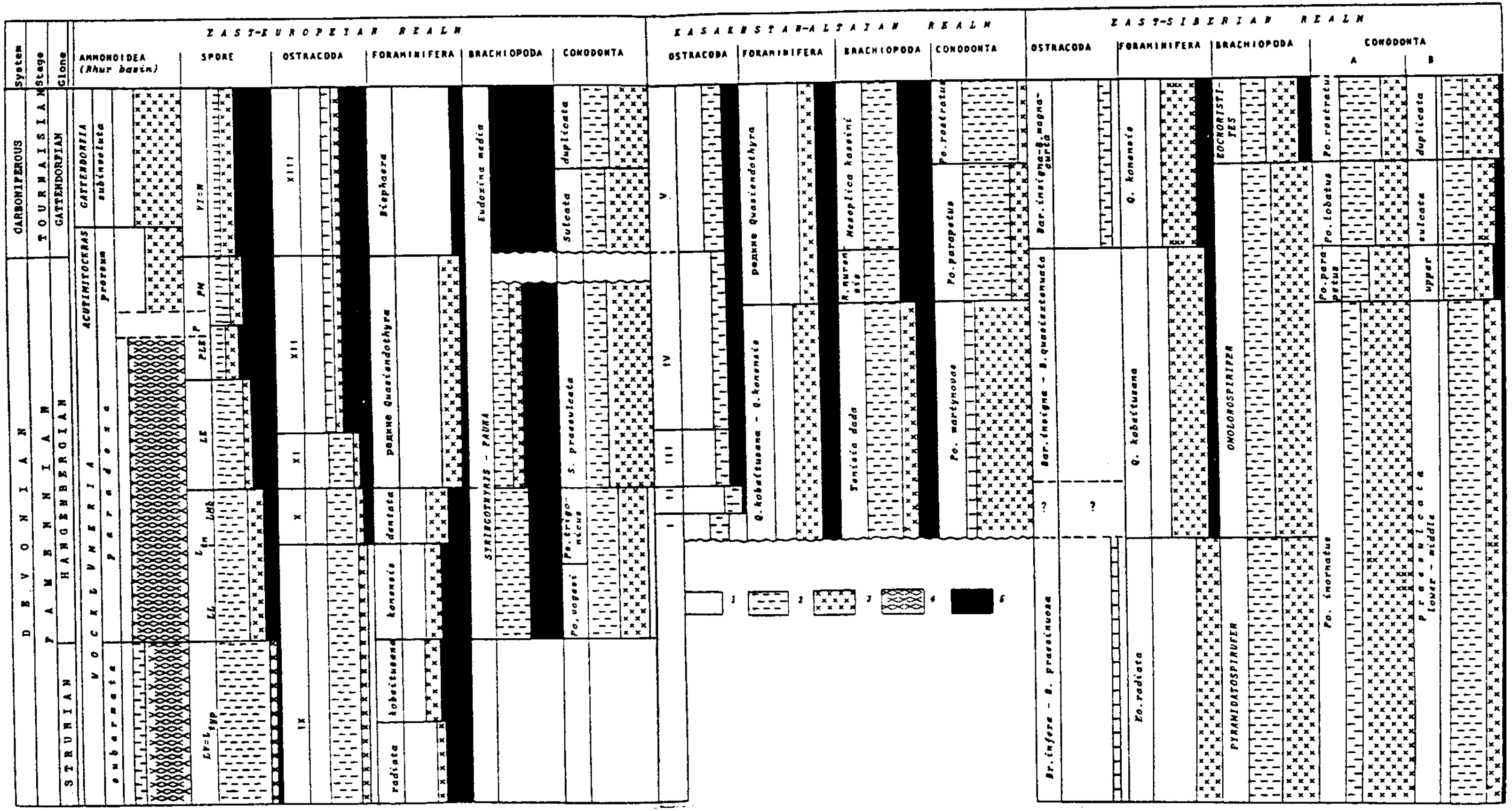


Fig.2. Compositional and relational changes in different zonal assembladges through the Devonian-Carboniferous transition. Taxa with the following archetypes: 1. persistent, 2. Devonian, 3. tempotone (intermediate), 4. ephemerid, 5. Carboniferous. Ostracode zones: East European Realm: IX. Maternella hemisphaerica-Quasiglyptopleura miranda, X. Maternella hemisphaerica-Effiminatopleura regime, XI. Richterina latior-Maternella hemisphaerica-Shishaella okeni, XII. Richterina latior-Pseudoleperditia tuberculifera, XIII. Richterina latior-Pseudoleperditia venulosa-Shivaella microphtalma. Kazakhstan-Altayan Realm: I. Serenida tarchanica-Bairdia talovkensis, II. Armenites asiaticus-Cryptocyprois subsymmetrica, III. Bairdia quasicognata-Bairdia quasiextenuata, IV. Coryellina? tarchanica-Postropolonellus altaicus.